Assignment 2
C/C++ Programming II

General Information

How many bits are in a *byte*?

Contrary to what many people mistakenly think, the number of bits in a byte is not necessarily 8. Instead, a byte is more accurately defined in the C language standard as an "addressable unit of data storage large enough to hold any member of the basic character set of the execution environment". Specifically, this means that the number of bits in a byte is dictated by and is equal to the number of bits in type **char**. While on the vast majority of implementations the number of bits in such an "addressable unit" is 8, there have been implementations in which this has not been true and has instead been 6 bits, 9 bits, or some other value. To maintain compatibility with all standards-conforming implementations the macro `CHAR_BIT` has been defined in standard header file `limits.h` (`climits` in C++) to represent the number of bits in a byte on the implementation hosting that file. The implication of this is that no portable program will ever assume any particular number of bits per byte but will instead use `CHAR_BIT` in code whenever the actual number is needed. This ensures that the code will remain valid even if moved to an implementation having a different number of bits per byte.

How many bits are in an arbitrary data type?

The **sizeof** operator produces a count of the number of bytes of storage required to hold an object of the data type of its operand (note 2.12). Except for type **char**, however, not all of the bits used for the storage of an object are necessarily used to represent its value. Instead, some bits may simply be unused "padding" needed only to enforce memory alignment requirements. As a result, simply multiplying the number of bits in a **char** (byte) by the number of bytes in an arbitrary data type does not necessarily produce the number of bits used to represent that data type's value. Instead, the actual number of "active" bits must be determined in some other way.

Exercise 1 *(3 points – C Program)*

Exclude any existing source code files that may already be in your IDE project and add two new ones, naming them **C2A2E1_CountBitsM.h** and **C2A2E1_CountIntBitsF.c**. Also add instructor-supplied source code file **C2A2E1_main-Driver.c**. Do not write a `main` function! `main` already exists in the instructor-supplied file and it will use the code you write.

File **C2A2E1_CountBitsM.h** must contain a macro named `CountBitsM`.

`CountBitsM` syntax:

This macro has one parameter and produces a value of type **int**. There is no prototype (since macros are never prototyped).

Parameters:

`objectOrType` – any expression with an object data type (24, temp, printf("Hello"), etc.), or the literal name of any object data type (**int**, **float**, **double**, etc.)

Synopsis:

Determines the number of bits of storage used for the data type of `objectOrType` on any machine on which it is run. This is an extremely trivial macro.

Return:

the number of bits of storage used for the data type of `objectOrType`

File **C2A2E1_CountIntBitsF.c** must contain a function named `CountIntBitsF`.

`CountIntBitsF` syntax:

```
int CountIntBitsF(void);
```

Parameters:

none

Synopsis:

Determines the number of bits used to represent a type **int** value on any machine on which it is run.

Return:

the number of bits used to represent a type **int** value

`CountBitsM` and `CountIntBitsF`:

1. Shall not assume a **char**/byte contains 8 or any other specific number of bits;
2. Shall not call any function;
3. Shall not use any external variables;
4. Shall not perform any right-shifts;
5. Shall not display anything.

`CountBitsM`:

1. Shall not use any variables;
2. May use a macro from header file `limits.h`

`CountIntBitsF`:

1. Shall not use any macro;
2. Shall not use anything from any header file;
3. Shall not be in a header file.
4. Shall not perform any multiplications or divisions;

If you get an Assignment Checker warning regarding instructor-supplied file **C2A2E1_main-Driver.c** the problem is actually in your macro.

Questions:

Could the value produced by `CountBitsM` for type **int** be different than the value produced by `CountIntBitsF`? If so, why? If not, why not? Place the answers to these questions as comments in one of your "Title Blocks".

Submitting your solution

Send all three source code files to the Assignment Checker with the subject line **C2A2E1_*ID***, where ***ID*** is your 9-character UCSD student ID.

See the course document titled "Preparing and Submitting Your Assignments" for additional exercise formatting, submission, and Assignment Checker requirements.

Hints:

In macro `CountBitsM` multiply the number of bytes in the data type of its argument by the number of bits in a byte. In function `CountIntBitsF` start with a value of 1 in a type **unsigned int** variable and left-shift it one bit at a time, keeping count of number of shifts, until the variable's value becomes 0.

