Assignment 2

C/C++ Programming II

C2A2 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 language standards 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. <u>It is important to note that the data type of CHAR_BIT is always **int**.</u>

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.

Get a Consolidated Assignment 2 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.

C2A2E1 *(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 function `CountIntBitsF` and no `#define` or `#include`.
`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` must:
1. not assume a **char**/byte contains 8 or any other specific number of bits;
2. not call any function;
3. not use any external variables;
4. not perform any right-shifts;
5. not display anything.

`CountBitsM` must:
1. not use any variables;
2. use a macro from header file `limits.h`

`CountIntBitsF` must:
1. not use any macro or anything from any header file;
2. not be in a header file.
3. 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 `CountBitsM` macro.

Questions:
If run on the same implementation, could the value produced by `CountBitsM` for type **int** be different than the value produced by `CountIntBitsF`? Why or why not? The answer has nothing to do with the value CHAR_BIT. Place your answers as comments in the “Title Block” of file **C2A2E1_CountIntBitsF.c**.

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 "How to Prepare and Submit 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 implementation-dependent 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. If you use a plain **int** (which is always signed) for this purpose you have made a portability mistake.

C2A2E2 *(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 an exact copy of the `CountIntBitsF` function you wrote for the previous exercise, except omit the keyword **void** from its parameter list.

File **C2A2E2_Rotate.cpp** must contain function `Rotate` and no `#define` or `#include`.
`Rotate` syntax:

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

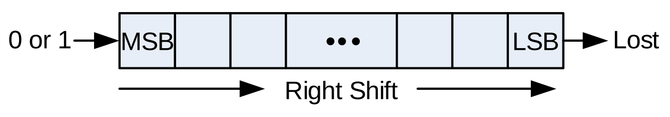
Parameters:
    `object` – the value to rotate
    `count` – the number of bit positions & direction to rotate: negative=>left and positive=>right
Synopsis:
    Produces the value of parameter `object` as if it had been rotated by the number of positions and in the direction specified by `count`.
Return:
    the rotated value

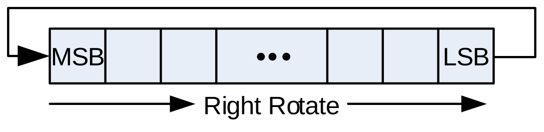
The `Rotate` function must:
1. Call `CountIntBitsF` once and only once to determine the number of bits in parameter `object`.
2. not call any function other than `CountIntBitsF`.
3. not assume a **char**/byte contains 8 or any other specific number of bits.
4. not use loops, recursion, **sizeof**, macros, or anything from any header file.
5. not implement a special case for handling a `count` value of 0.
6. not display anything.

Here are some examples for a 32-bit type **unsigned int**:

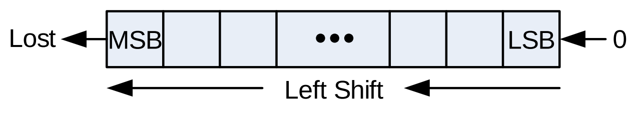
Function Call	Return		Function Call	Return
(right rotate)	Value		(left rotate)	Value
`Rotate(0xa701, 1)`	`0x80005380`		`Rotate(0xa701, -1)`	`0x14e02`
`Rotate(0xa701, 225)`	`0x80005380`		`Rotate(0xa701, -225)`	`0x14e02`
`Rotate(0xa701, 1697)`	`0x80005380`		`Rotate(0xa701, -1697)`	`0x14e02`
`Rotate(0xdefacebd, 2)`	`0x77beb3af`		`Rotate(0xdefacebd, -2)`	`0x7beb3af7`
`Rotate(0xdefacebd, 194)`	`0x77beb3af`		`Rotate(0xdefacebd, -194)`	`0x7beb3af7`
`Rotate(0xdefacebd, 5378)`	`0x77beb3af`		`Rotate(0xdefacebd, -5378)`	`0x7beb3af7`

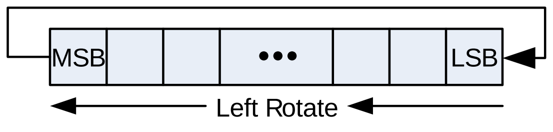
Explanation
When a pattern is "shifted" each bit shifted off the end is simply lost. In "rotation", however, the end bits are treated as if they are connected. That is, when a pattern is right-rotated the LSB (least significant bit) is placed into the MSB (most significant bit MSB) rather than being 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 "How to Prepare and Submit Assignments" for additional exercise formatting, submission, and assignment checker requirements.

Hints:

1. Bit patterns for values greater than 9 must always be represented in hexadecimal; representing them in decimal is cryptic and inappropriate. Shift/rotation counts should always be represented in decimal.

2. For shifting operations the language standards state that if the value of the right operand (the shift count) is negative or is greater than or equal to the width of the promoted left operand the behavior is undefined.

3. Although rotation can be achieved one bit at a time using a loop or recursion, it is extremely inefficient and should never be done. Instead, a rotation of any size can always be accomplished with only two shift operations. To demonstrate this, assume an 8-bit data type contains a pattern that must be rotated right by 5 positions. If done bit at a time with a loop the following would occur:

```
00100001   <- arbitrary original pattern
10010000   <- rotated right by 1 bit
01001000   <- rotated right by 2 bits
00100100   <- rotated right by 3 bits
00010010   <- rotated right by 4 bits
00001001   <- done - rotated right by 5 bits
```

   However, if done the efficient way the unaltered original pattern will be shifted right by 5 bits, the unaltered original pattern will be shifted left by the total number of bits it contains minus 5, and the results of the two shifts will be bitwise-OR'd together to produce the final result as follows:

```
00100001   <- original pattern from above
00000001   <- original pattern shifted right by 5 bits
00001000   <- original pattern shifted left by 8 minus 5 bits
00001001   <- done - bitwise-OR of the two shifted patterns
```

   If you understand what is going on in the right rotate example above you should be able to easily develop a left rotate version too.

