Lecture #6 – Advanced File Operations

Review: **Text files**

5 Steps to read a file (or write to a file):

```
#include <iostream>
#include <fstream>          <-- Step #1 - Include the file stream library

int main()
{
   // (int and string variables here)

   ifstream infile;         <-- Step #2 - Create a file object.
   ofstream outfile;                      (ifstream to read - ofstream to write)


   infile.open("c:\\data.txt");    <-- Step #3 - Open the file
   outfile.open("c:\\names.txt");

   infile >> number;        <-- Step #4 - Read a file, or write to a file
   outfile << name;


   infile.close();          <-- Step #5 - Close the file.
   outfile.close();

   return 0;
}
```

Note: Although all files are closed when a program ends, it is good coding style to include code to close a file when it is no longer needed.

Fail state - The file input stream can fail if the file name is misspelled.

- C++ does not automatically generate an error message if a file does not open.
- The programmer must include code to check to see if a file fails to open.

Two ways to check the file stream**:** (next page)

1.) Call the fail() function

```
if (outFile.fail())          // Function returns true or false.
{
   cout << "File did not open\n";

   return 1;                 // When this statement is in main(), 1 is returned to
}                            //      the operating system, and the program closes.
```

```
if (!inFile)          // if the file does not open, …….
{
   cout << "Error opening file.  ";
   exit(1);           // When this statement is used in any function, 1 is
                      //    returned to the OS, and the program closes.
}                     // Defined in <cstdlib>, but not required in Visual Studio )
```

End-of-file marker - When a file is written, the operating system automatically writes an EOF marker at the end of the file.

- The end-of-file character is different for different operating systems.
- **`.eof() function`** - Use this function to detect the end of a file.

Ex 1:
```
while (!inFile.eof())          // While it's not the end of the file
{                              //    read numbers and output them.
    inFile >> number;
    cout << number << endl;
}
```

Another way to read a text file → `while (inFile >> number)`

Run-time input of file names:

Ex 2:
```
ifstream inFile;
char fileName[30];

cout << "Enter the input file name:  ";
cin >> fileName;      // (or → cin.getline(fileName, 30)

inFile.open(fileName);
```

Using the fstream Data Type

Ex 3:
```
#include <fstream>

int main()
{
   int num1, num2, num3;
   fstream dataFile;        //  fstream – The I/O mode must be specified.

   // open() function takes 2 arguments:
   dataFile.open("info.txt", ios::out);
                            filename   file access flag – Open in output mode.
```

File Access Flags - C++ Access Flags specifies how a file will be read or written (for text and binary files).

- **`ios::in`** - Input mode.
- **`ios::out`** - Output mode.

  - By default, data that is already in the file is overwritten.

- **ios::trunc** - If a file already exists, its contents will be deleted (truncated).
  - This is the default mode used by ios::out.

- **ios::app** - Append mode.
  - If a file exists, its contents are preserved and all ouput is written to the end of the file.

- **ios::binary** - Binary mode.
  - When a file is opened in binary mode, data is read or written in binary form. (Text is default)

- Flags can be used with ifstream and ofstream objects.

- Several flags can be used together, by using the | operator.

Note: Opening for input and output at the same time does not work with text (**binary only**).

Ex 4: `dataFile.open("info.txt", ios::out | ios::app);`

Note: Another way to open a file is to open it when the file object is declared.

- This eliminates the open() function.

Ex 5:
```
fstream dataFile("names.txt", ios::out | ios::app);
if (!dataFile)
   cout << "Error opening file";
```

NOTE: A file can be opened in input mode and output mode, in binary only (not text files).

File Output Formatting - File output may be formatted in the same way screen output is formatted.

Ex 6:
```
#include <fstream>
#include <iomanip>          // for setprecision()

int main()
{
  fstream dataFile("numbers.txt", ios::out);
  double number = 17.123456;

  dataFile << fixed << showpoint << setprecision(3)
           << number << endl << setprecision(1);
           << number << endl;
  dataFile.close();
  return 0;
}
```

