CSE 231 **Fall 2020**

Computer Project #4

This assignment focuses on the design, implementation and testing of a Python program which is all about numbers' representation and converting or computing with them.
It is worth 40 points (4% of course grade) and must be completed no later than **11:59 PM on Monday, October 12 (two weeks because of the first exam).**

Assignment Overview

In this assignment, you will practice with functions, strings, controls.

Assignment Background

Number representation
When working with any kind of digital electronics in which numbers are being represented, it is important to understand how numbers are represented in these systems.
Human beings use decimal (base 10) and duodecimal (base 12) systems for counting and measurements (probably because we have 10 fingers and two big toes ☺)[1]. Computers use binary (base 2) number system because they are made from electronics operating in two states: on and off (only two possible digits 0 or 1). In computing, we also use hexadecimal (base 16) or octal (base 8) systems to more easily represent groups of 4 and 3 binary digits (bits) respectively.

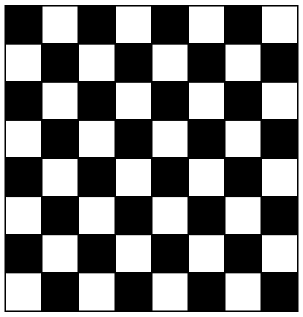
You should all have some familiarity with the decimal system as a *positional* notation. For instance, to represent the integer one hundred and twenty-three as a decimal number, we can write:

$$123 = 1\times100 + 2\times10 + 3\times1 = 1\times10^2 + 2\times10^1 + 3\times10^0$$

Binary number system has two symbols: 0 and 1, called bits. Eight bits is called a byte (why 8-bit unit? Probably because $8 = 2^3$). It is also a positional notation, for example,

$$10110 = 1\times2^4 + 0\times2^3 + 1\times2^2 + 1\times2^1 + 0\times2^0$$

Black and white images representation
Up to now we've explored how numbers are represented in binary, but in this problem we'll explore the representation of images using 0's and 1's. Let's begin by considering 8-by-8, black-and-white images such as the one below:

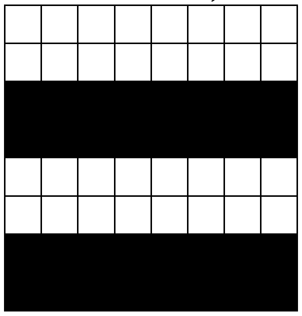


[1] Historical trivia: Babylonians used base 60 which is the source of our 60 minutes, 60 seconds and 360 degrees.

Each cell in the image is called a "pixel". A black pixel is represented by the digit `1` and a white pixel is represented by the digit `0`. The first digit represents the pixel at the top left corner of the image. The next digit represents the pixel in the top row and the second column. The eighth bit (digit) represents the pixel at the right end of the top row. The next bit represents the leftmost pixel in the second row and so forth. Therefore, the image above is represented by the following binary string of length 64 (note the quotes for the string representation):

```
   '1010101001010101101010100101010110101010010101011010101001010101'
```

<u>*Run-length image compression*</u>
Imagine that we have an 8x8 image that looks like this, for example:



Using our standard sequence of 64 bits, this image is represented by a binary string beginning with 16 consecutive 0's (for two rows of white pixels) followed by 16 consecutive 1's (for two rows of black pixels) followed by 16 consecutive 0's followed by 16 consecutive 1's.
Run-length encoding (which, by the way, is used as part of the JPEG image compression algorithm) says: Let's represent that image with the code "16 white, 16 black, 16 white, 16 black". That's a much shorter description than listing out the sequence of 64 pixels "white, white, white, white, ...".
In general, our run-length coding represents an image by a sequence of strings of length 8 (called a "run-length sequence"):

- The first character of the string represents the color that will appear next in the image, either `0` (for white) or `1` (for black).
- The final seven characters contain the number in binary of those bits that appear consecutively at the current location in the image. If the binary number is less than 7 characters, append 0 to the left until it is 7 characters. For example, 16 in binary is '10000' which is a 5-character long string. We extend the string to length 7 by adding 0's to the left resulting in "0010000". Note that in this project, the maximum length of the string representing an image is 64. Therefore, the binary number representation of each color count will never exceed 7 characters (because 7 bits can represent 0-127 since 2^7 is 128 and the number 64 is smaller than 127).

For example, the run-length sequence of the image above:

```
Original image:
   '0000000000000000111111111111111100000000000000001111111111111111'

Intermediate results (number of consecutive whites and blacks):
"16 white, 16 black, 16 white, 16 black"
```

```
Final results (run-length sequence):
                    '00010000100100000001000010010000'
```

The character in ‘red’ is the color (0 or 1) representing white or black respectively.

