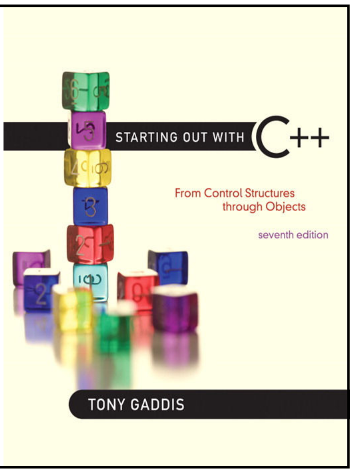
Chapter 4:

Making Decisions



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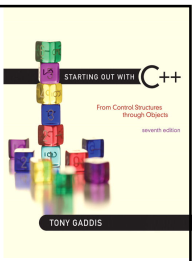
4.1



Relational Operators

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Relational Operators

- Used to compare numbers to determine relative order
- Operators:

`>`	Greater than
`<`	Less than
`>=`	Greater than or equal to
`<=`	Less than or equal to
`==`	Equal to
`!=`	Not equal to

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Relational Expressions

- Boolean expressions – `true` or `false`
- Examples:

  `12 > 5` is `true`
  `7 <= 5` is `false`

  if `x` is 10, then
  `x == 10` is `true`,
  `x != 8` is `true`, and
  `x == 8` is `false`

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Relational Expressions

- Can be assigned to a variable:

```
result = x <= y;
```

- Assigns `0` for `false`, `1` for `true`
- Do not confuse `=` and `==`

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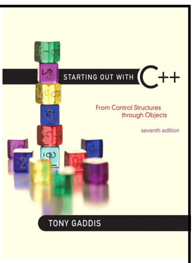

4.2

The `if` Statement

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The `if` Statement

- Allows statements to be conditionally executed or skipped over
- Models the way we mentally evaluate situations:
  - "If it is raining, take an umbrella."
  - "If it is cold outside, wear a coat."

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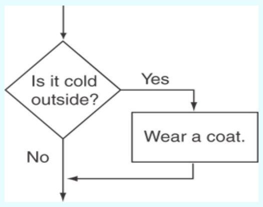
Flowchart for Evaluating a Decision



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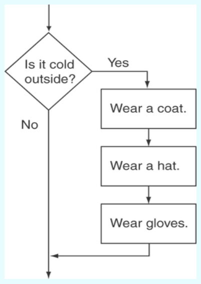
Flowchart for Evaluating a Decision



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The **`if`** Statement

- General Format:

```
if (expression)
      statement;
```

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The if Statement-What Happens

To evaluate:

```
if (expression)
    statement;
```

- If the *`expression`* is `true`, then *`statement`* is executed.
- If the *`expression`* is `false`, then *`statement`* is skipped.

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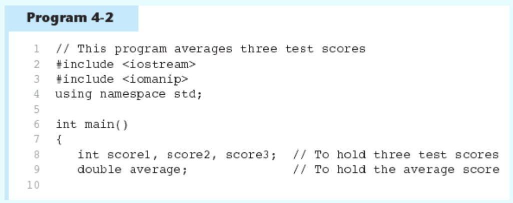
`if` Statement in Program 4-2



Program 4-2

```
// This program averages three test scores
#include <iostream>
#include <iomanip>
using namespace std;

int main()
{
   int score1, score2, score3;  // To hold three test scores
   double average;              // To hold the average score

```

Continued…

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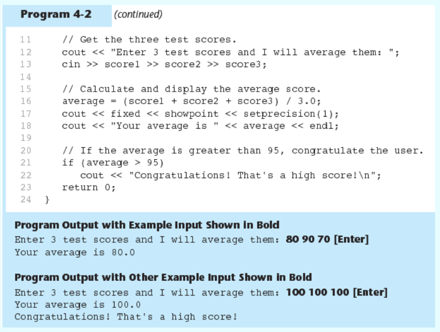
`if` Statement in Program 4-2



Program 4-2 *(continued)*

```
11     // Get the three test scores.
12     cout << "Enter 3 test scores and I will average them: ";
13     cin >> score1 >> score2 >> score3;
14
15     // Calculate and display the average score.
16     average = (score1 + score2 + score3) / 3.0;
17     cout << fixed << showpoint << setprecision(1);
18     cout << "Your average is " << average << endl;
19
20     // If the average is greater than 95, congratulate the user.
21     if (average > 95)
22        cout << "Congratulations! That's a high score!\n";
23     return 0;
24  }
```