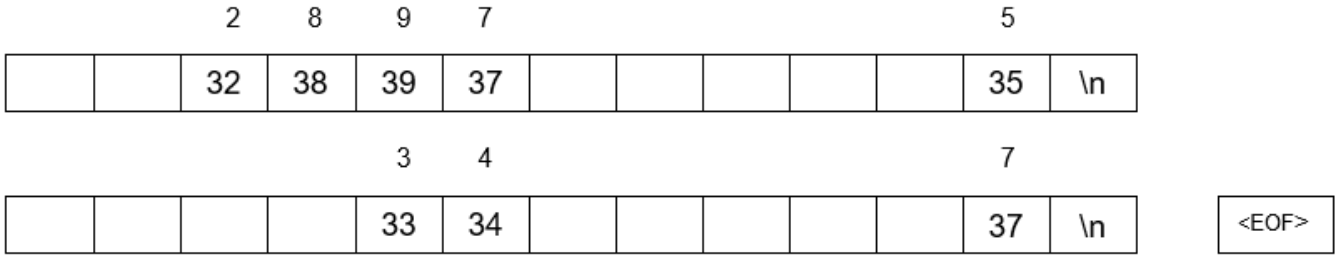
```
OUTPUT:

17.123
17.1
```

Ex 7: Writing 2 rows of data to a file:

```
#include <fstream>
#include <iomanip>          // for setw()

const int ROWS = 2;
const int COLS = 2;

int main()
{
   fstream outFile("table.txt", ios::out);

   int numbers[ROWS][COLS] = {{2897, 5},{34, 7}};

   for (int row = 0; row < ROWS; row++)
   {
      for (int col = 0; col < COLS; col++
      {
          outFile << setw(6) << numbers[row][col];
      }
      outFile << endl;
   }
  return 0;
}
```

ASCII Code		
Dec		Hex
0	-	30
1	-	31
2	-	32
3	-	33
4	-	34
5	-	35
6	-	36
7	-	37
8	-	38
9	-	39

This is how the characters appear in the file:



Passing File Stream Objects to Functions

- File stream objects are always passed by reference.
- Pass 2 arguments:

Function Prototype: `bool readFile(fstream & file, char * name);`

file stream — pointer to the file name

Ex 8: Program reads names from in a file – up to 80 characters per line.

```
// ===========================================
#include <iostream>
#include <fstream>
using namespace std;

const int SIZE = 81;
```

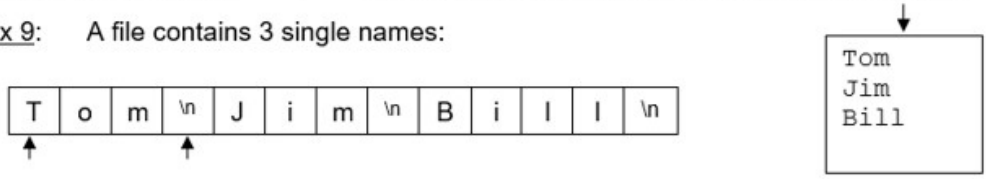
```
bool readFile(fstream &, char *);
void showContents(fstream &);

int main()
{
   fstream inFile;
   if (!readFile(inFile, "data.txt"))
   {
      cout << "Error opening file!\n";
      return 0;
   }
   cout << "File opened successfully.\n";

   cout << "Now reading file\n";
   showContents(inFile);

   inFile.close();
   return 0;
}

// ==== readFile() ============================
bool readFile(fstream & file, char * name)
{
   file.open(name, ios::in);

   if (file.fail())
     return false;
   else
     return true;
}
// ==== showContents() ========================
void showContents(fstream & file)
{
   char line[SIZE];

   while (file >> line)     // (or  file.getline(line, SIZE);
   {
      cout << line << endl;
   }
}
// ============================
```

```
/*  OUTPUT:
File opened successfully.
Now reading file.
Jones
Smith
Willis
Davis   */
```

getline() vs. **extraction operator** (**>>**)

Extraction operator (>>) – This operator is used to extract data from a text file.

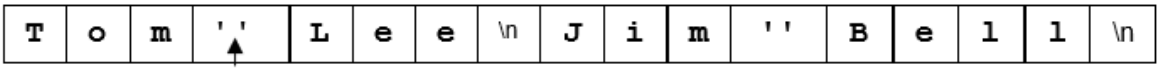
Ex 9: A file contains 3 single names:




```
string name;

while (!inFile.eof())
{
     inFile >> name;        // The extraction operator reads Tom and stops when it
                            //  encounters any white space ('\n',  '\t',  ' ')
```

Problem: The extraction operator cannot read names with white spaces.

Ex 10: A file contains full names:




```
string name;
inFile >> name;
```

- The extraction operator reads Tom and stops when it encounters ''.
- The variable *fullName* contains only Tom, and not Tom Lee.

Solution: Use the getline() function() to read strings and c_strings in a file.

- getline() has 3 parameters.
- The 3rd parameter, by default, is '\n', but can be changed.

