LAB 3 Arrays and Strings, Relational and Logic operators, Type conversion, Bitwise operations

Due: Oct 4 (Monday), 11:59 pm **total mark: 90pt**

Problem A Arrays and Strings (cont.)

This and the next question walk you through more exercises on manipulating arrays and strings. Arrays are so important in C that we will deal with them throughout the C part of the course. Download `lab3.c`. This short program uses an array of size 12 to store input strings read in using `scanf`, and simply outputs the array elements (char and its index) after each read (similar to the last part of `lab2D.c` of lab2).

First observe the initial values of the array. Arrays without explicit initializer get random values. Run it again and you might see the change of the strange values. This implies that when you manually store characters into a char array to create a string, don't assume that the uninitialized array was filled with \0s. You need to manually add a \0 after the last stored character.

Now enter `helloworld`, observe that the array is now stored as

h	e	l	l	o	w	o	r	l	d	\0	?

where `\0` is added to the end of the input texts, and `?` is `\0` or a random value. `printf("%s")` prints `helloworld`, with size `12` and length `10`.

Next, enter a shorter word such as `good`, then observe that the array is stored as

g	o	o	d	\0	w	o	r	l	d	\0	?

and thus `printf("%s")` prints `good` with size `12`, length `4`.

Next, enter `hi`, then observe that the array is store as

h	i	\0	d	\0	w	o	r	l	d	\0	?

and `printf("%s")` prints `hi` with size `12`, and length `2`. Now enter a word that is longer than `hi` (such as `01234567`), see what happens. Also as in lab2, you can manually add `\0` into the array. If your `\0` is before the first existing `\0`, you essentially create a shorter string.

The key point here is that when an array is used to store a string, not all array elements got reset. Thus, when you enter `hello`, don't assume that the array contains character `h e l o` and `\0` only – there may exist random values, there may also exist characters from previous storage. So it is always critical to identify the **first** `\0` encountered when scanning from left to right, ignoring characters thereafter. As observed, string manipulation library functions, such as `printf("%s")`, `strlen`, `strcpy`, `strcmp` follow this rule: *scan from left to right, terminate after encountering the first `\0` character*. Your string related functions should follow the same rule.

Now enter `quit`, and observe that the program does not terminate. As discussed in class, comparing arrays/string using == will not compare the content of the arrays/strings. Press Ctrl+C to terminate the program "brutally". You will explore different ways to compare string content soon.

Finally, uncomment the statement `str[15]='a';` and compile again. Observe that no compiling error or warning is given. When running the program, it may or may not crash. So unlike in Java, C compilers will not do array boundary checking.

No submission for problem 0.

Problem B0 Character arrays and strings (cont.)

Specification

Standard library defines a library function `atoi`. This function converts an array of digit characters, which represents a decimal integer literal, into the corresponding decimal integer. E.g., given a char array (string) `s` of "134", which is internally stored as `'1' '3' '4' '\0' .....`, function `atoi(s)` returns an integer 134.
Implement your version of `atoi`, call it `my_atoi`, which does exactly the same conversion.

Implementation

Download the partially implemented program `lab3myatoi.c`. For each input, which is assumed to be a valid integer literal, the program first prints it as a string, and then call both `atoi` and `myatoi` to convert it, and output its numerical value in decimal, hex and oct, followed by double the value and square of the value. The program keeps on reading from the user until `quit` is entered.
Complete the `while` loop in `main()`, and implement function `my_atoi`.

- Page 43 of the recommended K&R book "The C programing language" describes an approach to convert a character array into decimal value, this approach traverses the array from left to right. (You probably used a similar approach in lab2.)
  A more intuitive approach, which **you should implement here**, is to calculate by traversing the array from **right to left**, following the traditional concept `'2' '1' '3' '4' '\0' .....`

  10^3 10^2 10^1 10^0 ←

  Hint: the loop body you are going to write is different from, and slightly more complicated than that in the recommended textbook, but the logic is clearer (IMHO).
- For finding the right end of string, you can use your `length()` function you implemented earlier. You can also explore the string library function `strlen()`.
  If you need, you can implement a helper function `power(int base, int n)` to calculate the power. In next class we will learn to use math library functions. Don't use Math library function here.
- For detecting `quit`, since strings content cannot be compared directed. You can use the `isQuit()` function you seen earlier, but you are also encouraged to explore the string library function `strcmp()`. You can issue **`man strcmp`** to view the manual. Note that `strcmp()` returns 0 (false) if the two argument strings are equal.