Program Output with Example Input Shown in Bold

```
Enter 3 test scores and I will average them: 80 90 70 [Enter]
Your average is 80.0
```

Program Output with Other Example Input Shown in Bold

```
Enter 3 test scores and I will average them: 100 100 100 [Enter]
Your average is 100.0
Congratulations! That's a high score!
```

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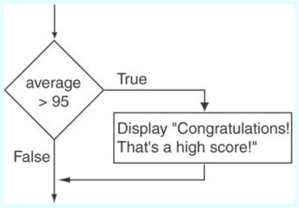
Flowchart for Program 4-2 Lines 21 and 22



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`if` Statement Notes

- Do not place `;` after `(expression)`
- Place `statement;` on a separate line after `(expression)`, indented:

```
if (score > 90)
    grade = 'A';
```

- Be careful testing `float`s and `double`s for equality
- `0` is `false`; any other value is `true`

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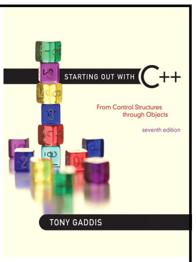

4.3

Expanding the `if` Statement

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Expanding the `if` Statement

- To execute more than one statement as part of an `if` statement, enclose them in `{ }`:

```
if (score > 90)
{
    grade = 'A';
    cout << "Good Job!\n";
}
```

- `{ }` creates a block of code

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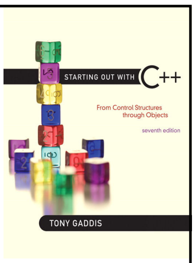

4.4

The `if/else` Statement

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The `if/else` statement

- Provides two possible paths of execution
- Performs one statement or block if the *`expression`* is true, otherwise performs another statement or block.

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The `if/else` statement

- General Format:

```
if (expression)
     statement1;  // or block
else
     statement2;  // or block
```

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`if/else`-What Happens

To evaluate:

```
if (expression)
   statement1;
else
   statement2;
```

- If the *`expression`* is `true`, then *`statement1`* is executed and *`statement2`* is skipped.
- If the *`expression`* is *`false`*, then *`statement1`* is skipped and *`statement2`* is executed.

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The `if/else` statement and Modulus Operator in Program 4-8

Program 4-8

```
 1  // This program uses the modulus operator to determine
 2  // if a number is odd or even. If the number is evenly divisible
 3  // by 2, it is an even number. A remainder indicates it is odd.
 4  #include <iostream>
 5  using namespace std;
 6
 7  int main()
 8  {
 9     int number;
10
11     cout << "Enter an integer and I will tell you if it\n";
12     cout << "is odd or even. ";
13     cin >> number;
14     if (number % 2 == 0)
15        cout << number << " is even.\n";
16     else
17        cout << number << " is odd.\n";
18     return 0;
19  }
```

Program Output with Example Input Shown in Bold

```
Enter an integer and I will tell you if it
is odd or even. 17 [Enter]
17 is odd.
```

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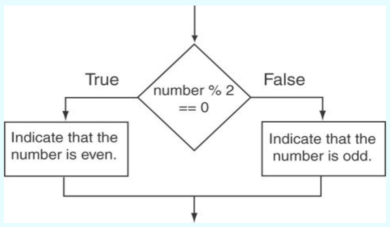
Flowchart for Program 4-8 Lines 14 through 18


True
number % 2 == 0
False
Indicate that the number is even.
Indicate that the number is odd.

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Testing the Divisor in Program 4-9

Program 4-9

```
// This program asks the user for two numbers, num1 and num2.
// num1 is divided by num2 and the result is displayed.
// Before the division operation, however, num2 is tested
// for the value 0. If it contains 0, the division does not
// take place.
#include <iostream>
using namespace std;

int main()
{
   double num1, num2, quotient;

```

Continued…

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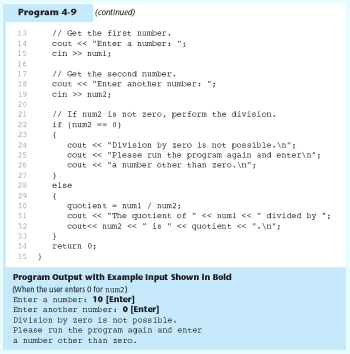
Testing the Divisor in Program 4-9