Ex 11: `getline(inFile, name, '\n');` // string name;

Ex 12: `inFile.getline(name, 30, '/');` // char name[30];

Delimiter – A character used to separate fields in a file.

Ex 13: Comma delimited → 20,Jimmy Page,400 Oak Street,23,Tom Lee, 223 **…**

Ex 14: Slash delimited → 18/Bill Bell/123 Main Street/33/Pete Townsend/**…**

- To read a slash-delimited file, specify the delimiter in the 3rd argument.

Ex 15: **Read a delimited text file containing strings:**

```
string name;

while (true)
{
   if (file.eof())
       break;
   getline(file, name, '/');      // getline reads text and stops
                                  //    at the '/' delimiter.
                                  // The '/' is absorbed and the
                                  //     pointer advances.
       cout << name << endl;
}
```

Ex 16: **Read a comma delimited text file, containing c_strings**

```
char name[30];

while (!file.eof())
{
   file.getline(name,30, ',');    // getline() reads characters until
                                  //    it has read 29 characters, or
                                  //    it encounters a ',' character
                                  // The ',' is absorbed and the
                                  //     pointer advances.
       cout << name << endl;
}
```

get() function

- The ***get()*** function reads the next character from a text file.
- It will read any character, but only one, including white spaces (`'\n', '\t', ' '`)

Ex 17: The following can read the Gettysburg Address in a file and output it to the screen.

```
inFile.get(character);

while(!inFile.eof())
{
    cout << character;
    inFile.get(character);     //  char character;
}
```

putback() function - The function moves the ***get pointer*** back one character in a text file

Ex 19: The following reads text, one character at a time from a text file.

- The character is then checked to see if it is a `'<'` or `'>'`.
- If it is, then the ***get pointer*** is moved back one character.

```
inFile.get(character);
```

```
while(!inFile.eof())
{
   if (character == '<')
   {
      inFile.putback(character);
      //   Put the character back on the buffer and then do something
   }
   else
      inFile.get(character);   //  Otherwise get the character
}    //   end of while loop
```

peek() function

- The ***peek()*** function looks ahead to the next character in the text file, before getting it.

  Ex 20: The following reads text, one character at a time.

```
inFile.get(character);
while(!inFile.eof())
{
   if ((inFile.peek(character) == '>')
      //   do something;
   else
     inFile.get(character);
}
```

Text vs. Binary Files

Text File – Default is text file.

- A text file contains ASCII characters.
- Bytes are interpreted as ASCII characters.
  - Data is stored character by character.
  - The length of each line is not fixed.
  - The extraction (**>>**) and Insertion (**<<**) operators work only with text files.
  - The extraction operator (>>) and the getline() function read in bytes and interpret them as ASCII characters.
- Searching a text file is linear (slower than searching a binary file).

Binary File – Contains strings of bits, un-interpreted by the file system

- Data is stored based on data type declarations, which have fixed lengths.

  Ex 21: float gpa and int age require 4 bytes each.

- **binary** must be specified when creating a binary file.
- Use the `'|'` operator specify binary and out

  Ex 22: `file.open("c:\\data.bin", ios::binary | ios::out);`

- Records in a binary file can be accessed, changed, and re-inserted back into the same location within the file.

Note for binary: Instead of the insertion operator (<<) - use the **`write()`** function.

Instead of the extraction operator (>>) - use the **`read()`** function.

`sizeof( )` – This function returns the number of bytes of the parameter.

- This function can return the number of bytes of memory a data type requires.
- It works with standard (native) C++ data types, as well as struct and class objects.

Ex 23:
```
cout << sizeof(int);          // output = 4 (bytes)
cout << sizeof(float);        // output = 4 (bytes)
cout << sizeof(double);       // output = 8 (bytes)
cout << sizeof(char);         // output = 1 (byte)
```

