Chapter: 12

**C++ I/O system**

Formatted I/O, ***width()***, ***precision()***, ***fill()***,

Manipulator & User Defined manipulators, inserter, extractor, file I/O, Random access etc.

**12.1 C++ I/O Stream**

* C++ I/O stream: The C++ I/O system, like the C I/O system, operates through streams. Some important points about streams are:
* A stream is a logical device that either produces or consumes information.
* A stream is linked to a physical device by the C++ I/O system.
* All streams behave in the same manner, even if the actual physical devices they are linked to differ. For example, the same function that you use to write to the screen can be used to write to a disk file or to the printer.
* Predefined streams of C++: when a C program begins execution, three predefined streams are automatically opened: stdin, stdout, and stderr. Similarly when a C++ program begins, these four streams are automatically opened:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Stream | Meaning | Default Devices | Stream | Meaning | Default Devices |
| ***cin*** | Standard input | Keyboard | ***cerr*** | Standard error | Screen |
| ***cout*** | Standard output | Screen | ***clog*** | Buffered version of ***cerr*** | Screen |

* The streams cin, cout, and cerr correspond to C's stdin, stdout, and stderr. clog is buffered version of cerr.
* Standard C++ also opens wide (16-bit) character versions of these streams called wcin, wcout, wcerr, and wclog.
* By default, the standard streams are used to communicate with the console. However, in proper environments these streams can be redirected to other devices.
* <iostream> and template classes: C++ provides support for its I/O system in the header file ***<iostream>***. In this file, a rather complicated set of class hierarchies is defined that supports I/O operations.
* The I/O classes begin with a system of template classes.
* Template classes/ generic classes: Template classes, also called generic classes *(will be discussed in next Chapter)*. Briefly, a template class defines the form of a class without fully specifying the data upon which it will operate. Once a template class has been defined, specific instances of it can be created.
* Standard C++ creates 2 specific versions of the I/O template classes: one for 8-bit characters and another for wide characters.
* The C++ I/O system is build upon two related, but different, template class hierarchies.
* basic\_streambuf: Derived from the low-level I/O class. This class supplies the basic, *low-level input and output operations* and provides the underlying *support for the entire C++ I/O system*. It is used in advanced I/O programming.
* basic\_ios: The class hierarchy that you will most commonly be working with is derived from basic\_ios. This is a high-level I/O class that provides: formatting, error-checking, and status information related to stream I/O.
* basic\_ios is used as a base for several derived classes, including :

|  |  |  |
| --- | --- | --- |
| 1. basic\_istream | 1. basic\_ostream | 1. basic\_iostream |

These classes are used to create streams capable of input, output, and input/output, respectively.

* The following character-based names will be used throughout the remainder of this note.

|  |  |  |  |
| --- | --- | --- | --- |
| Template Class | 8-Bit Character-Based Class | Template Class | 8-Bit Character-Based Class |
| ***basic\_ios*** | ios | ***basic\_streambuf*** | streambuf |
| ***basic\_istream*** | istream | ***basic\_fstream*** | fstream |
| ***basic\_ostream*** | ostream | ***basic\_ifstream*** | ifstream |
| ***basic\_iostream*** | iostream | ***basic\_ofstream*** | ofstream |

Note:

1. If you include ***<iostream>*** in you program, you will have access to ***ios*** class.
2. The ***ios*** class contains many member functions and variables that *control or monitor the fundamental operation of a stream*.

**12.2 Formatted I/O**

It is possible to output information in a wide variety of forms using C++'s I/O system as we did before with C's printf() function

* Each stream has associated with it a set of format flags that control the way information is formatted. The ios class declares a bitmask enumeration called fmtflags, in which the values are defined:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***adjustfield*** | ***dec*** | ***hex*** | ***oct*** | ***showbase*** | ***skipws*** |
| ***basefield*** | ***fixed*** | ***internal*** | ***right*** | ***showpoint*** | ***unitbuf*** |
| ***boolalpha*** | ***floatfield*** | ***left*** | ***scientific*** | ***showpos*** | ***uppercase*** |

* These values are used to set or clear the format flags and are defined within ios.

|  |  |
| --- | --- |
| * skipws: When the skipws flag is set, whitespace characters (spaces, tabs, and newlines) will be cleared for new input. When skipws is cleared, whitespace characters are not discarded. | * left, right, internal (for justified output): Default is right. * left and right flags make, left and right justified output. * internal flag makes a numeric value is padded to fill a field by inserting spaces between sign/base character. |
| * Dec, oct, hex : Decimal output is default * oct and hex flags produce octal and hexadecimal output respectively. * To return output to decimal, set the dec flag. | * showbase displays the base of numeric values. Eg. for hexadecimal conversion, ***1F*** will be displayed as ***0x1F***. * By default, the scientific notation ***"e"*** and hexadecimal notation ***"x"*** is displayed in *lowercase*, setting uppercase flag displays these characters in *uppercase*. |
| * scientific, fixed: If the scientific flag produce floating-point values using scientific notation. And fixed flag makes scientific-notation disabled, and normal notation returned. | * showpos flag displays **"+"** before positive values. * showpoint flag display **".000000"** for all floating-point output-whether needed or not. |
| * When neither flag is set, the compiler chooses an appropriate method. * unitbuf flushes the buffer after each insertion operation. | * Booleans can be input or output using the keywords true and false, when boolalpha is set. |

* basefield: the oct, dec, and hex fields can be collectively referred as basefield.
* adjustfield: the left, right, and internal fields collectively referred as adjustfield.
* floatfield: the scientific and fixed fields collectively referenced as floatfield.
* To set a format flag, use the ***setf()*** function which is a member of ios. Its form is: ***fmtflags setf (fmtflags flags);***
* This function returns the previous settings of the format flags and turns on those flags specified by ***flags***. (All other flags are unaffected.) For example, to turn on the showpos flag:

***stream.setf ( ios :: showpos );***

* Here ***stream*** is the stream that you wish to affect.
* Notice the use of the scope resolution operator (**::**). Because the *format flags* are defined within the ios class, you must access their values by using ios and the scope resolution operator.
* ***setf()*** is a member function of the ***ios*** class and affects streams created by that class.
* Therefore, any call to ***setf()*** is done relative to a specific stream.
* ***setf()*** cannot be called by itself
* There is no concept in C++ of global format status. Each stream maintains its own format status information individually.
* To set more than one flag in a single call to ***setf()***: use ***"OR"*** together the values of the flags. For example, this call sets the ***showbase*** and ***hex*** flags for ***cout***:

**cout.setf( ios :: showbase | ios :: hex );**

* Note: ***showpos***, ***showbase***, ***hex*** all are enumerated constants within the ios class. Therefore, it is necessary to tell the compiler this fact by preceding ***showpos/showbase/hex*** with the class name "ios" and the scope resolution operator "**::**". Otherwise ***showpos/showbase/hex*** will not be recognized. We must specify ios::showpos or ios::showbase or ios::hex.
* The complement of ***setf()*** is ***unsetf()***.This member function of ios clears one or more format flags. Its prototype form is:

***void unsetf ( fmtflags flags );***

* The flags specified by ***flags*** are cleared. (All other flags are unaffected.)
* To know the current format settings without altering: Use the special member function of ***ios***, ***flags()***, which simply *returns the current setting for each format flag*. Its prototype is: **fmtflags flags();**
* The **flags()** also allows to set/reset *all format flags associated with a stream to those specified in the argument* to **flags()**. The prototype for this version of **flags()** is:

***fmtflags flags ( fmtflags f);***

* For this version, the bit pattern found in **f** is copied to the variable used to hold the format flags associated with the stream, and overwrites all previous flag settings. The function *returns the previous settings*.

|  |  |
| --- | --- |
| * Example 1: following program shows how to set several flags.   **int** **main**(){  **cout**.**unsetf**(**ios**::**dec**); /\* not required by all compilers \*/  **cout**.**setf** (**ios**::**hex** | **ios**::**scientific**);  **cout**<< 123.23 << "hello" << 100 <<'\n'; | **cout**.**setf**(**ios**::**showpos** );  **cout**<< 10 <<' '<< -10 <<'\n';  **cout**.**setf**(**ios**::**showpoint** | **ios**::**fixed** );  **cout**<< 100.0;  **return** 0; } |

* This program displays: 1.232300e+02 hello 64 a fffffff6 +100.000000
* Here ***showpos*** flag affects only decimal output (i.e. a fffffff6 is unaffected). It does not affect the value ***10*** when output in ***hexadecimal***.
* Also notice the ***unsetf()*** call that turns off the ***dec*** flag (which is on by default). It is *necessary to turn it off* when *turning on* either ***hex*** or ***oct***. In general, it is better to set only the number base that you want to use and clear the others.
* Example 2: The following program illustrates the effect of the ***uppercase*** flag. It first enable ***uppercase***, ***showbase***, and ***hex*** flags to output: ***99*** in ***hexadecimal***. Then disables the uppercase.

|  |  |
| --- | --- |
| **int** **main**() { **cout**.**unsetf**(**ios** :: **dec** );  **cout**.**setf**(**ios**::**uppercase** | **ios**::**showbase** | **ios**::**hex**);  **cout** << 88 << '\n'; | **cout**.**unsetf**(**ios**::**uppercase** );  **cout** << 88 << '\n';  **return** 0; } |

* Example3: The following illustrates the showflags() function. Displays which flag is on and which is off.

|  |  |  |
| --- | --- | --- |
| **void** showflags(); /\* Declaration of the function \*/  **int** **main**(){ showflags(); /\* first shows default flag settings \*/  **cout**.**setf**(**ios**::**oct** | **ios**::**showbase** | **ios**::**fixed** ); /\* Changing flags \*/  **showflags**(); /\* shows changed flag settings \*/ **return** 0;} | | |
| **void** showflags(){  **ios**::**fmtflags** f;  f = **cout**.**flags**(); /\* get flag settings \*/  **if**(f & **ios** :: **skipws** ) **cout** <<"skipws on \n";  **else** **cout** << " skipws off \n";  **if**(f & **ios** :: **left** ) **cout** << " left on\n";  **else** **cout** << " left off \n";  **if**(f & **ios** :: **right** ) **cout** << " right on\n";  **else** **cout** << " right off \n";  **if**(f& **ios** :: **internal**) **cout**<<"internal on\n";  **else** **cout** << " internal off \n";  **if**(f & **ios** :: dec ) **cout** << "dec on\n";  **else** **cout** << "dec off \n"; | **if**(f & **ios** :: **oct** ) **cout** << "oct on\n";  **else** **cout** << "oct off \n";  **if**(f & **ios** :: **hex** ) **cout** << "hex on\n";  **else** **cout** << "hex off \n";  **if**(f&**ios**:: **showbase** ) **cout**<<"showbase on\n";  **else** **cout** << " showbase off \n";  **if**(f&**ios**::**showpoint**) **cout**<<"showpoint on\n";  **else** **cout** << " showpoint off \n";  **if**(f& **ios** :: **showpos** ) **cout** << " showpos on\n";  **else** **cout** << " showpos off \n";  **if**(f&**ios**::**uppercase**) **cout**<<"uppercase on\n";  **else** **cout** << " uppercase off \n"; | **if**(f&**ios**::**scientific**) **cout** << " scientific on\n";  **else** **cout** << " scientific off \n";  **if**(f & **ios** :: **fixed** ) **cout** << " fixed on\n";  **else** **cout** << " fixed off \n";  **if**(f & **ios** :: **unitbuf** ) **cout** << " unitbuf on\n";  **else** **cout** << " unitbuf off \n";  **if**(f & **ios** :: **boolalpha** ) **cout** << " boolalpha on\n";  **else** **cout** << " boolalpha off \n";  **cout** << "\n"; } |

* Inside ***showags()***, the *local variable* ***f*** is declared to be of type fmtflags. If your compiler does not define fmtflags, declare this variable as long instead.

**12.3 width(), precision(), AND fill()**

To set these format parameters: the *field width*, the *precision*, and the *fill character*, there are three member functions defined by ***ios***. These are ***width()***, ***precision()*** and ***fill()***, respectively.