Sample Inputs/Outputs:

```
red 127 % a.out
Enter a word of positive number or 'quit': 2
2
atoi:    2 (02, 0X2)    4       4
my_atoi: 2 (02, 0X2)    4       4

Enter a word of positive number or 'quit': 4
4
atoi:    4 (04, 0X4)    8       16
my_atoi: 4 (04, 0X4)    8       16

Enter a word of positive number or 'quit': 9
9
atoi:    9 (011, 0X9)   18      81
my_atoi: 9 (011, 0X9)   18      81
```

```
Enter a word of positive number or 'quit': 12
12
atoi:    12 (014, 0XC)  24      144
my_atoi: 12 (014, 0XC)  24      144

Enter a word of positive number or 'quit': 75
75
atoi:    75 (0113, 0X4B)        150     5625
my_atoi: 75 (0113, 0X4B)        150     5625

Enter a word of positive number or 'quit': 100
100
atoi:    100 (0144, 0X64)       200     10000
my_atoi: 100 (0144, 0X64)       200     10000

Enter a word of positive number or quit: quit
red 128 %
```

No submission for this exercise.

Problem B Character arrays and strings (cont.) (20 pts)

Extend the program you developed above, so that `myatio()` function can convert any base of 2~10. (The library function `atoi` can only handle decimal literals correctly.) This version of `my_atoi` takes two arguments: an integer literal and a base. Assume the input string is always a valid integer literal of the specified base. For example, if the base is 2, the literals only contain 0 and 1. If the base is 5, the literals contain digit 0~4.

Note:

- Use `scanf("%s %d",…)` to read in a string followed by an integer of 2~10.
- The program terminates when use enter `quit` followed by any integer.
- Apparently, you should not call `atoi()` in `my_atoi()`.
- In `my_atoi()`, you also should not call other functions declared in `<stdlib.h>`, such as `atol(), atof(), strtol(), strtoul()`.
- In `my_atoi()`, you also should not call library functions declared in `<stdio.h>`, such as `sscanf(), fscanf()`.

Sample Inputs/Outputs:

```
red 127 % a.out
Enter a word of positive number and base, or 'quit': 37 10
37
my_atoi: 37 (045, 0X25) 74      1369

Enter a word of positive number and base, or 'quit': 37 8
37
my_atoi: 31 (037, 0X1F) 62      961

Enter a word of positive number and base, or 'quit': 122 4
122
my_atoi: 26 (032, 0X1A) 52      676

Enter a word of positive number and base, or 'quit': 122 5
122
my_atoi: 37 (045, 0X25) 74      1369
```

```
Enter a word of positive number and base, or 'quit': 122 7
122
my_atoi: 65 (0101, 0X41)        130     4225

Enter a word of positive number and base, or 'quit': 1101 2
1101
my_atoi: 13 (015, 0XD)  26      169

Enter a word of positive number and base, or 'quit': 1001100 2
1001100
my_atoi: 76 (0114, 0X4C)        152     5776

Enter a word of positive number and base, or 'quit': 345 6
345
my_atoi: 137 (0211, 0X89)       274     18769

Enter a word of positive number and base, or 'quit': 345 8
345
my_atoi: 229 (0345, 0XE5)       458     52441

Enter a word of positive number and base, or 'quit': 3214 5
3214
my_atoi: 434 (0662, 0X1B2)      868     188356

Enter a word of positive number and base, or 'quit': 11111111 2
11111111
my_atoi: 255 (0377, 0XFF)       510     65025

Enter a word of positive number and base, or 'quit': quit 4
red 128 %
```

Submit your program using **`submit 2031AC lab3 lab3myatoi.c`**

Problem C0 Increment and Decrement Operators

As discussed in class, C and other modern languages such as Java, C++ all support increment and decrement operators `++` and `--`. These operators can be used as *prefix* or *postfix* operators, appearing before or after a variable.