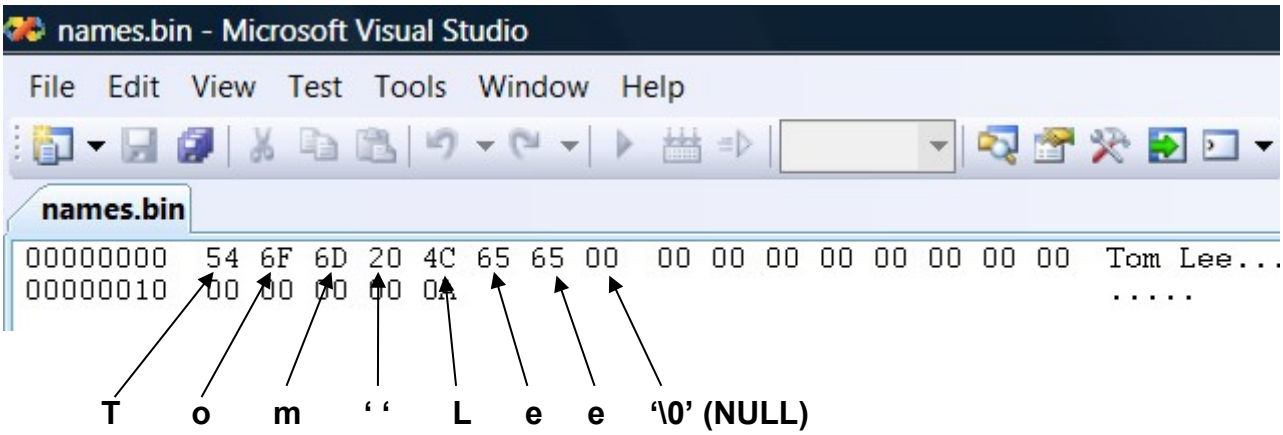
`write()` - The write() function is defined in <fstream> and is used to write data to a binary file.

- The general format is: `fileObject.write(address, size);`

Important: The first parameter of the *write()* function is a pointer to a char variable.

- Therefore, the following works fine, because name is a character array.

Ex 24:
```
char name[20] = "Tom Lee";
outFile.write(name, sizeof(name);   // Pass the address of name,
                                    //    and the size of name.
```



(2 Hex digits = 1 character (byte)

`read()` - The **read()** function is defined in <fstream> and is used to read a binary file.

- **`read()`** - The read() function reads un-interpreted characters. (binary files)
- **Un-interpreted characters** - Include ASCII characters plus other non-printable formatting characters (provided by such programs as Word).
- The general format is: `fileObject.read(address, size);`

Important: Like the *write()* function, the first parameter is a pointer to a char variable.

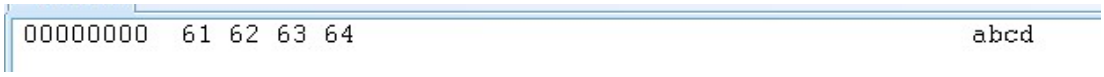
- Therefore, the following works fine, because name is a character array.

Ex 25:
```
char name[20] = "Tom Lee"

file.read(name, sizeof(name);   // Pass the address of name,
                                //  and the size of name.
```

Ex 26:
```
#include <iostream>
#include <fstream>
using namespace std;

const int SIZE = 4;
int main()
int main()
{
   char data[SIZE] = {'a','b','c','d'};
   fstream file;

   file.open("test.bin", ios::out | ios::binary);

   cout << "Writing characters to file.\n";
   file.write(data, sizeof(data));
   file.close();

   file.open("test.bin", ios::in | ios::binary);

   cout << "Now reading the data back into memory.\n";
   file.read(data, sizeof(data);

   cout << "Here is the data:\n";

   for (int i = 0; i < SIZE; i++)
     cout << data[i] << " ";

   cout << endl;
   file.close();
   return 0;
}
```

```
/*  OUTPUT
Writing characters to file.
Now reading the data back into memory.
a b c d
```

test.bin



To read and write data that is <u>not char</u> data type:

- The first parameter in the *read()* and *write()* functions <u>must be typecast</u>.

<u>Ex 27</u>:

```
#include <iostream>
#include <fstream>
using namespace std;

const int SIZE = 5;
int main()
{
   int ages[SIZE] = {21,27,13,42,15};
   fstream file;

   file.open("data.bin", ios::out | ios::binary);

   cout << "Writing data to file.\n";


   file.write(reinterpret_cast<char *>(ages), sizeof(ages));

   file.close();

   file.open("data.bin", ios::in | ios::binary);

   cout << "Now reading the data back into memory.\n";

   file.read(reinterpret_cast<char *>(ages), sizeof(ages));
   cout << "Here is the data:\n";

   for (int i = 0; i < SIZE; i++)
      cout << ages[i] << " ";

   file.close();

   return 0;
}
```

Typecast an *int* * pointer to a *char* * pointer, because ages is an *int* array.

Typecast *int* * pointer to *char* *

```
/*  OUTPUT
Writing data to file.
Now reading the data back
into memory.
21 27 13 42 15
Press any key to continue.*/
```

<u>Note</u>: In the above program, an *int* array is written to a file by typecasting the *int* * pointer to a *char* * pointer.

