Figure 1-11

1. Clearly define what the program is to do.
2. Visualize the program running on the computer.
3. Use design tools such as a hierarchy chart, flowcharts, or pseudocode to create a model of the program.
4. Check the model for logical errors.
5. Type the code, save it, and compile it.
6. Correct any errors found during compilation. Repeat Steps 5 and 6 as many times as necessary.
7. Run the program with test data for input.
8. Correct any errors found while running the program. Repeat Steps 5 through 8 as many times as necessary.
9. Validate the results of the program.

The steps listed in Figure 1-11 emphasize the importance of planning. Just as there are good ways and bad ways to paint a house, there are good ways and bad ways to create a program. A good program always begins with planning.

With the pay-calculating program as our example, let's look at each of the steps in more detail.

1. **Clearly define what the program is to do.**

This step requires that you identify the purpose of the program, the information that is to be input, the processing that is to take place, and the desired output. Let's examine each of these requirements for the example program:

Purpose	To calculate the user's gross pay.
Input	Number of hours worked, hourly pay rate.
Process	Multiply number of hours worked by hourly pay rate. The result is the user's gross pay.
Output	Display a message indicating the user's gross pay.

2. **Visualize the program running on the computer.**

Before you create a program on the computer, you should first create it in your mind. Step 2 is the visualization of the program. Try to imagine what the computer screen looks like while the program is running. If it helps, draw pictures of the screen, with sample input and output, at various points in the program. For instance, here is the screen produced by the pay-calculating program:

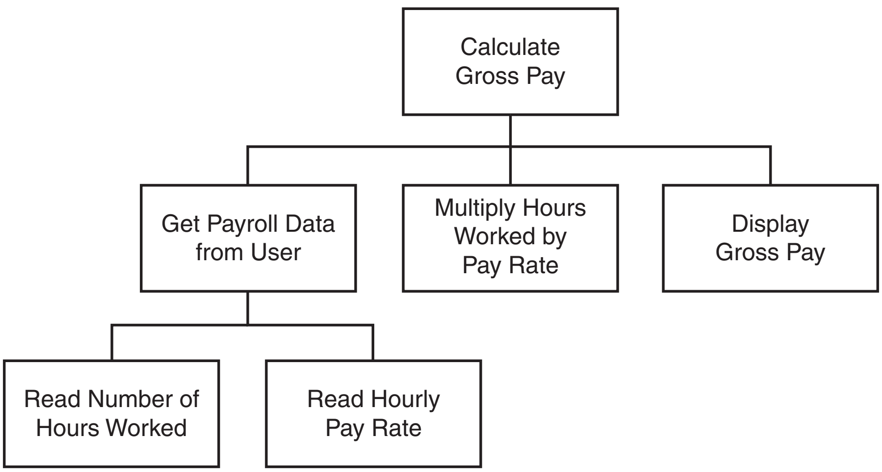
```
How many hours did you work? 10
How much do you get paid per hour? 15
You have earned $150
```

In this step, you must put yourself in the shoes of the user. What messages should the program display? What questions should it ask? By addressing these concerns, you will have already determined most of the program's output.

3. **Use design tools such as a hierarchy chart, flowcharts, or pseudocode to create a model of the program.**

While planning a program, the programmer uses one or more design tools to create a model of the program. Three common design tools are hierarchy charts, flowcharts, and pseudocode. A *hierarchy chart* is a diagram that graphically depicts the structure of a program. It has boxes that represent each step in the program. The boxes are connected in a way that illustrates their relationship to one another. Figure 1-12 shows a hierarchy chart for the pay-calculating program.

Figure 1-12



A hierarchy chart begins with the overall task and then refines it into smaller subtasks. Each of the subtasks is then refined into even smaller sets of subtasks, until each is small enough to be easily performed. For instance, in Figure 1-12, the overall task "Calculate Gross Pay" is listed in the top-level box. That task is broken into three subtasks. The first subtask, "Get Payroll Data from User," is broken further into two subtasks. This process of "divide and conquer" is known as *top-down design*.

VideoNote **Introduction to Flowcharting**

A *flowchart* is a diagram that shows the logical flow of a program. It is a useful tool for planning each operation a program performs and the order in which the operations are to occur. For more information see Appendix D, Introduction to Flowcharting.