Program 4-9 *(continued)*

```
    // Get the first number.
    cout << "Enter a number: ";
    cin >> num1;

    // Get the second number.
    cout << "Enter another number: ";
    cin >> num2;

    // If num2 is not zero, perform the division.
    if (num2 == 0)
    {
       cout << "Division by zero is not possible.\n";
       cout << "Please run the program again and enter\n";
       cout << "a number other than zero.\n";
    }
    else
    {
       quotient = num1 / num2;
       cout << "The quotient of " << num1 << " divided by ";
       cout<< num2 << " is " << quotient << ".\n";
    }
    return 0;
 }
```

Program Output with Example Input Shown in Bold
(When the user enters 0 for `num2`)

```
Enter a number: 10 [Enter]
Enter another number: 0 [Enter]
Division by zero is not possible.
Please run the program again and enter
a number other than zero.
```

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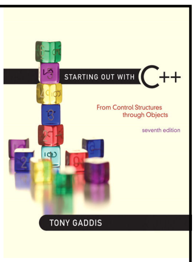

4.5

Nested `if` Statements

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Nested `if` Statements

- An `if` statement that is nested inside another `if` statement
- Nested `if` statements can be used to test more than one condition

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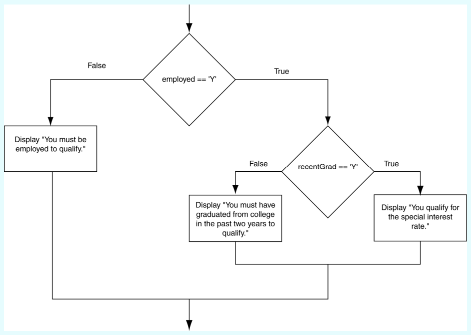
Flowchart for a Nested `if` Statement


employed == 'Y'
False
True
Display "You must be employed to qualify."
recentGrad == 'Y'
False
True
Display "You must have graduated from college in the past two years to qualify."
Display "You qualify for the special interest rate."

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Nested `if` Statements

- From Program 4-10

```
   // Determine the user's loan qualifications.
   if (employed == 'Y')
   {
      if (recentGrad == 'Y') //Nested if
      {
         cout << "You qualify for the special ";
         cout << "interest rate.\n";
      }
   }
```

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Nested `if` Statements

- Another example, from Program 4-1

```
   // Determine the user's loan qualifications.
   if (employed == 'Y')
   {
      if (recentGrad == 'Y') // Nested if
      {
         cout << "You qualify for the special ";
         cout << "interest rate.\n";
      }
      else // Not a recent grad, but employed
      {
         cout << "You must have graduated from ";
         cout << "college in the past two\n";
         cout << "years to qualify.\n";
      }
   }
   else // Not employed
   {
      cout << "You must be employed to qualify.\n";
   }
```

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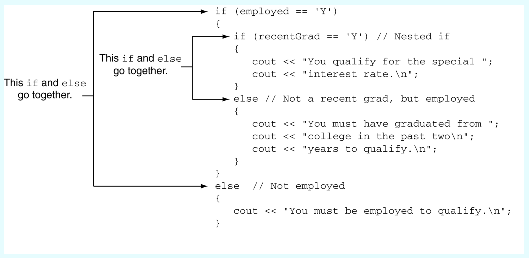
Use Proper Indentation!



```
if (employed == 'Y')
{
   if (recentGrad == 'Y') // Nested if
   {
      cout << "You qualify for the special ";
      cout << "interest rate.\n";
   }
   else // Not a recent grad, but employed
   {
      cout << "You must have graduated from ";
      cout << "college in the past two\n";
      cout << "years to qualify.\n";
   }
}
else  // Not employed
{
   cout << "You must be employed to qualify.\n";
}
```

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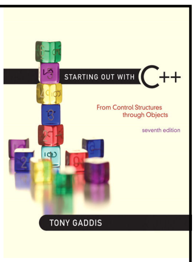

4.6

The `if/else if` Statement

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The `if/else if` Statement

- Tests a series of conditions until one is found to be true
- Often simpler than using nested `if/else` statements
- Can be used to model thought processes such as:

  "If it is raining, take an umbrella,
  else, if it is windy, take a hat,
  else, take sunglasses"

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`if/else if` Format

```
if (expression)
     statement1;  // or block
else if (expression)
     statement2;  // or block
    .
    . // other else ifs
    .
else if (expression)
     statementn;  // or block
```