- If an object of a class or struct is written to a binary file, then the pointer to the object must be typecast to *char* *, like this:

```
Person person;

file.write(reinterpret_cast<char *>(& person), sizeof(person));
```

Typecast *Person* * pointer to *char* *

<u>This also works</u>:

```
file.write((char*)&person, sizeof(person));
```

Sequential File Access - All previous examples have dealt with sequential file access.

- When a file is opened, the position to read or write is at the beginning of the file, (unless `ios::app` is used).
- To read a file sequentially, the ***read()*** function begins reading at the beginning of the file and continues until done.
- Problem: Sequential file access can be very inefficient, because to read one record in a file, all records preceding the record must be read first.

  Solution: Random-Access of files

Random File Access - With this type of file, a program can jump to any byte in the file without reading the preceding bytes.

Seeking – The action of moving to a certain position in a file is called seeking.

- Two **seek** functions are included in C++ stream classes: **`seekp()`** and **`seekg()`**
- C++ has a **get pointer** that holds the address where to read the next byte.
- C++ has a **put pointer** that holds the address where to write the next byte.
- The **get** and **put** pointers can be moved by using functions **seekg()** and **seekp()**.
- These 2 functions move the *read / write* position to any byte in a file.

1. **`seekp()`** - Use the seekp() function with files opened for output. (p for put)

`seekp()` moves the **put pointer** to a location before writing to a file.

Syntax: **file.seekp(byteOffset, origin);**

- **byteOffset** – The number of bytes from the origin.
- **origin** – The present position of the pointer (beg, end, cur).

```
Ex 28:  file.seekp(0L, ios::beg);   // Moves the put pointer to the
                                    //      beginning of the file.
Ex_29:  file.seekp(0L, ios::end);   // Moves the put pointer to the end of file
Ex_30:  file.seekp(20L, ios::cur);  // Moves the put pointer 20 bytes from
                                    //      its current position in the file.
```

Note: After moving the *put pointer*, then use the *write()* function to write to the file.

2. **`seekg()`** - Use seekg() function with files opened for input. (g for get)

- `seekg()` moves the *get pointer* to a location before beginning to read a file.

Syntax: **file.seekg(byteOffset, origin);**

Ex 31: `file.seekg(10L, ios::beg);` // Moves the **get** pointer 10 bytes from // the beginning

Ex 32: `file.seekg(-10L, ios::end);` // Moves the **get** pointer 10 bytes from // the end of the file.

Note: After moving the *get pointer*, then use the *read()* function to read the file.

SUMMARY Binary Files

- **Declare a file object and open a file**

```
fstream file("students.bin", ios::out | ios::in | ios::binary);
```

- **Write to a file** - When a file opens, the "put" pointer points to the beginning of the file.

```
file.write(reinterpret_cast<char*>(&student), sizeof(Student));
```

- When something is written to a file, both "put" and "get" pointers move.
  Therefore, to read the first record in a file, move the get pointer to the beginning of the file by using the seekg() function.

```
file.seekg(0L, ios::beg);
```

- **Read the first record**

```
file.read(reinterpret_cast<char*>(&student), sizeof(Student));
```

- Assuming the first record exists in a file, it can be overwritten. But first, the "put" pointer must be moved to the beginning of the file.

```
file.seekp(sizeof(student), ios::beg);
```

- **Write a record**

```
file.write(reinterpret_cast<char*>(&s1), sizeof(Student));
```

- **To write a record at the end, move the "put" pointer to the end.**

```
file.seekp(0L, ios::end);
```

Variable-length file - A variable-length file is one in which each record in the file can change in size, and all records do not have to be the same size.

- For example, objects of the following struct could be written to a file, and each object could be a different size.
- A string class object of string class can vary in size.
- Ex 33: If a person's name is Bob Jones, the string uses 10 bytes (approximately).

However, if the name is Orenthal James Simpson, the string occupies about 23 bytes – so the size of the record varies depending on the data.

Fixed-length file - In a fixed-length file, all records are the same size.

- For example, objects of the following struct could be written to a file, and each object would be the same size (158 bytes).
- For c_strings, the number of bytes of memory or file space is the size of the array.

Ex 34: If a person's name is Bob Jones, the array uses 50 bytes, even though the name is only 10 bytes (including the NULL character).

```
struct student
{
   int id;                ← 4 bytes
   char name[50];         ← 50 bytes
   char address[100];     ← 100 bytes
   float gpa;             ← 4 bytes

};                          158 bytes
```