Assignment Specifications

You have been hired by TASA ("Tatooine Air and Space Administration"). TASA has a deep-space satellite that takes 8-by-8 black-and-white images and sends them back to Tatooine as binary strings of 64 bits as described above. To save precious energy required for transmitting data, TASA would like to "compress" the images sent into a format that uses as few bits as possible. One way to do so is to use the run-length encoding algorithm.

You will develop a Python program which allows the user to select from a menu of options and which performs the requested calculations. You must use at least the four functions specified below. You are encouraged to use more functions of your own design. Global variables are not allowed. That is, any variable names used within any function must be parameters or be created in the function. You are not allowed to use advanced data structures such as lists, dictionaries, classes, etc. However, you are allowed to read ahead and use try-except. You are also not allowed to use built-in functions that are not specified in the function descriptions below:

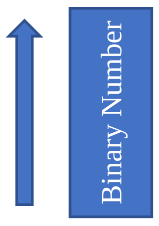
`numtobase(N, B)---→ str:`

a. This function accepts as input a non-negative integer `N` (base 10, aka. decimal) and a “new” base `B` (an integer between 2 and 10 inclusive); it should return a string representing the number N in base B. Your function must output the empty string when the input value of N is 0. (This avoids leading zeros!)
a. Parameters: `N (int),  B (int)`
b. Returns : `str`
c. The function displays nothing.
d. Steps to convert decimal to other base system:
   Step 1 − Divide the decimal number to be converted by the value of the new base.
   Step 2 − Get the **remainder** from Step 1 as the rightmost digit (least significant digit) of new base number.
   Step 3 − Divide the **quotient** of the division from Step 1 by the new base.
   Step 4 − Record the remainder from Step 3 as the next digit (to the left) of the new base number.
   Step 5 − Repeat Steps 3 and 4, getting remainders from right to left, until the quotient becomes zero in Step 3. The last remainder thus obtained will be the Most Significant Digit (MSD) of the new base number.

   Example on how to convert from decimal to binary base system (N=29 and B=2):

```
Decimal Number: 29
Calculating Binary Equivalent –
```

Step	Operation	Quotient	Remainder
Step 1	29 / 2	14	1
Step 2	14 / 2	7	0
Step 3	7 / 2	3	1
Step 4	3 / 2	1	1



Step 5	1 / 2	0	1

Decimal Number – 29 = Binary Number – 11101

As you can see, the remainders have to be arranged in the reverse order so that the first remainder (calculated in Step 2) becomes the Least Significant Digit (LSD) and the last remainder becomes the Most Significant Digit (MSD).

Now ask yourself... what has to change in order to output base B instead of base 2?

```
In [1]: numtobase(29, 2)
Out[1]: '11101'

In [2]: numtobase(4, 4)
Out[2]: '10'

In [3]: numtobase(0, 2)
Out[3]: '' # notice the empty string for an input N of 0 !
```

Hint: while developing this function I printed the quotient and remainder in the loop so I could observe those values as they were calculated in the example above, i.e. `14    1`, then `7     0`, then `3   1`, etc. Note that when you start with the skeleton `proj04.py` code we provide, you can run the program and then call the function in the Spyder shell (lower right window of Spyder). Finally, notice the "until quotient becomes zero" in the algorithm. That tells you a lot about the control choices in this function.

basetonum (S, B) ---→ int:

a. This function accepts as input a string `S` and a base `B` (int) where `S` represents a number in base `B` where `B` is between 2 and 10 inclusive. It should then return an integer in base 10 representing the same number as `S`. It should output 0 when `S` is the empty string. This function is the inverse of the previous function `numtobase()`.
b. Parameters: `S (string), B (int)`
c. Returns : `integer`
d. The function displays nothing.
e. Steps to convert any base system to decimal:
   Step 1 − Determine the column (positional) value of each digit (this depends on the position of the digit and the base of the number system).
   Step 2 − Multiply the obtained column values (in Step 1) by the digits in the corresponding columns.
   Step 3 − Sum the products calculated in Step 2. The total is the equivalent value in decimal.