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The `if/else if` Statement in Program 4-13

```
   // Determine the letter grade.
   if (testScore >= A_SCORE)
      cout << "Your grade is A.\n";
   else if (testScore >= B_SCORE)
      cout << "Your grade is B.\n";
   else if (testScore >= C_SCORE)
      cout << "Your grade is C.\n";
   else if (testScore >= D_SCORE)
      cout << "Your grade is D.\n";
   else
      cout << "Your grade is F.\n";
```

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Using a Trailing `else` to Catch Errors in Program 4-14

- The trailing `else` clause is optional, but it is best used to catch errors.

```
   // Determine the letter grade.
   if (testScore >= A_SCORE)
      cout << "Your grade is A.\n";
   else if (testScore >= B_SCORE)
      cout << "Your grade is B.\n";
   else if (testScore >= C_SCORE)
      cout << "Your grade is C.\n";
   else if (testScore >= D_SCORE)
      cout << "Your grade is D.\n";
   else if (testScore >= 0)
      cout << "Your grade is F.\n";
   else
      cout << "Invalid test score.\n";
```

This trailing `else` catches invalid test scores

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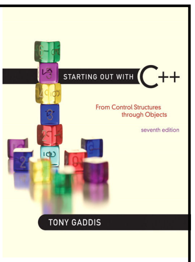

4.7

Flags

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Flags

- Variable that signals a condition
- Usually implemented as a `bool` variable
- Can also be an integer
  - The value `0` is considered `false`
  - Any nonzero value is considered `true`
- As with other variables in functions, must be assigned an initial value before it is used

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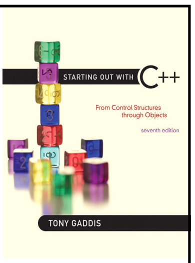

4.8

Logical Operators

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Logical Operators

- Used to create relational expressions from other relational expressions
- Operators, meaning, and explanation:

`&&`	AND	New relational expression is true if both expressions are true
`||`	OR	New relational expression is true if either expression is true
`!`	NOT	Reverses the value of an expression – true expression becomes false, and false becomes true

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Logical Operators-Examples

```
int x = 12, y = 5, z = -4;
```

`(x > y) && (y > z)`	`true`
`(x > y) && (z > y)`	`false`
`(x <= z) || (y == z)`	`false`
`(x <= z) || (y != z)`	`true`
`!(x >= z)`	`false`

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The logical `&&` operator in Program 4-15

```
// Determine the user's loan qualifications.
if (employed == 'Y' && recentGrad == 'Y')
{
   cout << "You qualify for the special "
        << "interest rate.\n";
}
else
{
   cout << "You must be employed and have\n"
        << "graduated from college in the\n"
        << "past two years to qualify.\n";
}
```

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The logical `||` Operator in Program 4-16

```
// Determine the user's loan qualifications.
if (income >= MIN_INCOME || years > MIN_YEARS)
   cout << "You qualify.\n";
else
{
   cout << "You must earn at least $"
        << MIN_INCOME << " or have been "
        << "employed more than " << MIN_YEARS
        << " years.\n";
}
```

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The logical `!` Operator in Program 4-17

```
// Determine the user's loan qualifications.
if (!(income >= MIN_INCOME || years > MIN_YEARS))
{
   cout << "You must earn at least $"
        << MIN_INCOME << " or have been "
        << "employed more than " << MIN_YEARS
        << " years.\n";
}
else
   cout << "You qualify.\n";
```

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Logical Operator-Notes

- `!` has highest precedence, followed by `&&`, then `||`
- If the value of an expression can be determined by evaluating just the sub-expression on left side of a logical operator, then the sub-expression on the right side will not be evaluated (*short circuit evaluation*)

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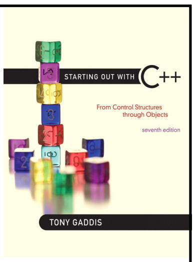

4.9

Checking Numeric Ranges with Logical Operators

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Checking Numeric Ranges with Logical Operators

- Used to test to see if a value falls **inside** a range:
```
if (grade >= 0 && grade <= 100)
   cout << "Valid grade";
```
- Can also test to see if value falls **outside** of range:
```
 if (grade <= 0 || grade >= 100)
   cout << "Invalid grade";
```
- Cannot use mathematical notation:
```
if (0 <= grade <= 100) //doesn't work!
```