C2A2E3 (6 points – Drawing only – No program required)

Please refer to figure 8 of note 12.4D and figure 5 of note12.6C in the course book. Both illustrate the final state of the call stack before any returns have occurred in their respective programs. Create a similar single figure based upon the assumptions and program code provided below. **If you create multiple figures you are doing this exercise incorrectly.** Your figure must:

- Begin with the "startup" stack frame shown in figure A on the next page and append additional stack frames using the general format and item ordering illustrated in the next frame in that figure. Show only stack frame items for the functions below.
- Use a double question mark for all return object values, values dependent upon return objects, and values for which you believe insufficient information has been provided.
- Represent all addresses and **BP** offsets in hexadecimal and all other numeric values in decimal. Suffix all hexadecimal values with an ***h*** but do not suffix decimal values.

Create your figure using a computer application of your choice, such as a text editor, Word, Visio, Excel, etc. Then convert it to a PDF file named **C2A2E3_StackFrames.pdf** for submission.

NO CREDIT will be given if your file:

- ...contains anything hand-drawn or difficult to read, or
- ...cannot be printed on one standard 8-1/2" by 11" page without size reduction, or
- ...contains a stack frame item that will not fit entirely on one line.

The code below uses different types and sizes for exercise diversity. Assume the following:

- Any necessary header files and prototypes are present.
- "C calling convention"
- **short**: 4 bytes, **int**: 5 bytes, **long**: 8 bytes, addresses(pointers): 7 bytes

```
int main()   ←――――   
{
    int result = ready();
    return 0;
}

long ready()
{
    short temp = gcd(480, 360);
    return temp;
}

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

The "startup function" calls *main* and *main* returns to it.

Function main	
Operation	Instruction Address
assignment to `result`	62D*h*

Function ready	
Operation	Instruction Address
assignment to `temp`	3F0*h*

Function gcd	
Operation	Instruction Address
the **return** on line 42	45D*h*

Waypoints:

Check the following to help you determine if you might have a problem:

- The `gcd` function will have 3 stack frames, each containing 5 items.
- The absolute address of the last item in the last stack frame will be **AF9*h***.
- There should be exactly 8 stack values that are double questions marks.

Continued on the next page...

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 "How to Prepare and Submit Assignments" for additional exercise formatting, submission, and assignment checker requirements.

Figure A

Required "startup" Stack Frame and General Stack Frame Format

The figure below was created as a table in Microsoft Word, but you may use any computer application you wish as long as you present the required information in the same basic format. Place a divider prior to each stack frame that indicates the name of the function. If the function is being used recursively, indicate the recursion level after the name starting with 1.

Relative Address	Absolute Address	Stack Value	Description
----------	----------	startup	----------
BP+7*h*	B8F*h*	1005*h*	Function Return Address
BP	B88*h*	0*h*	Previous Frame Address
----------	----------	*FunctionName 1*[3]	----------
BP+...	...	??	Return Object[1]
BP+...	...	...	*names of specifically ordered formal parameters*[1,2]
BP+...	...	...	
BP+...	...	...	
BP+...	...	...	Function Return Address
BP	...	...	Previous Frame Address
BP-...	...	...	*names of arbitrarily ordered local automatic variables*[1]
BP-...	...	...	
BP-...	...	...	

As many of these stack frames as needed.

Notes:

1. *Space for the return object, formal parameters, and local automatic variables is not allocated if the function does not have them.*
2. *The order of formal parameters depends upon which calling convention is used.*
3. *Only indicate a level if the function is being used recursively.*

C2A2E4 (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 and next to next to last characters 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 non-const 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 "How to Prepare and Submit Assignments" for additional exercise formatting, submission, and assignment checker requirements.

Hints:

1. See course book notes 12.7 and 12.8 for some recursive examples.

2. Recursive functions should have as few automatic variables as is practical, but also should not use any external or static variables.

3. Pass the expression `level + 1` as the second argument of the `Reverse` function.

4. Rather than directly testing for any separators in the `Reverse` function, write an **`inline`** function that returns type **`bool`** that determines if its parameter is a separator, noting that:
    a. Whitespace is not just the *space* character itself but is every character defined as whitespace by the `isspace` function.
    b. The `ispunct` function is not suitable for this exercise because it detects more than just the punctuator characters allowed as separators.
    c. The `EOF` macro is always type **`int`** and always has an implementation-dependent negative value.

5. Remember that because `EOF` is type **`int`**, the value it represents cannot be reliably represented by type **`char`**. Casting a type **`char`** expression to type **`int`** does not eliminate the problem because the extra bits needed to represent `EOF` will have already been lost. Also, if a type **`int`** expression contains the value of `EOF`, casting it to type **`char`** results in a value that cannot represent `EOF`.

6. The step by step algorithm I used is shown below. Although you are not required to use it, I recommend that you do. One important thing to note is that separators are never displayed by the `Reverse` function but are merely returned by it. The code in the "driver" file I supplied is instead responsible for displaying separators returned to it by `Reverse`.

   Algorithm: Each time function `Reverse` is entered, it must do the following:

```
A. Read the next input character and store it in a type int automatic variable named thisChar.
B. IF the character in thisChar is a separator
       Return the character to the caller.
   ELSE
       1) Call Reverse and store its return value in a type int automatic variable named thisSeparator.
       2) IF the current recursive level is a capitalization level
              Display the character in thisChar as capitalized.
          ELSE
              Display the character in thisChar unaltered.
       3) Return the character in thisSeparator to the caller.
```