   Example with `S = '11101'` and `B = 2`
   Binary Number – 11101
   Calculating Decimal Equivalent –

Step	Binary	Decimal Number
Step 1	11101	$(1\times2^4) + (1\times2^3) + (1\times2^2) + (0\times2^1) + (1\times2^0)$
Step 2	11101	16 + 8 + 4 + 0 + 1
Step 3	11101	29

```
Binary Number – 11101 = Decimal Number – 29
```

Again, the key is to ask yourself... what has to change in order to output base B instead of base 2?

```
In [1]: basetonum('11101', 2)
Out[1]: 29
In [2]: basetonum('', 4)
Out[2]: 0
```

Hint: notice how you do one calculation for each digit of the input string S. That tells you a lot about the best control construct for this function. Notice how the exponents in the formula decrease as you move left-to-right (or increase as you move right-to-left) and that the smallest value is 0. How can you calculate the largest exponent?

basetobase(B1,B2,S_1)---→ str:

a. Now, we can assemble what we've written to write a function that takes three inputs: a base `B1`, a base `B2` and `S_1`, which is a string representing a number in base `B1`. Then, your function should return a string representing the same number in base `B2`.
b. Parameters: `B1(int), B2(int), S_B1(str)`
c. Returns : `string`
d. The function displays nothing.
e. **Hint**: Don't rewrite any conversions at all! Instead, use the above functions to convert to decimal and then back to the desired final base! The result is a three-line function: a call to each function and a return.

```
In [1]: basetobase(2, 10, "11") # 11 in base 2 is 3 in base 10...
Out[1]: '3'
In [2]: basetobase(10, 2, "3") # 3 in base 10 is 11 in base 2...
Out[2]: '11'
In [3]: basetobase(3, 5, "11") # 11 in base 3 is 4 in base 5...
Out[3]: '4'
In [4]: basetobase( 2, 3, '101010' )
Out[4]: '1120'
In [5]: basetobase( 2, 4, '101010' )
Out[5]: '222'
In [6]: basetobase( 2, 10, '101010' )
Out[6]: '42'
In [7]: basetobase( 5, 2, '4321' )
Out[7]: '1001001010'
In [8]: basetobase( 2, 5, '1001001010' )
Out[8]: '4321'
```

addbinary(S, T)---→ string:

a. This function accepts as input two binary strings `S` and `T` as input and returns their sum, also in binary.
b. The easiest way of adding two binary numbers is to first convert them to base 10, add those two base 10 numbers, and then convert the result back to binary. You have two functions

that do those two steps so use them. The result is a three-line function: two conversions and a return.

c. *Optional*: If you want a challenge and do it the hard way, you can implement a different, more direct, method for adding two binary numbers, using the "elementary-school" binary addition algorithm, and not using base conversions. That is, this is purely syntactic addition!:

```
101110
100111
--------
```

which, after the addition would look like this:

```
  111
 101110
 100111
--------
1010101
```

Here the "carry" bits are in "bold red". Hint: have a carry for each column with the rightmost carry (called the "carry in") set to zero and a zero where there isn't a red one in the example. Then in each column you add two values and a carry.

d. Parameters: `S (str), T (str)`
e. Returns : `string`
f. The function displays nothing.

Here is some sample input and output:

```
In [1]: addbinary("11100", "11110")
Out[1]: '111010'
In [2]: addbinary("10101", "10101")
Out[2]: '101010'
In [3]: addbinary('1010','11')
Out[3]: '1101'
```

compress(S)---→ string:

a. This function takes a binary string S of length less than or equal to 64 as input and returns another binary string as output. The output binary string should be a run-length encoding of the input string, as described above. If the string is empty, the function should return an empty string. Also, note that in this project, the maximum length of the string representing an image is 64. Therefore, the binary number representation of each color count will never exceed 7 characters.
b. You may need a helper function or two - you may name these whatever you like. Also, you may want to use some of the functions previously defined.
c. Parameters: `S (str)`
d. Returns : `string`
e. The function displays nothing.
f. Here are a couple of examples of `compress`() in action:

```
In [1]: compress( 64*'0' )
Out[1]: '01000000'
In [4]: stripes = '0'*16 + '1'*16 + '0'*16 + '1'*16
In [5]: compress(stripes)
Out[5]: '00010000100100000001000010010000'
```

g. Hints: Remember that the run-length coding represents an image by a sequence of strings of length 8: (1) the first character of the string represents the color that will appear in the image, either 0 (for white) or 1 (for black); (2) the final seven characters contain the number in binary of those bits that appear consecutively at the current location in the image. If the binary number is less than 7 characters, you need to append 0 to the left until it is 7 characters. There are two ways to do it. Either do it incrementally by adding 0 to the left many times until you reach length 7, or use the built-in function `zfill()` from `str` class which is very helpful. For example, if the string is of length 4, and we want to have a string of length 6:

```
stripes = '1'*4 ----------------→ '1111'
stripes.zfill(6) ---------------→  '001111'
```

it will append 2 `0`'s to the left of the string. The `stripes` variable string will not change.