Exercise 2 *(5 points – C++ Program)*

Exclude any existing source code files that may already be in your IDE project and add two new ones, naming them **C2A2E2_CountIntBitsF.cpp** and **C2A2E2_Rotate.cpp**. Also add instructor-supplied source code file **C2A2E2_main-Driver.cpp**. Do not write a `main` function! `main` already exists in the instructor-supplied file and it will use the code you write.

File **C2A2E2_CountIntBitsF.cpp** must contain a copy of the `CountIntBitsF` function you wrote for the previous exercise, except omit the keyword **`void`** from its parameter list (leave it empty).

File **C2A2E2_Rotate.cpp** must contain a function named `Rotate`.

`Rotate` syntax:

```
unsigned Rotate(unsigned object, int count);
```

Parameters:

`object` – the object to rotate

`count` – the number of bit positions & direction to rotate: negative=>left and positive=>right

Synopsis:

Rotates all bits in `object` by the number of bit positions and direction specified by `count`.

Return:

the value of the rotated object

The `Rotate` function must:

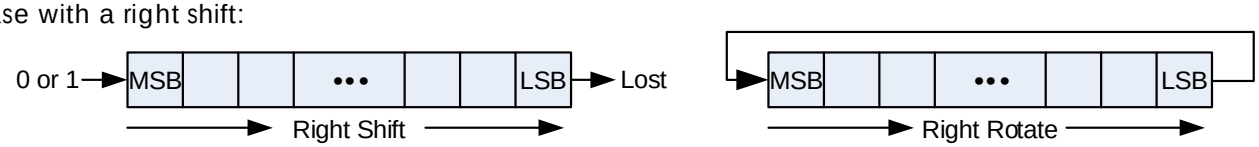
1. call `CountIntBitsF` if the number of bits in type **unsigned** is needed;
2. not call `CountIntBitsF` more than once or in a loop;
3. not make any assumptions about the number of bits the data type of parameter *object*;
4. not make any assumptions about the number of bits in a **char**/byte (such as 8);
5. not use `CHAR_BIT` or **sizeof** or call any function or macro that does;
6. not implement a special case for handling a `count` value of 0.
7. not display anything.

Here are some typical results:

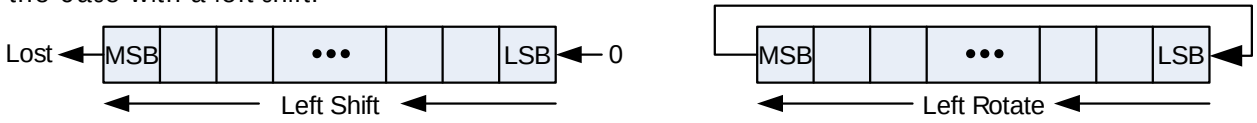
Function Call	Return values for a 16-bit object	Return values for a 32-bit object
`Rotate(0xA701, 1)`	0xD380	0x80005380
`Rotate(0xA701, 256)`	0xA701	0x0000A701
`Rotate(0x000C, 2)`	0x0003	0x00000003
`Rotate(0x8000, -1)`	0x0001	0x00010000
`Rotate(0x3000, -2)`	0xC000	0x0000C000

Explanation

When a pattern is "shifted" each bit shifted off the end is simply lost. In "rotation", however, the end bits (the least significant bit LSB and the most significant bit MSB) are treated as if they are adjacent. That is, when a pattern is right-rotated the LSB is placed into the MSB rather than being lost, as would be the case with a right shift:



Conversely, when a pattern is left-rotated the MSB is placed into the LSB rather than being lost, as would be the case with a left shift:



Submitting your solution

Send all three source code files to the Assignment Checker with the subject line **C2A2E2_*ID***, where ***ID*** is your 9-character UCSD student ID.

See the course document titled "Preparing and Submitting Your Assignments" for additional exercise formatting, submission, and Assignment Checker requirements.

Hints:

1. To avoid needless loss of credit be sure you understand lines 14 & 15 of note 11.7 of the course book. Displaying bit patterns in decimal is meaningless; bit patterns must always be displayed in hexadecimal.

2. Although rotation can be achieved by shifting bits one at a time in a loop, a cleaner and more efficient implementation requiring only two shifting operations and no loops can be achieved by merely right shifting the original pattern by an appropriate number of bits and bitwise-ORing the result with the result of left shifting the original pattern by an appropriate number of bits.