* width(): To specify a minimum field width we use the width() function. Its prototype is:

***streamsize width( streamsize w);***

* Here ***w*** becomes the *field width*, and the previous field width is returned.
* The ***streamsize*** type is defined by ***<iostream>*** as some form of integer.
* It might be necessary to *set the minimum field width before each output* statement.
* When a value uses *less than the specified width*, the field is padded with the current fill character (the space, by default) so that the field width is reached.
* If the size of the output value *exceeds the minimum field width*, the field will be overrun. No values are truncated.
* precision(): By default, six digits of precision are used. You can set this number by using the ***precision()*** function. Its prototype:

***streamsize precision( streamsize p);***

* Here the ***precision*** is set to ***p*** and the old value is returned.
* fill(): by default, when a field needs to be filled, it is filled with spaces. To specify the fill character use ***fill()*** function. Prototype:

***char fill( char ch);***

* After a call to ***fill()***, ***ch*** becomes the new fill character, and the old one is returned.
* Example 1: Following illustrates the basics of width, precision and fill.

|  |  |
| --- | --- |
| **int main**(){ **cout**.**width**(10) ; *// set minimum filed width*  **cout**<< "hello"<<'\n'; *// right - justify by default*  **cout**.**fill** ('%'); *// set fill character*  **cout**.**width**(10) ; *// set width*  **cout**<< "hello" << '\n'; *// right - justify default*  **cout**.**setf**(**ios** :: **left** ); *// left - justify*  **cout**.**width** (10) ; *// set width*  **cout**<< "hello" <<'\n'; *// output left justified* | **cout**.**width**(10) ; *// set width*  **cout**.**precision** (10) ; *// set 10 digits of precision*  **cout**<< 123.234567 << '\n';  **cout**.**width**(10) ; *// set width*  **cout**.**precision**(6) ; *// set 6 digits of precision*  **cout**<< 123.234567 << '\n';  **return** 0; } |

* Notice that the *field width is set before each output* statement.
* Example 2: The following segment uses the C++ I/O format functions to create an aligned table of numbers:

|  |  |
| --- | --- |
| **int** **main**(){ **double** x;  **cout**.**precision**(4) ;  **cout**<< "x sqrt(x) x^2 \n\n"; | **for**(x=2.0; x<=20.0; x++) { **cout**.**width**(7); **cout**<<x<<" ";  **cout**.**width**(7); **cout**<<sqrt(x)<<" ";  **cout**.**width**(7); **cout**<<x\*x<< \n';}  **return** 0; } |

**12.4 I/O MANIPULATORS**

I/O manipulators are special I/O format functions that can occur within an I/O statement. (Where ios member functions stay separate from I/O statement). For example: **cout** << **oct** << 100 << **hex** << 100;

**cout** << **setw**(10) << 100;

* The first statement tells ***cout*** to display integers in octal and then outputs ***100*** in octal. It then tells the stream to display integers in hexadecimal and then outputs ***100*** in hexadecimal format.
* The second statement sets the field width to ***10*** and then displays ***100*** in hexadecimal format again (last base setting active).
* Notice that *when a manipulator does not take an argument*, such as oct in the example*, it is not followed by parentheses*. This is because it is the address of the manipulator that is passed to the overloaded ***<<*** operator.
* The main advantages of using manipulatior over the ios member functions is that they are easier to use and allow compact coding.
* Many of the I/O manipulators parallel member functions of the ios class.
* An I/O manipulator affects only the stream of which the I/O expression is a part and doesn't affect all currently opened streams.
* To access manipulators that take parameters, such as setw(), you must include <iomanip> in you program. This is not necessary when you are using a manipulator that does not require an argument.
* Example 1: Following includes ***setfill()*** and ***setw()*** so we have to include <iomanip>

#include <iostream>

#include <iomanip>

using namespace std;

**int** **main**() { **cout** << **hex** << 100 << **endl** ;

**cout** << **setfill**('X') << **setw**(10) ;

**cout** << 100 << " hi " << **endl** ;

**return** 0;}

* Boolalpha: ***boolalpha*** allows you to input and output Boolean values using the keywords ***true*** and ***false*** (normally you must enter ***1*** for ***true*** and ***0*** for ***false***).
* Must set the boolalpha flags for ***cin*** and ***cout*** separately. Eg: ***cin >> boolalpha >> b;*** // enter true or false
* As with all format flags, setting boolalpha for one stream does not imply that it is also set for another. For Example 2:

|  |  |  |
| --- | --- | --- |
| **int** **main**() { **bool** b;  **cout** << " Before boolalpha:";  b = **true** ;  **cout** << b <<" ";  b = **false** ;  **cout** << b << **endl**; | **cout** << " After boolalpha:";  b = **true** ;  **cout** << **boolalpha** << b << " ";  b = **false** ;  **cout** << b << **endl**;  **return** 0;} | OUTPUT:  Before boolalpha: 1 0  After boolalpha: true false |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| * Set/Reset: | | * To set specific format flags manually by manipulator, use ***setiosflags()*** which is equivalent to ***setf()***. * To turn off flags use the ***resetiosflags()*** manipulator which is equivalent to ***unsetf()***. | | | | |
| * Table of Slandered C++ I/O Manipulators: | | | | | | |
| Manipulator | Purpose | | I/O | Manipulator | Purpose | I/O |
| boolalpha | Turns on boolalpha flag | | I/O | oct | Turns on oct ag | I/O |
| dec | Turns on dec flag | | I/O | right | Turns on right flag | Output |
| endl | newline and flushes stream | | Output | resetiosflags(fmtflags f) | Turns off the flags specified in f | I/O |
| ends | Outputs a null | | Output | scientific | Turns on scientific flag | Output |
| fixed | Turns on fixed flag | | Output | setbase(int base) | Sets the number base to base | I/O |
| flush | Flushes a stream | | Output | setfill(int ch) | Sets the fill character to ch | I/O |
| hex | Turns on hex flag | | I/O | setiosflags(fmtflags f) | Turns on the flags specified in f | Output |
| internal | Turns on internal flag | | Output | setprecision(int p) | Sets the number of digits of precision | Output |
| left | Turns on left | | Output | setw(int w) | Sets the field width to w | Output |
| noboolalpha | Turns off boolalpha flag | | I/O | showbase | Turns on showbase flag | Output |
| noshowbase | Turns off showbase flag | | Output | showpoint | Turns on showpoint flag | Output |
| noshowpoint | Turns off showpoint flag | | Output | showpos | Turns on showpos flag | Output |
| noshowpos | Turns off showpos flag | | Output | skipws | Turns on skipws flag | Input |
| noskipws | Turns off skipws flag | | Input | unitbuf | Turns on unitbuf flag | Output |
| nounitbuf | Turns off unitbuf flag | | Output | uppercase | Turns on uppercase flag | Output |
| nouppercase | Turns off uppercase flag | | Output | ws | Skips leading white space | Input |