uncompress(S)---→ string:

a. This function takes a binary string S of length less than or equal to 64 as input and returns another binary string as output. Note that the length of string S will always be a multiple of 8 (e.g., 0, 8, 16, 32, 64). The function "inverts" or "undoes" the compressing in your `compress`() function, i.e. it is its inverse. That is, `uncompress(compress(S))` should give back `S.`
b. You may need a helper function or two. Also, you may want to use some of the functions previously defined.
c. Parameters: `S (str)`
d. Returns : `string`
e. The function displays nothing.
f. Here are a couple of examples of `uncompress`() in action:

```
In [1]: uncompress( '10000101' ) # 5 1's
Out[1]: '11111'
In [2]: stripes = '0'*16 + '1'*16 + '0'*16 + '1'*16
In [3]: stripes_out = uncompress(compress(stripes))
Out[3]:
'0000000000000000111111111111111100000000000000001111111111111111'
In [4]: stripes_out == stripes
Out[4]: True
```

g. Hints: Remember that a run-length sequence is a sequence of 8-character long strings. You should slice the string into 8-character long strings and convert back to its uncompressed format.

main():

a. This function is used to interact with the user. It takes no input and returns nothing. Call the functions from here. The program should prompt the user to choose between 6 options (<u>capitalization does not matter</u>) until the user enters `'X'`:

'A' - Convert a decimal number to another base system.
'B' – Convert decimal number from another base.
'C' – Convert from one representation system to another.
'D' - Display the sum of two binary numbers.
'E' - Compress an image.
'U' - Uncompress an image.
'M' - Display the menu of options.
'X' - Exit from the program.

b. The program will repeatedly prompt the user to enter a letter (upper or lower case) which corresponds to one of the supported options. For example, the user will enter the letter A (or the letter a) to select Option A (Convert a decimal number in another base system).
c. The program will display the menu of options once when execution begins, whenever the user selects Option `M`, and whenever the user selects an invalid menu option.
d. If the user enters option `A`, the program will ask the user to enter a numeric value N and a base number B in the range between 2 and 10 inclusive. If N is a non-negative number and B is valid (an integer between 2 and 10), the program will calculate and display the string representation of the number in base B. Otherwise, the program will display an appropriate message and reprompt to enter the invalid input. Note that the string method `.isdigit()` is useful here.
e. If the user enters option `B`, the program will ask the user to enter a string S and a base number B in the range between 2 and 10 inclusive. If B is valid, it will calculate and display the decimal representation of the string. Otherwise, the program will display an appropriate message and reprompt to enter the invalid input
f. If the user enters option `C`, the program will ask the user to enter three inputs: a base `B1`, a base `B2` (both of which are between 2 and 10, inclusive) and `s_1`, which is a string representing a number in base `B1`. If `B1` and `B2` are valid, it will calculate and display a string representing `s_1` in base `B2`. Otherwise, the program will display an appropriate message and reprompt to enter the invalid input.
g. If the user enters option `D`, the program should ask the user to enter two binary strings. The program will calculate and display the sum of the two binary numbers.
h. If the user enters option `E`, the program will ask the user to enter a binary string. The program will compress the image and display the run-length encoding string of the image.
i. If the user enters option `U`, the program will ask the user to enter a binary string representing a run-length encoding string of an image. The program will uncompress the image and display the original representation of the image.
j. If the user enters option `M`, the program will display the menu.
k. If the user enters `X`, the user wants to quit. The program should display a goodbye message.

Assignment Notes and Hints

1. The coding standard for CSE 231 is posted on the course website:

   http://www.cse.msu.edu/~cse231/General/coding.standard.html

Items 1-9 of the Coding Standard will be enforced for this project.

2. The program will produce reasonable and readable output, with appropriate labels for all values displayed.

3. You may assume that the user enters a string representing a numeric value when prompted for a number. However, you should not assume that the value is valid in that particular context. For example, the user might enter '-5' for Option A; that numeric value is not a non-negative number.

4. Be sure to prompt the user for the inputs in the correct order. And, your program cannot prompt the user for any supplementary inputs.