Pseudocode is a cross between human language and a programming language. Although the computer can't understand pseudocode, programmers often find it helpful to write an algorithm in a language that's "almost" a programming language, but still very similar to natural language. For example, here is pseudocode that describes the pay-calculating program:

VideoNote **Designing a Program with Pseudocode**

Get payroll data.
Calculate gross pay.
Display gross pay.

Although the pseudocode above gives a broad view of the program, it doesn't reveal all the program's details. A more detailed version of the pseudocode follows.

Display "How many hours did you work?".
Input hours.
Display "How much do you get paid per hour?".
Input rate.
Store the value of hours times rate in the pay variable.
Display the value in the pay variable.

Notice the pseudocode contains statements that look more like commands than the English statements that describe the algorithm in Section 1.4 (What Is a Program Made of?). The pseudocode even names variables and describes mathematical operations.

4. **Check the model for logical errors.**

Logical errors are mistakes that cause the program to produce erroneous results. Once a hierarchy chart, flowchart, or pseudocode model of the program is assembled, it should be checked for these errors. The programmer should trace through the charts or pseudocode, checking the logic of each step. If an error is found, the model can be corrected before the next step is attempted.

5. **Type the code, save it, and compile it.**

Once a model of the program (hierarchy chart, flowchart, or pseudocode) has been created, checked, and corrected, the programmer is ready to write source code on the computer. The programmer saves the source code to a file and begins the process of translating it to machine language. During this step the compiler will find any syntax errors that may exist in the program.

6. **Correct any errors found during compilation. Repeat Steps 5 and 6 as many times as necessary.**

If the compiler reports any errors, they must be corrected. Steps 5 and 6 must be repeated until the program is free of compile-time errors.

7. **Run the program with test data for input.**

Once an executable file is generated, the program is ready to be tested for run-time errors. A run-time error is an error that occurs while the program is running. These are usually logical errors, such as mathematical mistakes.

Testing for run-time errors requires that the program be executed with sample data or sample input. The sample data should be such that the correct output can be predicted. If the program does not produce the correct output, a logical error is present in the program.

8. **Correct any errors found while running the program. Repeat Steps 5 through 8 as many times as necessary.**

When run-time errors are found in a program, they must be corrected. You must identify the step where the error occurred and determine the cause. Desk-checking is a process that can help locate run-time errors. The term *desk-checking* means the programmer starts reading the program, or a portion of the program, and steps through each statement. A sheet of paper is often used in this process to jot down the current contents of all variables and sketch what the screen looks like after each output operation. When a variable's contents change, or information is displayed on the screen, this is noted. By stepping through each statement, many errors can be located and corrected. If an error is a result of incorrect logic (such as an improperly stated math formula), you must correct the statement or statements involved in the logic. If an error is due to an incomplete understanding of the program requirements, then you must restate the program purpose and modify the hierarchy and/or flowcharts, pseudocode, and source code. The program must then be saved, recompiled and retested. This means Steps 5 though 8 must be repeated until the program reliably produces satisfactory results.

9. **Validate the results of the program.**

When you believe you have corrected all the run-time errors, enter test data and determine whether the program solves the original problem.

What Is Software Engineering?

The field of software engineering encompasses the whole process of crafting computer software. It includes designing, writing, testing, debugging, documenting, modifying, and maintaining complex software development projects. Like traditional engineers, software engineers use a number of tools in their craft. Here are a few examples:

- Program specifications
- Charts and diagrams of screen output
- Hierarchy charts and flowcharts
- Pseudocode
- Examples of expected input and desired output
- Special software designed for testing programs

Most commercial software applications are very large. In many instances one or more teams of programmers, not a single individual, develop them. It is important that the program requirements be thoroughly analyzed and divided into subtasks that are handled by individual teams, or individuals within a team.

In Step 3 of the programming process, you were introduced to the hierarchy chart as a tool for top-down design. The subtasks that are identified in a top-down design can easily become modules, or separate components of a program. If the program is very large or complex, a team of software engineers can be assigned to work on the individual modules. As the project develops, the modules are coordinated to finally become a single software application.

1.7 Procedural and Object-Oriented Programming

CONCEPT: Procedural programming and object-oriented programming are two ways of thinking about software development and program design.

C++ is a language that can be used for two methods of writing computer programs: *procedural programming* and *object-oriented programming*. This book is designed to teach you some of both.

In procedural programming, the programmer constructs procedures (or functions, as they are called in C++). The procedures are collections of programming statements that perform a specific task. The procedures each contain their own variables and commonly share variables with other procedures. This is illustrated by Figure 1-13.