3. Only if you chose to implement the rotation by shifting bits one at a time in a loop (the complex and inefficient solution), you will need a mask for the LSB and the MSB. The LSB mask is always **1** but the MSB mask depends upon the number of bits in the data type of integer value being shifted. If that data type is not subject to the "Usual Unary Conversions" (note 2.10) determining the MSB mask is trivial and requires no knowledge of the number of bits in the object. For example, for the type **`unsigned int`** object being shifted in this exercise the MSB mask is merely the compile-time constant **~(~0u >> 1)**.

Exercise 3 *(6 points – Drawing only – No program required)*

Create a stack frame illustration using the format shown on the next page and place it in a PDF file named **C2A2E3_StackFrames.pdf**. Although using Excel, Word, Visio, etc. to create such an illustration and the required PDF file is easy, you may instead do it the hard way by drawing it by hand and scanning it in if you wish as long as it is neat and easily readable. Your illustration must start with the following "startup" stack frame:

Memory Addresses		Stack Values	Description	
Relative	Absolute			
BP+??	??	??	??	***startup* Stack Frame**
BP+??	FA9*h*	??	??	

The remaining stack frames must be based upon the data type sizes and code shown below. Do not show stack frames for library functions. This is a theoretical exercise only and should not be compared to any values obtained from actually running the program. Assume all appropriate headers and prototypes are present and that the "C calling convention" is being used:

Assume: type **int** is 3 bytes; type **long** is 4 bytes; all addresses (pointers) are 5 bytes.

```
int main(void)◄──────  "startup function" calls main
{                      and main returns to it.
    long val = Ready();

    printf("Return from main: val = %ld\n", val);
    return(EXIT_SUCCESS);
}

long Ready(void)
{
    long res = gcd(128L, 96L);

    printf("Return from Ready: res = %ld\n", res);
    return res;
}

long gcd(long x, long y)
{
    if (y == 0)
        return(x);
    return(gcd(y, x % y));
}
```

Function `main`	
Operation	Instruction Address
assignment to `val`	AB4*h*

Function `Ready`	
Operation	Instruction Address
assignment to `res`	108*h*

Function `gcd`	
Operation	Instruction Address
the **return** on line 42	7C0*h*

Waypoints:

To help you determine if you might have a problem, note the following:

1. There will be 3 stack frames for the `gcd` function, each containing 5 items;
2. The absolute address of the final item in the final stack frame of your drawing will be **F44*h***.

Submitting your solution

Send your PDF file to the Assignment Checker with the subject line **C2A2E3_*ID***, where ***ID*** is your 9-character UCSD student ID.

See the course document titled "Preparing and Submitting Your Assignments" for additional exercise formatting, submission, and Assignment Checker requirements.

Hint:

The illustration below demonstrates the required general format for this exercise and was taken directly from Note 12.6C of the course book. Create only one diagram. It must represent the finished stack with all stack frames on it. Since the value of a return object is not known until a function returns, use question marks to represent the values of such objects.

Figure 5

Stack View -- Final State

Memory Addresses		Stack Values	Description	
Relative	Absolute			
BP+??	??	??	??	*startup* Stack Frame
BP+??	FA9*h*	??	??	
BP+6*h*	FA7*h*	??	Return Object (int)	
BP+3*h*	FA4*h*	??	Function Return Address	*main* Stack Frame
BP	FA1*h*	??	Previous Frame Address	
BP-2	F9F*h*	??	x	
BP+3	F9C*h*	200*h*	Function Return Address	*Ready* Stack Frame
BP	F99*h*	FA1*h*	Previous Frame Address	
BP+6*h*	F97*h*	397	value	
BP+3*h*	F94*h*	116*h*	Function Return Address	*Recur* Stack Frame 1
BP	F91*h*	F99*h*	Previous Frame Address	
BP+6*h*	F8F*h*	39	value	
BP+3*h*	F8C*h*	7BE*h*	Function Return Address	*Recur* Stack Frame 2
BP	F89*h*	F91*h*	Previous Frame Address	
BP+6*h*	F87*h*	3	value	
BP+3*h*	F84*h*	7BE*h*	Function Return Address	*Recur* Stack Frame 3
BP	F81*h*	F89*h*	Previous Frame Address	

BP F81*h*
SP F81*h*

Exercise 4 *(6 points – C++ Program)*

Exclude any existing source code files that may already be in your IDE project and add two new ones, naming them **C2A2E4_OpenFile.cpp** and **C2A2E4_Reverse.cpp**. Also add instructor-supplied source code file **C2A2E4_main-Driver.cpp**. Do not write a `main` function! `main` already exists in the instructor-supplied file and it will use the code you write.