Download program `IncreDecre.c`, compile and run it. Observe that,

- the first two printf statements, one after `x++` and one after `++x`, both output 2. Do you understand why? `++x` does pre-increment, incrementing `x` 'immediately' , and `x++` does post-increment, incrementing `x` 'later' – at some point after the current statement but before the next statement. Thus in both case when the printf statement is executed, `x` has already been incremented.
- Since post-increment `x++` increments `x` 'later' – some point after the current statement (and before the next statement), the two printf statement `printf("%d", x++)` and `printf("%d",++x)` produce different results. In particular, since `x++` increments `x` after the current function call, `printf("%d", x++)` outputs the value before the increment happens, whereas `printf("%d", ++x)` output the value after the increment happens. In both cases, the printf statements after these two printf statements both output 2, as `x` has been incremented at that point.

- When other operators such as assignment operators are involved, the result are also different.
  - `y = x++` will assign `y` the un-incremented value of `x`, as `x` will be incremented after the assignment statement.
  - On the other hand, `y = ++x` will assign `y` the incremented value of `x`, as `x` is incremented immediately, before the assignment is executed.
- By using `++` and `--` operators judiciously, code for traversing arrays can become succulent, as shown in the last block of the code.

Download the Java version of program `IncreDecre.java`, compile and run it in command line, and observe the same result as in C (so in this course you will also improve your Java skills too, as I have promised 😊)

No submission for this question.

Problem C0 'Boolean' in ANSI-C. Relational and logical operators

As discussed in class, ANSI-C has no type 'Boolean'. It uses integers instead. It treats non-zero value as true, and returns 1 for ture result. It treats 0 as false, and return 0 for false result. Download program `lab3C0.c`, compile and run it.

- Observe that
  - relational expression `3>2` has value 1, and `3<2` has value 0
  - `!` non-zero has value 0, `!0` has value 1.
    - Note that in Java, these are invalid expressions.
  - `&&` return 1 if both operands are non-zero, return 0 otherwise. `||` return 1 if either operand is non-zero, and return 0 otherwise.
    - Note that in Java, these are invalid expressions.

- Assume the author mistakenly used `=`, rather than `==`, in three of the five `if` conditions. Observe that although `x` has initial value 100, both `if(x=4)` and `if(x=-2)` clauses were executed. This illustrates a few interesting things in ANSI-C:
  - Unlike a Java complier, `gcc` does not treat this as a syntax error.
  - Assignment expression such as `x=4` has a return value, which is the value being assigned to. So `if(x=4)` becomes `if(4)`, and `if(x=-2)` becomes `if(-2)`, and `if(x=0)` becomes `if(0)`
  - Any non-zero number is treated as 'true' in selection statement. Thus `if(x=4)` and `if(x=-2)` are both evaluated to be true and their corresponding statements were executed. On the other hand, 0 is treated as 'false', so `if(x=0)` was evaluated to be false and its statement was not executed.
  - Also observe that although `if(x=0)` condition was evaluated to be false, the assignment `x=0` was executed (before the evaluation) and thus `x` has value 0 after the three `if` clauses.

- Observe that although the loop in the program intends to break when `i` becomes 8 and thus should execute and prints 8 times, only `hello 0` is printed. Look at the code for the loop, do you see why? Fix the loop so that the loop prints 9 times, as shown below.

```
hello 0
hello 1
hello 2
```

```
hello 3
hello 4
hello 5
hello 6
hello 7
hello 8
```

No submissions for this exercise.

Problem C scanf, arithmetic and logic operators (20 pts)

Specification

Write an ANSI-C program that reads an integer from standard input, which represents a year, month and day, and then determines how many days has elapsed in the year.

Implementation

- name your program `lab3Leap.c`
- keep on reading a (4 digit) integer of year, followed by month and day, until a negative year is entered (followed by any month and day).
- define a 'Boolean' function `int isLeap(int year)` which determines if `year` represents a leap year. A year is a leap year if the year is divisible by 4 but not by 100, or otherwise, is divisible by 400.
- implement function `int countDays(int month, int day, int isLeap)` where `month` and `day` represent the current month and day of a year, and `isLeap` indicates whether the year is a leap year. The function calculates how many days have elapsed since the start of the year, including current day. There are 31 days in Jan, Mar, May, July, Aug, Oct and Dec, and there are 30 days in April, June, Sep, and Nov. There are 29 days in Feb if the year is a leap year, and 28 days in Feb if the year is not a leap year.
- call the functions in main, and produce output as shown below. (the two functions do not produce output). Note that if a year is leap year then the output ends with `[leap year]`.
- put the definition (implementation) of your functions after your main function.