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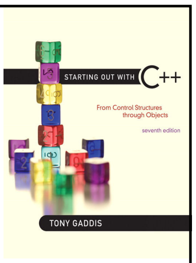

4.10

Menus

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Menus

- Menu-driven program: program execution controlled by user selecting from a list of actions
- Menu: list of choices on the screen
- Menus can be implemented using `if/else if` statements

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Menu-Driven Program Organization

- Display list of numbered or lettered choices for actions
- Prompt user to make selection
- Test user selection in *`expression`*
  - if a match, then execute code for action
  - if not, then go on to next *`expression`*

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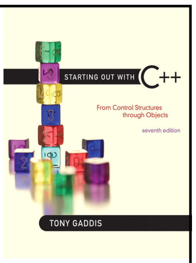

4.11

Validating User Input

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Validating User Input

- Input validation: inspecting input data to determine whether it is acceptable
- Bad output will be produced from bad input
- Can perform various tests:
  - Range
  - Reasonableness
  - Valid menu choice
  - Divide by zero

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Input Validation in Program 4-19

```
   int testScore;  // To hold a numeric test score

   // Get the numeric test score.
   cout << "Enter your numeric test score and I will\n"
        << "tell you the letter grade you earned: ";
   cin >> testScore;

   // Validate the input and determine the grade.
   if (testScore >= MIN_SCORE && testScore <= MAX_SCORE)
   {
      // Determine the letter grade.
      if (testScore >= A_SCORE)
        cout << "Your grade is A.\n";
      else if (testScore >= B_SCORE)
        cout << "Your grade is B.\n";
      else if (testScore >= C_SCORE)
        cout << "Your grade is C.\n";
      else if (testScore >= D_SCORE)
        cout << "Your grade is D.\n";
      else
        cout << "Your grade is F.\n";
   }
   else
   {
      // An invalid score was entered.
      cout << "That is an invalid score. Run the program\n"
           << "again and enter a value in the range of\n"
           << MIN_SCORE << " through " << MAX_SCORE << ".\n";
   }
```

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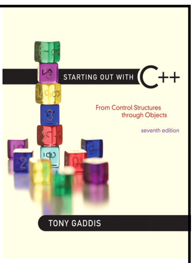

4.12

Comparing Characters and Strings

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Comparing Characters

- Characters are compared using their ASCII values
- 'A' < 'B'
  - The ASCII value of 'A' (65) is less than the ASCII value of 'B'(66)
- '1' < '2'
  - The ASCII value of '1' (49) is less than the ASCI value of '2' (50)
- Lowercase letters have higher ASCII codes than uppercase letters, so 'a' > 'Z'

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Relational Operators Compare Characters in Program 4-20

```
10    // Get a character from the user.
11    cout << "Enter a digit or a letter: ";
12    ch = cin.get();
13
14    // Determine what the user entered.
15    if (ch >= '0' && ch <= '9')
16       cout << "You entered a digit.\n";
17    else if (ch >= 'A' && ch <= 'Z')
18       cout << "You entered an uppercase letter.\n";
19    else if (ch >= 'a' && ch <= 'z')
20       cout << "You entered a lowercase letter.\n";
21    else
22       cout << "That is not a digit or a letter.\n";
```

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Comparing `string` Objects

- Like characters, strings are compared using their ASCII values

```
string name1 = "Mary";
string name2 = "Mark";

name1 > name2   // true
name1 <= name2 // false
name1 != name2  // true

name1 < "Mary Jane" // true
```

The characters in each string must match before they are equal

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Relational Operators Compare Strings in Program 4-21

```
   // Determine and display the correct price
   if (partNum == "S-29A")
      cout << "The price is $" << PRICE_A << endl;
   else if (partNum == "S-29B")
      cout << "The price is $" << PRICE_B << endl;
   else
      cout << partNum << " is not a valid part number.\n";
```

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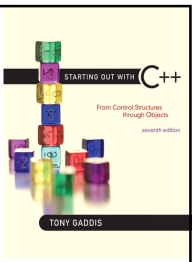

4.13

The Conditional Operator

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The Conditional Operator

- Can use to create short `if/else` statements
- Format: `expr ? expr : expr;`

$$\underbrace{\texttt{x<0}}_{\text{First Expression: Expression to be tested}} \texttt{ ? } \underbrace{\texttt{y=10}}_{\text{2nd Expression: Executes if first expression is true}} \texttt{ : } \underbrace{\texttt{z=20}}_{\text{3rd Expression: Executes if the first expression is false}}\texttt{;}$$