**12.5 Inserters and Extractors**

* Insertion and inserter: In C++, the output operation is called an insertion and the **<<** is called the insertion operator. (The reason for this term: an output operator inserts information into a stream).
* Overloading the **<<** for output, creates an *inserter function*, or inserter for short. All inserted functions have this general form:

**ostream** &operator**<<(ostream** &stream**,** class\_name obj**) {** /\* body of inserter \*/

**return stream; }**

* The inserted function "**ostream &operator<<**" returns a reference to stream, which is of type ostream. This is required if the overloaded **<<** is going to be used in a series of I/O expressions, such as ***cout<< ob1 << ob2 << ob3 ;***
* The first parameter is a reference to an object of type ostream. This means that stream *must be an output* stream. (ostream is derived form the ios class.)
* The second parameter receives the *object that will be output*. (This can also be a reference parameter).
* Extraction and extractor: In C++, the **>>** is referred to as the extraction operator. The reason for this term is that the act of inputting information from a stream removes (that is, extracts) data from it.
* A function that overloads **>>** is called an extractor. The general form of an extractor function is:

**istream** &operator**>>(istream** &stream**,** class\_name &ob**) {** /\* body of extractor \*/

**return stream; }**

* Extractors return a reference to stream " **istream &operator>>**", which is of type istream an input stream.
* The first parameter must be a reference to an input stream.
* The second parameter is a reference to the object that is receiving input.
* Inserter and extractor cannot be a member of a class: If an overloaded operator function is a *member of a class*, the left operand (which implicitly passed through this and also generates the call to the operator) must be an *object of that class*.
* When you create an inserter/extractor, the left operand is a stream and the right operand is the object that you want to output/input. Therefore, an inserter/extractor cannot be a member function.
* Inserter and extractor as **friend** of a class: Inserters/extractors can be friends of the class. In fact, in most programming situations you will encounter, an overloaded inserter will be a friend of the class for which it was created.
* Example 1: This program contains an inserter and an extractor for the coord class.

|  |  |
| --- | --- |
| **class** **coord** { **int** x, y;  **public**:  **coord**() { x = 0; y = 0; }  **coord**(**int** i, **int** j) { x = i; y = j; }  **friend** **ostream** & operator <<( **ostream** **&stream** , coord ob); /\* inserter \*/  **friend** **istream** & operator >>( **istream** **&stream** , coord &ob); /\* extractor \*/  }; | |
| **ostream** &operator<<(**ostream** **&stream**, coord ob){  **stream** << ob.x << ", " << ob.y << '\n';  **return** **stream** ; }  **istream** &operator>>(**istream** **&stream**, coord &ob){  **cout** << " Enter coordinates : ";  **stream** >> ob.x >> ob.y;  **return** **stream** ; } | **int** **main**() { **coord** a(1, 1) , b(10 , 23);  **cout** << a << b;  **cin** >> a;  **cout** << a;  **return** 0; } |

* Make inserter/extractor as general as possible: In this case, the I/O statement inside the inserter/extractor outputs/inputs the values of ***x*** and ***y*** to "stream", which is *whatever stream* is passed to the function *( "****stream****" is general for* ***cin****,* ***cout*** *and both* ***"<<"*** *&* ***">>"*** *can be used with it)*. As you will see in the following chapter, when written correctly the same inserter that outputs to the screen can be used to output to any stream.
* However the following is *not for general streaming*. In this case, the output statement is hard-coded to display information on the *standard output device* linked to ***cout***. This prevents the inserter from being used by other streams.

**ostream** &operator<<(**ostream** **&stream**, coord ob){

**cout** << ob.x << ", " << ob.y << '\n'; /\* using "cout" instead of "stream" \*/

**return** stream ;}

* Non-Friend inserter/extractor: If inserter/extractor are not friends to any class, they cannot use the private members of any class. However all public members are accessible.

**12.6 User Defined Manipulators**

* Custom manipulators are important for *two main reasons*.
* First, a manipulator can consolidate a sequence of several separate I/O operations: in which the same sequence of I/O operations occurs frequently within a program.
* Second, a custom manipulator can be important when you need to perform I/O operations on a nonstandard device. For example, you could use a manipulator to send control codes to a special type of *printer or an optic recognition* system.
* Types of Manipulators: there are *two basic types of manipulators*: those that operate on input streams and those that operate on output streams. There is a secondary division: those manipulators that take an argument and those that don't:

|  |  |
| --- | --- |
| 1. parameterized manipulator and | 1. parameterless manipulator |

* parameterized manipulator: The procedures necessary to create a parameterized manipulator vary widely from compiler to compiler, and even between two different versions of the same compiler. For this reason, you must consult the documentation to your compiler for instructions on creating parameterized manipulators. Parameterized manipulator is out of scope of this note.
* parameterless manipulators: However, the creation of parameterless manipulators is straightforward and the same for all compilers.
* Output functions: All *parameterless manipulator* output *functions* have this skeleton:

***ostream &manip\_name( ostream &stream ){*** /\* your code here \*/

***return stream ; }***

* Here ***manip\_name*** is the name of the manipulator and
* ***stream*** " &stream " is a reference to the invoking stream which must be returned by the manipulator ***" return stream; "***. This is necessary if a manipulator is used as part of a larger *I/O expression*.
* Here the manipulator has a single argument "a reference to the stream upon which it is operating", but no argument will be used when the manipulator is called in an output operation.
* Input functions: All *parameterless* input *manipulator functions* have this skeleton:

***istream &manip\_name( istream &stream ){*** /\* your code here \*/

***return stream ; }***

* An input manipulator receives a reference to the stream on which it was invoked. This stream must be returned by the manipulator.
* Example 1: Following creates a manipulator called ***setup()*** that sets field width to **10**, precision to **4**, and fill character to **\***.

|  |  |
| --- | --- |
| **ostream** &setup(**ostream** **&stream**){ **stream.width**(10);  **stream.precision**(4);  **stream.fill**('\*');  **return** **stream** ;} | **int main**(){ **cout** <<**setup**<< 123.123456;  **return** 0;} |

* Example 2: Following creates the **getpass()** input manipulator, which rings the bell and then prompts for a password:

|  |  |
| --- | --- |
| #include<cstring >  /\* A simple input manipulator \*/  **istream** &getpass(**istream** **&stream**){  **cout** << '**\a**'; /\* sound bell \*/  **cout** << " Enter password : ";  **return** **stream** ; } | **int main()**{ **char** pw[80];  /\* comparing password \*/  **do**{ **cin** >> **getpass** >> pw; }  **while**(**strcmp**(pw, "password"));  **cout** << " Logon complete \n";  **return** 0; } |

**12.7 File I/O**

* The same class hierarchy that supports console I/O also supports file I/O. To perform file I/O, you must include the header ***<fstream>*** in your program. It defines several classes, including ifstream, ofstream, and fstream which are derived from istream & ostream. And istream, ostream are derived fron ios.
* So ifstream, ofstream, and fstream also have access *to all operations* defined by ios.
* In C++, a file is opened by *linking it to a stream*. Before you can open a file, you must first obtain a stream. There are *three types* of streams:

1. input: To create an input stream, declare an object of type ifstream.
2. output: To create an output stream, declare an object of type ofstream.
3. input/output: Streams that will be performing both input and output operations must be declared as objects of type fstream.

For example, this fragment creates an *input* stream, an *output* stream, and one stream capable of *both input and output*:

**ifstream** in; /\* input \*/

**ofstream** out; /\* output \*/

**fstream** io; /\* input and output \*/

* Associate stream with a file: Use the function ***open()*** to associate a stream with a file. This function is a member of each ifstream, ofstream, and fstream. The prototype for each:

**void ifstream :: open(const char** \*filename**, openmode mode = ios::in);**

**void ofstream :: open(const char** \*filename**, openmode mode = ios::out | ios::trunc );**

**void fstream :: open(const char** \*filename**, openmode mode = ios::in | ios::out);**

* Here ***filename*** is the name of the file, which can include a path specifier.
* The value of ***mode*** determines how the file is opened. It must be a value of type ***openmode***, which is an enumeration defined by ios that contains the following values:

1. ios::app causes all output to that file to be appended to the end. This value can be used only with files capable of output.
2. ios::ate causes a seek to the end-of-file to occur when the file is opened (I/O can still occur anywhere within the file).
3. ios::binary value causes a file to be opened in binary mode (text is default mode). In binary mode *no character translations* (carriage return/linefeed sequences) will occur.
4. ios::in value specifies that the file is capable of input.
5. ios::out value specifies that the file is capable of output.
6. ios::trunc value causes the contents of a *preexisting file by the same name* to be destroyed and the file to be truncated to zero length.

* When output stream using ofstream created, any *preexisting file with the same name is automatically truncated*.
* These six values can be combined using OR.
* Example 1: The following fragment opens an *output file* called test:

**ofstream** mystream;

mystream.**open**(" test ");

* Since the mode parameter to ***open()*** defaults to a *value appropriate to the type of stream* being opened, there is no need to specify its value in the preceding example.
* Confirmation test: If ***open()*** fails, the stream will *evaluate to false when used in a Boolean* expression. Which can be used in a confirmation test (consider Example 1) :

**if**(!mystream) { **cout** << "Cannot open file. \n";

/\* handle error \*/ }

* Always check the result of a call to ***open()*** before attempting to access the file.
* Use the ***is\_open()*** function to see if a file successfully opened. ***is\_open()*** is a member of fstream, ifstream, and ofstream. It has this prototype: **bool** is\_open();
* It returns true if the *stream is linked to an open file* and false otherwise. For example, the following checks if ***mystream*** is currently open:

**if**( !mystream.is\_open() ){ **cout** << " File is not open .\n";

. . . . . }

* Bypass the open() function: Most of the times we don’t need to use the function ***open()*** because the ifstream, ofstream, and fstream classes have *constructor functions that automatically open the file*. And those constructor functions have the *same parameters and defaults* as the ***open()***. Therefore, the most common way to open a file is:

**ifstream** mystream**("**myfile**");** /\* open file for input \*/

* If the file cannot be opened, the stream variable will evaluate as false when used in a conditional/Boolean statement.
* Therefore, in this case we also need the confirmation test as stated above.
* Closing a file: To close a file, use the member function ***close()***. For example, to close the file linked to a stream called mystream:

mystream.**close()**;

* The ***close()*** function takes *no parameters* and returns *no value*.
* The eof() function: Use the ***eof()*** member function of ios to detect when the *end-of-input-file* has been reach. It has this prototype:

***bool eof();***

* It *returns* true when the end-of-file has been encountered and false otherwise.
* Read/Write textual data: to read/write textual data from/to an *opened file* we simply use **<<** and **>>** operators (more like C's **fprintf()** and **fscanf()**).
* A file produced by using **<<** is a *formatted text* file. A file read by **>>** must be a *formatted text* file.
* Typically, formatted text files are operated through the **>>** and **<<** operators. They are *not for binary mode*. Binary mode is best used on unformatted files.
* Example 2: Following creates an output file, write information to it, closes the file and opens it again as an input file, and reads in the information:

|  |  |
| --- | --- |
| #include<iostream>  #include<fstream>  using namespace std;  **int** **main**(){ **ofstream** f\_out("test"); // create output file  **if**(!f\_out){ **cout** << "Cannot open output file .\n";  **return** 1;} //notice !f\_out Boolean!!!  f\_out **<<** "Hello !\n";  f\_out **<<** 100 **<<** ' ' **<<** **hex** << 100 << **endl** ;  f\_out.**close**(); //closing the created file | **ifstream** f\_in("test"); //open input file  if**(!**f\_in ){ **cout** << "Cannot open input file .\n";  **return** 1; }  **char** str[80];  **int** i;  f\_in **>>** str **>>** i;  **cout** << str << ' ' << i << **endl** ;  f\_in.**close**(); //closing the opened file  **return** 0; } |

* When the **<<** and **>>** operators are used to perform file I/O, information is formatted exactly as it would appear on the screen.