4.3 Sample Inputs/Outputs:

```
red 364 % gcc -Wall lab3Leap.c -o leap
red 365 % leap
Enter date ('YYYY MM DD'): 2010 1 1
1 days of year 2010 have elapsed

Enter date ('YYYY MM DD'): 2011 8 8
220 days of year 2011 have elapsed

Enter date ('YYYY MM DD'): 2012 8 8
221 days of year 2012 have elapsed [leap year]

Enter date ('YYYY MM DD'): 2400 8 8
221 days of year 2400 have elapsed [leap year]

Enter date ('YYYY MM DD'): 2010 10 1
274 days of year 2010 have elapsed

Enter date ('YYYY MM DD'): 2012 10 1
275 days of year 2012 have elapsed [leap year]
```

```
Enter date ('YYYY MM DD'): 2100 11 4
308 days of year 2100 have elapsed

Enter date ('YYYY MM DD'): 2032 11 4
309 days of year 2032 have elapsed [leap year]

Enter date ('YYYY MM DD'): 2031 2 12
43 days of year 2031 have elapsed

Enter date ('YYYY MM DD'): 2032 2 12
43 days of year 2032 have elapsed [leap year]

Enter date ('YYYY MM DD'): -1 5 4
red 366 %
```

Submit your program by issuing **`submit 2031AC lab3 lab3Leap.c`**

Problem D Type conversions in arithmetic, assignment, and function calls (10 pts)

Specification

Write an ANSI-C program that reads inputs from the user one integer, one floating point number, and a character operator. The program does a simple calculation based on the two input numbers and the operator. The program continues until both input integer and floating point number are -1.

Implementation

- download partially implemented program `lab3conv.c`, compile and run it. Observe that
  - 9/2 gives 4, not 4.5. (When the result is converted to `float`, get 4.0).
  - In order to get 4.5, we need to convert 9 or 2 (or both) to `float`, before division.
    - One trick is to multiply 9 or 2 by 1.0. This forces the conversion from `int` to `float`. Note that this must be done before the division.
    - The "official" approach, is to explicitly cast 9 or 2 to `float`, using the cast operator `(float)`. Note that this must be done before the division. Cast after the division does not work correctly.
  - When assigning a `float` value to an `int` variable, the `int` variable gets the integral part value. The floating point part is truncated (without any warning.) Also no rounding occur here.

  Note, the first two observations are the same in Java. For the last observation, when assigning a `float` value to an `int` variable, Java will give compilation error because "possible lossy conversion from float to int". In this case, an explicit cast is required. (If you try Java, even `float f2 = 3.963;` generates an complier error, why?)

- use `scanf` to read inputs (from Standard input), each of which contains an integer, a character `('+', '-' '*' or '/')` and a floating point number (defined as `float`) separated by blanks. Assume all the inputs are valid.
- define a function `float fun_IF (int, char, float)` which conducts arithmetic calculation based on the inputs

- define another function `float fun_II (int, char, int)` which conducts arithmetic calculation based on the inputs
- define another function `float fun_FF (float, char, float)` which conducts arithmetic calculation based on the inputs
- note that these three functions should have the same code in the body. They only differ in the parameter type and return type.
- pass the integer and the float number to both the three functions directly, without explicit type conversion (casting).
- display prompts and outputs as shown below.
- Once the program is running, observe the output of the first 2 lines, where conversions happen in arithmetic and assignment operations. Convince yourself of the outputs (why three arithmetic operations have different results, why i and j both get 3?)

Sample Inputs/Outputs:

```
red 330 % a.out
9/2=4.000000  9*1.0/2=4.500000  9/2*1.0=4.000000   9/(2*1.0)=4.500000

(float)9/2=4.500000  9/(float)2=4.500000  (float)(9/2)=4.000000

3.0*9/2/4=3.375000  9/2*3.0/4=3.000000  9*3/2*3.0/4=3.000000
i: 3  j: 3

Enter operand_1 operator operand_2 separated by blanks> 12 + 22.3024
Your input '12 + 22.302401' result in
34.302399 (fun_IF)
34.000000 (fun_II)
34.302399 (fun_FF)

Enter operand_1 operator operand_2 separated by blanks> 12 * 2.331
Your input '12 * 2.331000' result in
27.972000 (fun_IF)
24.000000 (fun_II)
27.972000 (fun_FF)

Enter operand_1 operator operand_2 separated by blanks> 2 / 9.18
Your input '2 / 9.180000' result in
0.217865 (fun_IF)
0.000000 (fun_II)
0.217865 (fun_FF)
Enter operand_1 operator operand_2 separated by blanks> -1 + -1
red 331 %
```