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The Conditional Operator

- The value of a conditional expression is
  - The value of the second expression if the first expression is true
  - The value of the third expression if the first expression is false
- Parentheses `()` may be needed in an expression due to precedence of conditional operator

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The Conditional Operator in Program 4-22

```cpp
// This program calculates a consultant's charges at $50
// per hour, for a minimum of 5 hours. The ?: operator
// adjusts hours to 5 if less than 5 hours were worked.
#include <iostream>
#include <iomanip>
using namespace std;

int main()
{
   const double PAY_RATE = 50.0;  // Hourly pay rate
   const int MIN_HOURS = 5;       // Minimum billable hours
   double hours,                  // Hours worked
          charges;                // Total charges

   // Get the hours worked.
   cout << "How many hours were worked? ";
   cin >> hours;

   // Determine the hours to charge for.
   hours = hours < MIN_HOURS ? MIN_HOURS : hours;

   // Calculate and display the charges.
   charges = PAY_RATE * hours;
   cout << fixed << showpoint << setprecision(2)
        << "The charges are $" << charges << endl;
   return 0;
}
```

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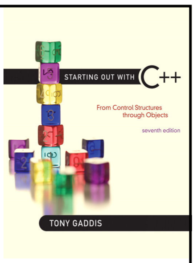

4.14

The `switch` Statement

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The `switch` Statement

- Used to select among statements from several alternatives
- In some cases, can be used instead of `if/else if` statements

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`switch` Statement Format

```
switch (expression) //integer
{
  case exp1: statement1;
  case exp2: statement2;
  ...
  case expn: statementn;
  default:   statementn+1;
}
```

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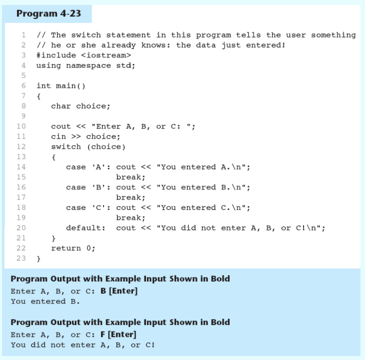
The `switch` Statement in Program 4-23



Program 4-23

```
// The switch statement in this program tells the user something
// he or she already knows: the data just entered!
#include <iostream>
using namespace std;

int main()
{
   char choice;

   cout << "Enter A, B, or C: ";
   cin >> choice;
   switch (choice)
   {
      case 'A': cout << "You entered A.\n";
                break;
      case 'B': cout << "You entered B.\n";
                break;
      case 'C': cout << "You entered C.\n";
                break;
      default:  cout << "You did not enter A, B, or C!\n";
   }
   return 0;
}
```

Program Output with Example Input Shown in Bold

```
Enter A, B, or C: B [Enter]
You entered B.
```

Program Output with Example Input Shown in Bold

```
Enter A, B, or C: F [Enter]
You did not enter A, B, or C!
```

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`switch` Statement Requirements

1) *`expression`* must be an integer variable or an expression that evaluates to an integer value
2) *`exp`***`1`** through *`exp`***`n`** must be constant integer expressions or literals, and must be unique in the `switch` statement
3) `default` is optional but recommended

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`switch` Statement-How it Works

1) *`expression`* is evaluated
2) The value of *`expression`* is compared against *`exp`***`1`** through *`exp`***`n`**.
3) If *`expression`* matches value *`exp`***`i`**, the program branches to the statement following *`exp`***`i`** and continues to the end of the `switch`
4) If no matching value is found, the program branches to the statement after `default:`

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`break` Statement

- Used to exit a `switch` statement
- If it is left out, the program "falls through" the remaining statements in the `switch` statement

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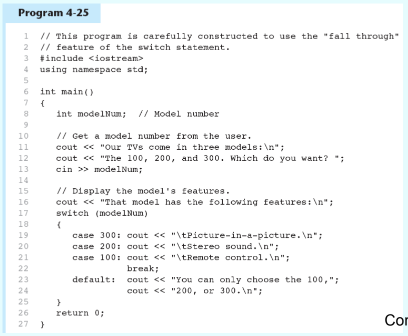
`break` and `default` statements in Program 4-25