**12.8 UNFORMATTED I/O & BINARY I/O**

Unformatted files contain the same *binary representation* of the data *as that used internally* *by* your *program* (rather than text data which is translated into by the **<<** and **>>**). Thus, unformatted functions give you detailed control over how files are written and read.

* Lowest-level unformatted I/O: The lowest-level unformatted I/O functions are **get()** and **put()**. **get()** is used to read a byte and **put()**is used to write a byte. These are members of all I & O stream classes respectively. Common version of **get()** & **put()** :

**istream &get(char &ch);**

**ostream &put(char &ch);**

* ***get()*** reads a single character from the *associated stream* and puts that value in ***ch***.
* It *returns a reference* to the stream.
* If a read is attempted at end-of-file, on return the invoking stream will evaluate to *false in Boolean expression*.
* ***put()*** writes ***ch*** to the stream and *returns a reference* to the stream.
* Overloading ***get()***: There are several different ways in which the ***get()*** function is overloaded. The prototypes for the three most commonly used overloaded forms are:

***istream &get(char \*buf, streamsize num);***

***istream &get(char \*buf, streamsize num, char delim);***

***int get();***

* The first form reads characters into the *array pointed to* by ***buf*** until either ***num-1*** characters have been read, *a newline is found*, or the end-of-file has been encountered.
* They *array pointed to* by ***buf*** will be null terminated by ***get()***.
* If the *newline character* is encountered in the input stream, it is not extracted (inputted). Instead, *it remains in the stream until the next input operation*.
* The second form reads characters into the *array pointed to* by ***buf*** until either ***num-1*** characters have been read, *the character specified by* delim *has been found*, or the end-of-file has been encountered.
* The *array pointed to* by ***buf*** will be null terminated by ***get()***.
* If the *delimiter character* is encountered in the input stream, it is not extracted (inputted). Instead, *it remains in the stream until the next input operation*.
  + Note (Delimiter character): A delimiter is one or more *characters that separate text strings*. Common delimiters are **commas(,)**, **semicolon(;)**, **quotes(",')**, **braces({})**, **pipes(|)**, or **slashes(/ \)**. Newline character is also a delimiter.
* The third form of ***get()*** returns the *next character from the stream*. It returns ***EOF*** if the end-of-file is encountered. This form of ***get()*** is similar to C's ***getc()*** function.
* **getline()** with overloaded form: ***getline()*** is another *input function*. It is a member of each input stream class. Its prototypes:

***istream &getline(char \*buf, streamsize num);***

***istream &getline(char \*buf, streamsize num, char delim);***

* The first form reads characters into the *array pointed to* by ***buf*** until either ***num-1*** characters have been read, *a newline is found*, or the end-of-file has been encountered.
* They *array pointed to* by ***buf*** will be null terminated by ***getline()***.
* If the *newline character* is encountered in the input stream, it is extracted (inputted), but it is not put into ***buf***.
* The second form reads characters into the *array pointed to* by ***buf*** until either ***num-1*** characters have been read, *the character specified by* delim *has been found*, or the end-of-file has been encountered.
* The *array pointed to* by ***buf*** will be null terminated by ***getline()***.
* If the *delimiter character* is encountered in the input stream, it is extracted (inputted), but it is not put into ***buf***.
* Comparison between **get()** and **getline()**: The two versions of ***getline()*** are virtually identical to the ***get(buf, num)*** and ***get(buf, num, delim)*** versions of ***get()***.
* The difference between ***get()*** and ***getline()*** is that ***getline()*** reads and removes the delimiter from the input stream; ***get()*** does not.
* Data blocks I/O: To *read* and *write* blocks of data, use the ***read()*** and ***write()*** functions, which are also members of the *I & O stream classes*, respectively. Their prototypes are:

***istream &read (char \*buf, streamsize num);***

***ostream &write (const char \*buf, streamsize num);***

* ***read()*** reads ***num*** bytes from the invoking stream and puts them in the buffer pointed to by ***buf***.
* ***write()*** writes ***num*** bytes to the associated stream from the buffer pointed to by ***buf***.
* ***streamsize*** type is some *form of integer*. An object of type ***streamsize*** is capable of *holding the largest number of bytes* that will be transferred in any one ***I/O*** operation.
* If the end-of-file is reached before ***num*** characters have been read, ***read()*** simply stops, and the buffer contains *as many characters as were available*.
* gcount():You can find out how many characters have been read by using the member function ***gcount()***. The prototype is:

***streamsize gcount();***

* It *returns the number of characters* read by the last unformatted input operations.
* peek(): Use ***peek()*** to obtain the *next character* in the input stream *without removing* it from that stream . It is a member of the input stream classes and has this prototype:

***int peek();***

|  |  |
| --- | --- |
| * It *returns the next character* in the stream. | * It returns **EOF** if the end-of-file is encountered. |

* putback():Use ***putback()*** to return the last character read from a stream to that stream. It is a member of the input stream classes. Its prototype is:

***istream &putback(char c);***

* Where ***c*** is the last character read.
* flush()***:*** When output is performed, data is *not immediately written* to the *physical device linked to the stream*. Instead, information is stored in an internal buffer until the buffer is full. Only then are the contents of that buffer written to disk.
* By calling ***flush()*** you can *force the information to be physically written* to disk before the *buffer is full*. ***flush()*** is a member of the output stream classes and has this prototype:

***ostream &flush();***

* Calls to ***flush()*** might be warranted when a program is going to be used in adverse environments (in situations where *power outages occur frequently*, for example).
* ios :: binary: For *unformatted file I/O* we always use binary operation (rather than text operations **>>** **<<**).
* specifying ***ios::binary*** prevents any character translations from occurring. This is important when the binary representations of data such as integers, float, and pointers are stored in the file.
* However, it is perfectly acceptable to use the unformatted functions on a file opened in text mode, but remember, some *character translations may occur*.
* Example 1: Following uses write() to write a double and a string to a file called test:

|  |  |
| --- | --- |
| #include<iostream>  #include<fstream>  #include<cstring>  using namespace std;  **int** **main**(){ **ofstream** out(" test ", **ios :: out** | **ios :: binary** );  **if**(!out ) { **cout** << " Cannot open output file .\n"; **return** 1; } | **double** num = 100.45;  **char** str[] = "This is a test";  out.**write**(( **char** \*) &num, **sizeof**(**double**)) ;  out.**write**(str , **strlen**(str));  out.**close**();  **return** 0; } |

* The type cast to (***char \****) inside the call to ***write()*** is necessary when *outputting a buffer that is not defined as a character array*. Because of C++'s strong type checking, *a pointer of one type will not automatically be converted into a pointer of another type*.
* Example 2: This program uses ***read()*** to read the file created by the program in Example 1:

|  |  |
| --- | --- |
| #include <iostream>  #include <fstream>  using namespace std;  **int** **main**() { **ifstream** in(" test ", **ios :: in** | **ios :: binary** );  **if** (!in) { **cout** << " Cannot open input file .\n"; **return** 1; } | **double** num; **char** str[80];  in.**read**(( **char** \*) &num , **sizeof** (**double**)) ;  in.**read**(str , 14) ;  str[14] = '\0 '; */\* null terminate str \*/*  **cout** << num << ' ' << str ;  in. **close**(); **return** 0;} |

* As is the case with the program in the preceding example, the type cast (***char \****) inside ***read()*** is necessary because *C++ will not automatically convert a pointer of one type to another*.
* Example 3: When you use **>>** to read a string, it *stops reading when the first whitespace character is encountered*. This makes it useless for reading a string containing spaces. ***getline()*** can resolve this problem:

|  |  |
| --- | --- |
| #include<iostream>  #includ <fstream>  using namespace std; | **int** **main**(){ **char** str[80];  **cout** << " Enter your name : ";  **cin**.**getline**(str , 79);  **cout** << str << '\n';  **return** 0; } |

* Here, the delimited used by ***getline()*** is the newline. This makes ***getline()*** act like the standard ***gets()*** function.
* Example 4: In real programming situations, the functions ***peek()*** and ***putback()*** are especially useful because they let you more easily handle situations in which you *do not know what type of information is being input at any point in time*. The following program gives the flavor of this. It reads either strings or integers from a file. *The strings and integers can occur in any order*.

|  |  |
| --- | --- |
| #include <iostream >  #include <fstream >  #include <cctype >  #include <cstdlib >  using namespace std;  **int** **main**(){**char** ch;  **ofstream** out("test", **ios::out** | **ios::binary** );  **if**(!out ){ **cout** << "Cannot open output file .\n";  **return** 1; } */\* confirmation \*/*  **char** str[80], \*p;  out << 123 << "this is a test" << 23;  out << "Hello there !" << 99 << "sdf" << **endl**;  out.**close**(); */\* closing 1st time \*/* | **ifstream** in("test", **ios::in** | **ios::binary**);  **if**(!in) { **cout** << "Cannot open input file .\n";  **return** 1; } /\* confirmation \*/  ***do***{ p = str;  ch = in.**peek**(); */\* see what type of char is next \*/*  **if**(**isdigit**(ch)){ **while**(**isdigit**( \*p=in.**get**() )) p++; */\* read integer \*/*  in.**putback**(\*p); */\* return char to stream \*/*  \*p = '\0 '; */\* null - terminate the string \*/*  **cout** << " Integer : " << **atoi**(str ); }  **else** **if**(**isalpha**(ch)){**while**(**isalpha**\*p=in.**get**() )) p++; */\* read a string \*/*  in.**putback** (\*p);  \*p = '\0 ';  **cout** << " String : " << str ; }  **else** in.**get**(); */\* ignore \*/*  **cout** << '\n'; } ***while*** (! in.**eof**());  in.**close**(); */\* final file closing \*/*  **return** 0; } |

* The ***atoi()*** is one of C's standard library function, it returns the integer equivalent of the number represented by its string argument.
* The ***isalpba()*** function returns nonzero if **ch** is a letter of the *alphabet*; otherwise **0** is returned.
* The ***isdigit()*** function returns nonzero if **ch** is a digit (***0 through 9***); otherwise **0** is returned.

***#include <ctype.h>***

***int isdigit(int ch);***

***int isalpha(int ch);***

Eg: **if(isalpha(ch)) printf("%c is a letter\n", ch);**

**if(isdigit(ch)) printf("%c is a digit\n", ch);**

**12.9 Checking I/O Status**

The current status of an I/O stream is described in an object of type iostate, it is an enumeration defined by ios that includes members:

|  |  |  |  |
| --- | --- | --- | --- |
| 1. goodbit *(Means-No errors occurred)* | 1. eofbit *(Means-End-of-file has been encountered)* | 1. failbit *(Means-A nonfatal I/O error has occurred)* | 1. badbit *(Means-A fatal I/O error has occurred)* |

* There are two ways in which you can obtain I/O status information.
* First, you can call the ***rdstate()*** function, which is a member of ios. It has this prototype: **iostate rdstate();**
* It returns the current status of the error flags.
* ***rdstate()*** returns ***goodbit*** when no error has occurred. Otherwise, an error flag is returned.
* Second way to determine whether an error has occurred is by using one or more of these ios member functions:

|  |  |  |  |
| --- | --- | --- | --- |
| 1. ***bool eof();***   The **eof()** was discussed earlier. | 1. ***bool bad();***   The **bad()** returns true if ***badbit*** is set. | 1. ***bool fail();***   The **fail()** returns true if ***failbit*** is set. | 1. ***bool good();***   The **good()** returns true if there are ***no errors***. |