Do you understand why the results of the `fun-IF` and `fun-FF` are same but both are different from `fun-II`? **Write a brief justification on the program file (as comments).**

Submit your program using **`submit 2031AC lab3 lab3conv.c`**

Problem E0 Bitwise operations

In class we covered bitwise operators `& | ~` and `<< >>`. It is important to understand that,

- A bit has value either 0 or 1. When using bitwise operator `& |`, value 0 is treated as False and 1 is treated as True. Following the truth table of Boolean Algebra (True AND True is

True, False AND True is False etc.), for a bit `b` (which is either 0 or 1), there are 4 combinations.

- `b & bit 0` **generates a bit that is 0** (anything AND with False is False)
- `b | bit 1` **generates a bit that is 1** (anything OR with True is True)
- `b & bit 1` **generates a bit that is the same as** `b`**.** (AND with True, no change)
- `b | bit 0` **generates a bit that is the same as** `b`**.** (OR with False, no change)

- each bitwise operation generates a new value but does not change the operand itself. For example, for an `int` variable `abc`, expression `abc <<4`, `abc & 3`, `abc | 5` does not change `abc`. In order to change `abc`, you have to use `abc = abc <<4`, `abc = abc & 3`, `abc = abc | 5`, or use their compound assignment versions `abc <<= 4`, `abc &=3`, `abc |= 5`. When these expressions are executed, based on the above observations, we got the following idioms:
  - `b = b & bit 0` **sets** `b` **to 0 ("turns bit** `b` **off"),**
  - `b = b | bit 1` **sets** `b` **to 1 ("turns bit** `b` **on"),**
  - `b = b & bit 1` **sets** `b` **to its original value ("keep the value of** `b`**").**
  - `b = b | bit 0` **sets** `b` **to its original value ("keep the value of** `b`**").**

Download provided file `lab3bit.c`. This program reads integers from stdin, and then performs several bitwise operations. It terminates when -1000 is entered.
Compile and run the program with several inputs, and observe

- what the resulting binary representations look like when the input `abc` is left bit shifted, and is bit flipped. Note that expression `abc << 3` or `~abc` does not modify `abc` itself, so the program uses the original value in other operations.
- how `1 << 4` is used with `|` to turn on bit-4 (denote the right-most bit as bit-0). Again, expression `abc | 1<<4` does not change `abc` itself.
  As a C programming idiom (code pattern), for an integer abc, **`abc = abc |(1<<j)` turns on bit-`j` of `abc`,** i.e., bit-j becomes 1 regardless of its original value (other bits remain unchanged).
- what the bit representation of `~(1<<4)` looks like, and how it is used with bitwise operator `&` to turn off bit 4. As a C programming idiom here, **`abc = abc & ~(1 << j)` turns off bit-`j` of `abc`,** i.e., bit-j becomes 0 regardless of its original value (other bits remain unchanged).
  Also observe here that parenthesis is needed around `1<<4` because operator `<<` has lower precedence than operator `~`. (What is the result of `~1<<4` ?)
- how `1 << 4` is used with `&` to keep bit 4 and turn off all other bits. As a programming idiom, **`if (abc & (1<<j))` is used to test whether bit-`j` of `abc` is on** (why?).
- what the bit representation of `077` looks like, and how it is used with `&` to keep the lower 6 bits and turn off all other bits. Change `077` to `0177` and then `0377` to see what happens.
- what the bit representation of `~077` looks like, and how it is used with `&` to turn off lower 6 bits and keep all other bits.

Enter different numbers, trying to understand these bitwise idioms.
When you terminate the loop, observe the for `unsigned int 0xFFFFFFFF`, whose binary representation is `11…111`, left shift `>> 3` add 000 on the left end, as specified in C. For `signed int 0xFFFFFFF`, C did not specify if 000 or 111 will be added in and it is implementation-dependent. If you run the program in the lab, it shows that 111 is added, but this maybe different in other platforms. So the rule of thumb is: *In C, don't do right shift on signed integers!* As mentioned in class, Java introduced `>>>` to resolve the ambiguity.