File **C2A2E4_OpenFile.cpp** must contain a function named `OpenFile`.
`OpenFile` syntax:

```
void OpenFile(const char *fileName, ifstream &inFile);
```

Parameters:
`fileName` – a pointer to the name of a file to be opened
`inFile` – a reference to the `ifstream` object to be used to open the file
Synopsis:
Opens the file named in `fileName` in the read-only text mode using the `inFile` object. If the open fails an error message is output to `cerr` and the program is terminated with an error exit code. The error message must mention the name of the failing file.
Return:
void if the open succeeds; otherwise, the function does not return.

File **C2A2E4_Reverse.cpp** must contain a function named `Reverse`.
`Reverse` syntax:

```
int Reverse(ifstream &inFile, const int level);
```

Parameters:
`inFile` – a reference to an `ifstream` object representing a text file open in a readable text mode.
`level` – recursive level of this function call: 1 => 1st call, 2 => 2nd call, etc.
Synopsis:
Recursively reads one character at a time from the text file in `inFile` until a separator is encountered. Those non-separator characters are then displayed in reverse order, with the last character displayed being capitalized. Finally, the separator is returned to the calling function. Separators are not reversed and are not printed by `Reverse`, but are instead merely returned. The code in the instructor-supplied driver file is responsible for printing the separators.
Definition of separator:
any whitespace (as defined by the standard library `isspace` function), a period, a question mark, an exclamation point, a comma, a colon, a semicolon, or the end of the file
Return:
the current separator

The `Reverse` function must:

1. implement a recursive solution and be able to display words of any length;
2. be tested with instructor-supplied data file **TestFile2.txt**, which must be placed in the program's "working directory".
3. not declare more than two variables other than the function's two parameters.
4. not use arrays, **static** objects, external objects, dynamic memory allocation, or the peek function;
5. not use anything from `<cstring>`, `<list>`, `<sstream>`, `<string>`, or `<vector>`.

Example

If the text file contains:

```
What!  Another useless, stupid, and unnecessary program?
Yes;  What else?:  Try input redirection.  /[.]/  /}.!?,;:=+#/
```

and `Reverse` is called using:

```
while ((thisSeparator = Reverse(inFile, 1)) != EOF)
     cout.put(thisSeparator);
```

the following is displayed:

```
tahW!  rehtonA sselesU, diputS, dnA yrassecennU margorP?
seY;  tahW eslE?:  yrT tupnI noitcerideR.  [/./]  }/.!?,;:/#+=
```

Submitting your solution

Send the three source code files to the Assignment Checker with the subject line **C2A2E4_*ID***, where ***ID*** is your 9-character UCSD student ID.

See the course document titled "Preparing and Submitting Your Assignments" for additional exercise formatting, submission, and Assignment Checker requirements.

Hints:

See course book notes 12.7 and 12.8. Write an inline function that returns type **bool** that determines if a character is a separator, noting that whitespace is not just the *space* character itself but is every character defined as whitespace by the `isspace` function. Recursive functions should have as few automatic variables as is practical, but should also not use any external or static variables. As each recursive level of function `Reverse` is entered a new character is read and stored in a local variable I'll call `thisChar`. If the character is a separator it is then returned to the caller. If it is not a separator the `Reverse` function is called again and its return value is stored in a variable I'll call `thisSeparator`. After each return the character in `thisChar` is displayed and, if at recursive level 1, is also capitalized. Variable `thisSeparator` is then returned to the caller. Separators are never printed by `Reverse` but are instead merely returned by it. My driver is responsible for printing the separators returned to it by `Reverse`.

Get a Consolidated Assignment Report (optional)

If you would like to receive a consolidated report containing the results of the most recent version of each exercise submitted for this assignment, send an empty email to the assignment checker with the subject line **C2A2_*ID***, where ***ID*** is your 9-character UCSD student ID. Inspect the report carefully since it is what I will be grading. You may resubmit exercises and report requests as many times as you wish before the assignment deadline.