* Otherwise they return false.
* clear(): To *clear an erro*r before your program continues use the ios member function ***clear()*** whose prototype is:

***void clear(iostate flags = ios::goodbit);***

* If ***flags*** is ***goodbit*** (as it is by default), all *error flags* are cleared. Otherwise, set ***flags*** to the settings you desire.
* Example 1: Following uses **rdstate()** to detect a *file error* for a file named "in":

**void** checkstatus(**ifstream** &in) { **ios :: iostate** i;

i = in.**rdstate**();

**if**(i & **ios::eofbit** ) **cout** << "EOF encountered \n";

**else** **if**(i & **ios::failbit** ) **cout** << "Non - Fatal I/O error \n";

**else** **if**(i & **ios::badbit** ) **cout** << "Fatal I/O error \n"; }

* Example 2: Following uses **good()** to detect a *file error* for a file named "in":

**if**(!in.**good**() && !in.**eof**()) { **cout** << "I/O Error ... terminating \n"; **return** 1; }

**12.10 Random Access**

Use the ***seekg()*** and ***seekp()*** to perform random access, these are members of the I & O stream classes, respectively. Common forms:

***istream &seekg(off\_type*** offset***, seekdir*** origin***);***

***ostream &seekp(off\_type*** offset***, seekdir*** origin***);***

* ***off\_type*** is an *integer type* defined by ios that is *capable of containing the largest valid value* that ***offset*** can have.
* ***seekdir*** is an *enumeration* defined by ios that has these values:

|  |  |  |
| --- | --- | --- |
| 1. **ios::beg** (Means-Seek from beginning) | 1. **ios::cur** (Means-Seek from current location) | 1. **ios::end** (Means-Seek from end) |

* C++ I/O system manages two pointers associated with a file. The appropriate pointer is automatically applied for each I/O operation.
* get pointer, which specifies where in the file the *next* input *operation will occur*.
* put pointer, which specifies where in the file the *next* output *operation will occur*.
* ***seekg()*** and ***seekp()*** can be used in *nonsequential* fashion.
* ***seekg()*** moves the associated file's current get pointer ***offset*** number of bytes from the specified origin.
* ***seekp()*** moves the associated file's current put pointer ***offset*** number of bytes from the specified origin.
* Files that will be accessed via ***seekg()*** and ***seekp()*** should be opened for *binary file operations*.
* Use following member functions to determine the current position of each file pointer.

***pos\_type tellg(); pos\_type tellp();***

* ***pos\_type*** is an *integer type* defined by ios that is *capable of holding the largest value* that defines a *file position*.
* Overloaded versions of **seekg()** and **seekp()**: There are overloaded versions of ***seekg()*** and ***seekp()*** that move the file pointers to the location specified by the return values of ***tellg()*** and ***tellp()***. Their prototypes are:

***istream &seekg( pos\_type position );***

***ostream &seekp( pos\_type position );***

* Example 1: The following program demonstrates the ***seekp()*** function. It *allows you to change a specific character in a file*. Specify a *file name* on the command line, followed by the *number of the byte* in the file you want to change, followed by the new character. Notice that the file is opened for *read/write operations*.

|  |  |
| --- | --- |
| #include <iostream>  #include <fstream>  #include <cstdlib>  using namespace std;  **int main** (**int argc**, **char \*argv[]**) {  **if**(argc !=4) { **cout** << " Usage : CHANGE <filename > <byte > <char >\n"; **return** 1;} | **fstream** out( argv[1] , **ios::in** | **ios::out** | **ios::binary** );  **if** (!out){**cout** << " Cannot open file .\n"; **return** 1; }  out.**seekp**( **atoi**(argv [2]), **ios::beg**);  out.**put**(\*argv[3]) ;  out.**close**();  **return** 0;} |

* Example 2: In the above program uses ***seekg()*** to position the get pointer into the *middle of a file named "in"* and then displays the contents of that file from that point. The name of the file and the location to begin reading from are specified on the command line.

in.**seekg**( **atoi**(argv[2]), **ios::beg** );

Note : ***\*argv[]*** and ***argc*** are used in ***main()***'s arguments. They are called the command line arguments. (Recall: 5.4)

**12.11 Customized I/O And Files**

*Overloaded* inserters and extractors, as well as I/O manipulators, can be used with *any stream* as long as they are written in a general manner. Because all C++ streams are the same, for example, the *same overloaded inserter function* can be used to output to the screen or to a file with no changes whatsoever.

* If you "hard-code" a specific stream into an I/O function, its use is, of course, *limited to only that stream*. This is why you were urged to *generalize your I/O functions* whenever possible. (Recall 12.5 : Make inserter/extractor as general as possible)
* Example 1: In the following program, the coord class overloads the << and >> operators. Notice that you can use the operator functions to write both to the screen and to a file.

|  |  |
| --- | --- |
| #include <iostream >  #include <fstream >  using namespace std;  **class** coord { **int** x, y;  **public** :  coord (**int** i, **int** j) { x = i; y = j; }  **friend ostream** &**operator** **<<**( **ostream** &**stream** , coord ob);  **friend istream** &**operator** **>>**( **istream** &**stream** , coord &ob);  };  **ostream** &**operator** <<( **ostream** &**stream** , coord ob){  **stream** << ob.x << ' ' << ob.y << '\n';  **return** **stream** ;}  **istream** & **operator** >>( **istream** &**stream** , coord &ob){  **stream** >> ob.x >> ob.y;  **return** **stream** ;} | **int** **main**() {**coord** o1(1, 2) , o2(3, 4);  **ofstream** out(" test ");  **if** (!out ) { **cout** << " Cannot open output file .\n";  **return** 1; }  out << o1 << o2;  out . close ();  **ifstream** in(" test ");  **if** (!in) { **cout** << " Cannot open input file .\n";  **return** 1; }  **coord** o3(0, 0) , o4(0, 0);  in >> o3 >> o4;  **cout** << o3 << o4;  in.**close** ();  **return** 0; } |