Finally, observe that bitwise operation is used in function `printBinary()` to generate artificial '0' or '1', printing the binary representation of an int. Try to understand the code.
No submission for this question, but doing the exercise gets you prepared for problems E1, E2 below.
What are Bitwise operators used for? The following two questions walk you through two applications of bitwise operations.

Problem E1 bits as Boolean flags (20 pts)

Specification

In class we mentioned that one usefulness of bitwise operator is to use bits as Boolean flags. Here is an example. Recall that in lab 2 we have the problem of counting the occurrence of digits in user inputs. We used an array of 10 integers where each integer element is a counter. Now consider a simplified version of the problem: there is no need to count the number of occurrences of each digit, instead we just need to record whether each digit has appeared in the input or not (no matter how many times they appear). For example, for input `EECS2031A, 2019-21FW, LAS0006,` we need to record that `0,1,2,3,6` and `9` appeared in the inputs, but `4,5,7` and `8` did not. One way to do this is to maintain an array of 10 (short) integers, where each integer element is used as a Boolean flag: 0 for False (absent) and 1 for True (present). Now imagine in old days when memory is very limited, and thus instead of 10 integers, which takes 160~320 bits, you can only afford to use one integer (16~32 bits) to do the job. Is it possible?
Here the bitwise operations come to the rescue. The idea is that since we only need a True/False info for each digit, 1 bit is enough for each digit, so we need only a total of 10 bits to record. Thus an integer or even a short integer is enough. Specifically, we declare a `short int` variable named `flags`, which usually has 16 bits. Then we designate 10 bits in `flags` as Boolean flags digits 0~9. For example, we designate the right most bit (denoted bit-0) as the Boolean flag for digit 0, designate the next bit (denoted bit-1) as the Boolean flag for digits 1, and so on. `flags` is initially set to 0. Then after reading the first digit, say, 2, we use bitwise operation to "turn on" (set to 1) bit-2 of `flags`. So `flags`' bit representation becomes `00000000 00000100`. Later when reading another 2, you can somehow check if bit-2 is on and turns it on if not, or alternatively, simply use the same operation to turn on bit-2 of `flags`, although bit-2 is already on. After reading all inputs `EECS2031A, FW2019-21, LAS1006A,` which contains digit `0,1,2,3,6` and `9,` the internal representation of `flags` becomes `0000010 01001111`. That is, bit 0,1,2,3,6 and 9 are on. Finally, we can use bitwise operations to examine the lower 10 bits of `flags`, determining which are 1 and which are 0.

Implementation

Download partially implemented file `lab3flags.c`. Similar to `lab2C.c`, this program keeps on reading inputs using `getchar` until end of file is entered. It then outputs if each digits is present in the inputs or not.

- Observe that by putting `getchar` in the loop header, we just need to call `getchar` once. (But a parenthesis is needed due to operator precedence).
- Complete the loop body, using one of the idioms mentioned on previous page, so that `flags` is updated properly after reading a digit char.
- Complete the output part, by checking the right most 9 bits one by one. Hint: there are at least two approaches to check whether a particular bit is 1 or 0. One of the idiom mention earlier can do this, another approach is hinted in the `printBinary` function provided.

- For your convenience, a function `printBinary()` is defined and used to output the binary representation of `flags`, both before and after user inputs. (This is the same function given in lab3bit.c)
  It is interesting to observe that function `printBinary()` itself uses bitwise operations to generate artificial '0' or '1' , printing the binary representation of an int. It would be interesting to trace the code. This may help you complete the output part.

Sample inputs/outputs (download `input2C.txt` from lab2)

```
red 369 % a.out
flags: 00000000 00000000
YorkU LAS C
^D (press Ctrl and D)

flags: 00000000 00000000
0: No
1: No
2: No
3: No
4: No
5: No
6: No
7: No
8: No
9: No
red 370 % a.out
flags: 00000000 00000000
EECS2031A FW2019-21
LAS1006A
^D (press Ctrl and D)

flags: 00000010 01001111
0: Yes
1: Yes
2: Yes
3: Yes
4: No
5: No
6: Yes
7: No
8: No
9: Yes
red 371 % a.out
flags: 00000000 00000000

EECS3421 this is good 3
address 500 yu264067
429Dk
^D (press Ctrl and D)

flags: 00000010 11111111
0: Yes
1: Yes
2: Yes
3: Yes
4: Yes
```

```
5: Yes
6: Yes
7: Yes
8: No
9: Yes
red 372 % a.out < input2C.txt
flags: 00000000 00000000


flags: 00000000 11111111
0: Yes
1: Yes
2: Yes
3: Yes
4: Yes
5: Yes
6: Yes
7: Yes
8: No
9: No
red 373 %
```