Program 4-25

```
// This program is carefully constructed to use the "fall through"
// feature of the switch statement.
#include <iostream>
using namespace std;

int main()
{
   int modelNum;  // Model number

   // Get a model number from the user.
   cout << "Our TVs come in three models:\n";
   cout << "The 100, 200, and 300. Which do you want? ";
   cin >> modelNum;

   // Display the model's features.
   cout << "That model has the following features:\n";
   switch (modelNum)
   {
      case 300: cout << "\tPicture-in-a-picture.\n";
      case 200: cout << "\tStereo sound.\n";
      case 100: cout << "\tRemote control.\n";
                break;
      default:  cout << "You can only choose the 100,";
                cout << "200, or 300.\n";
   }
   return 0;
}
```

Continued…

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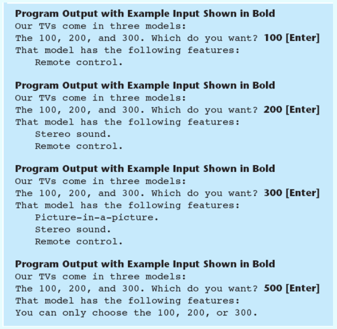
`break` and `default` statements in Program 4-25



Program Output with Example Input Shown in Bold

```
Our TVs come in three models:
The 100, 200, and 300. Which do you want? 100 [Enter]
That model has the following features:
    Remote control.
```

Program Output with Example Input Shown in Bold

```
Our TVs come in three models:
The 100, 200, and 300. Which do you want? 200 [Enter]
That model has the following features:
    Stereo sound.
    Remote control.
```

Program Output with Example Input Shown in Bold

```
Our TVs come in three models:
The 100, 200, and 300. Which do you want? 300 [Enter]
That model has the following features:
    Picture-in-a-picture.
    Stereo sound.
    Remote control.
```

Program Output with Example Input Shown in Bold

```
Our TVs come in three models:
The 100, 200, and 300. Which do you want? 500 [Enter]
That model has the following features:
You can only choose the 100, 200, or 300.
```

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Using `switch` in Menu Systems

- `switch` statement is a natural choice for menu-driven program:
  - display the menu
  - then, get the user's menu selection
  - use user input as `expression` in `switch` statement
  - use menu choices as *`expr`* in `case` statements

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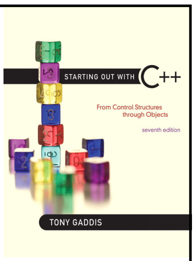

4.15

More About Blocks and Scope

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More About Blocks and Scope

- Scope of a variable is the block in which it is defined, from the point of definition to the end of the block
- Usually defined at beginning of function
- May be defined close to first use

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Inner Block Variable Definition in Program 4-29

```
if (income >= MIN_INCOME)
{
   // Get the number of years at the current job.
   cout << "How many years have you worked at "
        << "your current job? ";
   int years;     // Variable definition
   cin >> years;

   if (years > MIN_YEARS)
      cout << "You qualify.\n";
   else
   {
      cout << "You must have been employed for\n"
           << "more than " << MIN_YEARS
           << " years to qualify.\n";
   }
}
```

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Variables with the Same Name

- Variables defined inside `{ }` have <u>local</u> or <u>block</u> scope
- When inside a block within another block, can define variables with the same name as in the outer block.
  - When in inner block, outer definition is not available
  - Not a good idea

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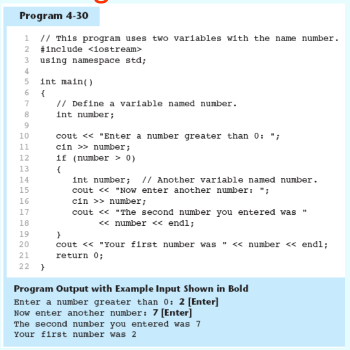
Two Variables with the Same Name in Program 4-30



Program 4-30

```
// This program uses two variables with the name number.
#include <iostream>
using namespace std;

int main()
{
   // Define a variable named number.
   int number;

   cout << "Enter a number greater than 0: ";
   cin >> number;
   if (number > 0)
   {
      int number;  // Another variable named number.
      cout << "Now enter another number: ";
      cin >> number;
      cout << "The second number you entered was "
           << number << endl;
   }
   cout << "Your first number was " << number << endl;
   return 0;
}
```

Program Output with Example Input Shown in Bold

```
Enter a number greater than 0: 2 [Enter]
Now enter another number: 7 [Enter]
The second number you entered was 7
Your first number was 2
```

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