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. It is important to note that the data type of `CHAR_BIT` is always **int**.

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:
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 "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 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:

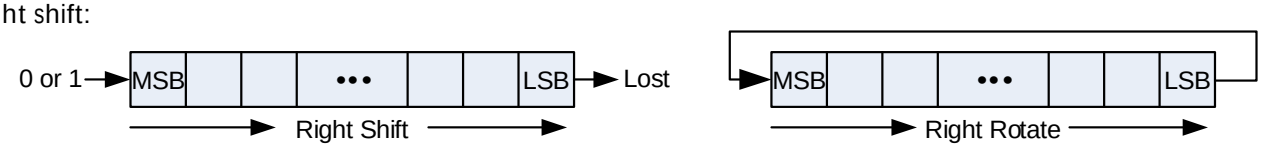
1. call `CountIntBitsF` once and only once to determine the number of bits in parameter `object`;
2. not call any function other than `CountIntBitsF`;
3. not assume a **char**/byte contains 8 or any other specific number of bits;
4. not use loops, **sizeof**, macros, or anything from any header file;
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**:

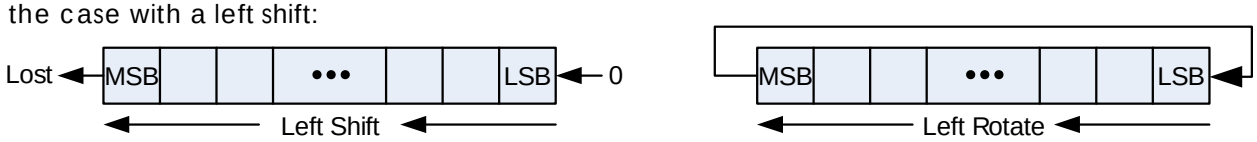
Function Call (right rotate)	Return Value		Function Call (left rotate)	Return Value
`Rotate(0xa701, 1)`	`0x80005380`		`Rotate(0xa701, -1)`	`0x14e02`
`Rotate(0xa701, 225)`	`0x80005380`		`Rotate(0xa701, -225)`	`0x14e02`
`Rotate(0xa701, 1697)`	`0x80005380`		`Rotate(0xa701, -1697)`	`0x14e02`
`Rotate(0xdefacebd, 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 "Preparing and Submitting Your 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, it is extremely inefficient and should never be done. Instead, a rotation of any size can always be accomplished with only two shift operations and no loops. 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-ORed 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. It must:

1. begin with the exact "startup" stack frame shown in figure A on the next page;
2. continue with as many additional stack frames as necessary, where each uses the general stack frame format and item ordering shown in figure A on the next page. Show only stack items that are actually present in the functions;
3. not contain stack frames for **printf**;
4. use a double question mark for all return objects values, values dependent upon return objects, and values you believe there has not been enough information provided to determine;
5. indicate hexadecimal values with an ***h*** suffix and decimal values with no ***h*** suffix; all addresses must be in hexadecimal.

If you create multiple figures you are wasting your time and doing this exercise incorrectly.

Create your illustration using any appropriate computer application of your choice, such as Visio, Excel, Word, OpenOffice, a text editor, etc., then it convert to a PDF file named **C2A2E3_StackFrames.pdf** for submission. **DO NOT SUBMIT** an illustration containing anything hand-drawn or difficult to read.

In the code below, assume:

1. all appropriate headers and prototypes are present;
2. the "Pascal calling convention";
3. type **int** is 4 bytes; type **long** is 5 bytes; all addresses (pointers) are 6 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(84L, 63L);

    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	AB3*h*

Function Ready	
Operation	Instruction Address
assignment to res	118*h*

Function gcd	
Operation	Instruction Address
the **return** on line 43	7C6*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 **F2D*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.

Figure A

Required "startup" Stack Frame and General Stack Frame Format

Relative Address	Absolute Address	Stack Value	Description	Function Name (level if recursive)
BP+6*h*	FAF*h*	3000*h*	Function Return Address	***startup***
BP	FA9*h*	0	Previous Frame Address	
BP+...	...	??	Return Object[1]	***FunctionName (Level 1)***[3]
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 doesn't 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 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:

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. 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 detects more than just the punctuator characters defined as separators in this exercise;
   c. the `EOF` macro is always type **`int`** and always has an implementation-dependent negative value.

Recommended Algorithm Description: 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, but 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`.