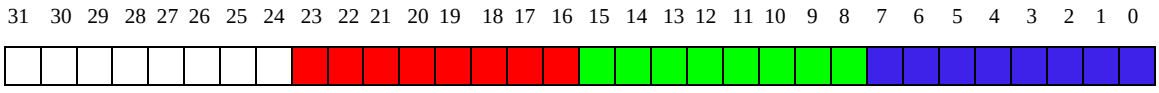
Submit your program by issuing **`submit 2031AC lab3 lab3flags.c`**

Problem E2 Bitwise operation (20 pt)

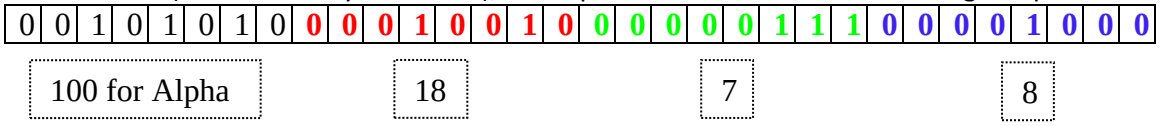
Specification

A digital image is typically stored in computer by means of its pixel color values, as well as some formatting information. Each pixel color value consists of 3 values of 0 ~ 255, representing red (R), green (G) and blue (B).

As mentioned in class, Java's BufferedImage class has a method `int getRGB(int x,int y)`, which allows you to retrieve the RGB color value of an image at pixel position `(x,y)`. How could the method return 3 values at a time? Instead of returning an int array or an object, the 'trick' is to return an integer (32 bits) that packs the 3 values into it. Since each value is 0~255 thus 8 bits are enough to represent it, a 32 bits integer has sufficient bits. They are packed in such a way that, counting from the right most bit, B values occupies the first 8 bits (bit 0~7), G occupies the next 8 bits, and R occupies the next 8 bits. This is shown below. (The left-most 8 bits is packed with some other information about the image, called Alpha, which we are not interested here.)



Suppose a pixel has R value 18 (which is binary 00010010), G value 7 (which is binary 00000111) and B value 8 (which is binary 00001000), and Alpha has value 100, then the integer is packed as



Implementation

In this exercise, you are going to use bitwise operations to pack input R,G and B values into an integer, and then use bitwise operations again to unpack the packed integer to retrieve the R, G and B values.

Download and complete `lab3RGB.c`. This C program keeps on reading input from the stdin. Each input contains 3 integers representing the R, G and B value respectively, and then outputs the 3 values with their binary representations (implemented for you). The binary representations are generated by calling function `void printBinary(int val)`, which is defined for you in another program `binaryFunction.c`.
Next is the packing part that you should implement. This packs the 3 input values, as well as Alpha value which is assumed to be 100, into integer variable `rgb_pack`.
Then the value of `rgb_pack` and its binary representation is displayed (implemented for you).

Next you should unpack the R, G and B value from the packed integer `rgb_pack`. **Note that you should not just use the original R,G and B value, as this is considered a "hoax".**
After that, the unpacked R,G and B value and their Binary, Octal and Hex representations are displayed (implemented for you).
The program terminates when you enter a negative number for either R, G or B value.

Hint: Packing might be a little easier than unpacking. Considering shifting R,G,B values to the proper positions and then somehow merge them into one integer (using bitwise operators). For unpacking, you can either do shifting + masking, or, masking + shifting, or, shifting only. Shifting + masking means you first shift the useful bits to the proper positions, and then turn off (set to 0) the unwanted bits while keeping the values of the useful bits. What you want to end up with, for example for R value, is a binary representation of the following, which has decimal value 18.

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**0**

Masking + shifting means you first use & to turn off some unrelated bits and keep the values of the good bits, and then do a shifting to move the useful bits to the proper position. When doing shifting, the rule of thumb is to avoid right shifting on signed integers. Explore different approaches for unpacking.
Finally, it is interesting to observe that function `printBinary()` itself uses bitwise operations to generate artificial '0' or '1', printing the binary representation of the int.
Since `printBinary()` is defined in another file, how to use a function that is defined in another file? **Don't do `include<binaryFunction.c>`**, instead, declare the function `printBinary()` in the main program `lab3RGB.c` (how?), and then compile the files together, as shown below. (We will talk more about multiple files next week).

Sample Inputs/Outputs:

pay attention to how the program is compiled

```
red 338 % gcc lab3RGB.c binaryFunction.c
red 339 % a.out
enter R value (0~255): 1
enter G value (0~255): 3
enter B value (0~255): 5
A: 100  binary: 00000000 00000000 00000000 01100100
R: 1    binary: 00000000 00000000 00000000 00000001
G: 3    binary: 00000000 00000000 00000000 00000011
B: 5    binary: 00000000 00000000 00000000 00000101

Packed: binary: 01100100 00000001 00000011 00000101 (1677787909)

Unpacking  ......
R: binary: 00000000 00000000 00000000 00000001  (1,01,0X1)
G: binary: 00000000 00000000 00000000 00000011  (3,03,0X3)
```

```
B: binary: 00000000 00000000 00000000 00000101  (5,05,0X5)
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enter R value (0~255): 22
enter G value (0~255): 33
enter B value (0~255): 44
A: 100  binary: 00000000 00000000 00000000 01100100
R: 22   binary: 00000000 00000000 00000000 00010110
G: 33   binary: 00000000 00000000 00000000 00100001
B: 44   binary: 00000000 00000000 00000000 00101100

Packed: binary: 01100100 00010110 00100001 00101100 (1679171884)

Unpacking  ......
R: binary: 00000000 00000000 00000000 00010110  (22, 026, 0X16)
G: binary: 00000000 00000000 00000000 00100001  (33, 041, 0X21)
B: binary: 00000000 00000000 00000000 00101100  (44, 054, 0X2C)
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enter R value (0~255): 123
enter G value (0~255): 224
enter B value (0~255): 131
A: 100  binary: 00000000 00000000 00000000 01100100
R: 123  binary: 00000000 00000000 00000000 01111011
G: 224  binary: 00000000 00000000 00000000 11100000
B: 131  binary: 00000000 00000000 00000000 10000011

Packed: binary: 01100100 01111011 11100000 10000011 (1685840003)

Unpacking  ......
R: binary: 00000000 00000000 00000000 01111011  (123, 0173, 0X7B)
G: binary: 00000000 00000000 00000000 11100000  (224, 0340, 0XE0)
B: binary: 00000000 00000000 00000000 10000011  (131, 0203, 0X83)
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enter R value (0~255): 254
enter G value (0~255): 123
enter B value (0~255): 19
A: 100  binary: 00000000 00000000 00000000 01100100
R: 254  binary: 00000000 00000000 00000000 11111110
G: 123  binary: 00000000 00000000 00000000 01111011
B: 19   binary: 00000000 00000000 00000000 00010011

Packed: binary: 01100100 11111110 01111011 00010011 (1694399251)

Unpacking  ......
R: binary: 00000000 00000000 00000000 11111110  (254, 0376, 0XFE)
G: binary: 00000000 00000000 00000000 01111011  (123, 0173, 0X7B)
B: binary: 00000000 00000000 00000000 00010011  (19, 023, 0X13)
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enter R value (0~255): -3
enter G value (0~255): 3
enter B value (0~255): 56
red 340 %
```

Assume all the inputs are valid.
Submit your program by issuing **`submit 2031AC lab3 lab3RGB.c`**

End of lab

Make sure your program compiles in the lab environment. The program that does not compile in the lab will get 0.

All submissions need to be done from the lab.

In summary, for this lab you should submit:
`lab3myatoi.c, lab3Leap.c, lab3conv.c, lab3flags.c, lab3RGB.c`

At any time and from any directory, you can issue **`submit -l 2031AC lab3`** to see the list of files that you have submitted.

Lower case L

Common Notes

All submitted files should contain the following header:

```
/**************************************
* EECS2031 – Lab3 *
* Author: Last name, first name *
* Email: Your email address *
* eecs_username: Your eecs login username *
* york_num: Your student number *
**************************************/
```