5. Several built-in function might be useful for this project:

```
str() – to convert a number to a string
int() – to convert a string to an int
.isdigit() – to check if the string is only digits
```

6. The program will calculate the value for Option D using only "elementary-school" binary addition method.

7. We provide a `proj04.py` program for you to start with.

8. You are not allowed to use advanced data structures such as list, dictionaries, classes, etc. However, you are allowed to read ahead and use try-except.

9. If you "hard code" answers, you will receive a grade of zero for the whole project. An example of hard coding is to simply print the correct value of the binary number rather than calculating it and then printing it.

Suggested Procedure

- *Solve the problem using pencil and paper first.* You cannot write a program until you have figured out how to solve the problem. This first step can be done collaboratively with another student. However, once the discussion turns to Python specifics and the subsequent writing of Python statements, you must work on your own.

- Cycle through the following steps to incrementally develop your program:

  - Edit your program to add new capabilities.
  - Run the program and fix any errors.
  - Use the **Mimir** system to submit the current version of your program.

- Be sure to use the **Mimir** system to submit the final version of your program.

- Be sure to log out when you leave the room, if you're working in a public lab.

The last version of your solution is the program which will be graded by your TA.

You should use the ***Mimir*** *system to back up your partial solutions, especially if you are working close to the project deadline. That is the easiest way to ensure that you won't lose significant portions of your work if your machine fails or there are other last-minute problems.*

Assignment Deliverable

The deliverable for this assignment is the following file:

`proj04.py` – the source code for your Python program

Be sure to use the specified file name and to submit it for grading via the **Mimir system** before the project deadline.

Test 1:

```
        .    .        .      .             . .     .        .          .
.
         .                 .                    .                .
  .               A long time ago in a galaxy far, far away...   .
              .   A terrible civil war burns throughout the  .        .     .
                 galaxy: a rag-tag group of freedom fighters   .  .
     .       .  has risen from beneath the dark shadow of the            .
.        .     evil monster the Galactic Empire has become.                .
.
    .      Outnumbered and outgunned,  the Rebellion burns across the   .    .
.      vast reaches of space and a thousand-thousand worlds, with only     .
    . their great courage - and the mystical power known as the Force -
     flaming a fire of hope. a                                  .

              .------.
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  ~~ Your mission: Tatooine planet is under attack from stormtroopers,
                   and there is only one line of defense remaining
                   It is up to you to stop the invasion and save the planet~~



Please choose one of the options below:
             A. Convert a decimal number to another base system
             B. Convert decimal number from another base.
             C. Convert from one representation system to another.
             D. Display the sum of two binary numbers.
             E. Compress an image.
             U. Uncompress an image.
             M. Display the menu of options.
             X. Exit from the program.

      Enter option: n
```

```
      Error:  unrecognized option [N]

Please choose one of the options below:
             A. Convert a decimal number to another base system
             B. Convert decimal number from another base.
             C. Convert from one representation system to another.
             D. Display the sum of two binary numbers.
             E. Compress an image.
             U. Uncompress an image.
             M. Display the menu of options.
             X. Exit from the program.

      Enter option: M

Please choose one of the options below:
             A. Convert a decimal number to another base system
             B. Convert decimal number from another base.
             C. Convert from one representation system to another.
             D. Display the sum of two binary numbers.
             E. Compress an image.
             U. Uncompress an image.
             M. Display the menu of options.
             X. Exit from the program.

      Enter option: X
May the force be with you.
```

Test 2:

```
        .    .        .      .             . .     .        .          .
.
         .                 .                    .                .
  .               A long time ago in a galaxy far, far away...   .
              .   A terrible civil war burns throughout the  .        .     .
                 galaxy: a rag-tag group of freedom fighters   .  .
     .       .  has risen from beneath the dark shadow of the            .
.        .     evil monster the Galactic Empire has become.                .
.
    .      Outnumbered and outgunned,  the Rebellion burns across the   .    .
.      vast reaches of space and a thousand-thousand worlds, with only     .
    . their great courage - and the mystical power known as the Force -
     flaming a fire of hope. a                                   .

              .------.
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  ~~ Your mission: Tatooine planet is under attack from stormtroopers,
                   and there is only one line of defense remaining
                   It is up to you to stop the invasion and save the planet~~



Please choose one of the options below:
             A. Convert a decimal number to another base system
             B. Convert decimal number from another base.
             C. Convert from one representation system to another.
             D. Display the sum of two binary numbers.
             E. Compress an image.
             U. Uncompress an image.
             M. Display the menu of options.
             X. Exit from the program.

      Enter option: a
```

```
      Enter N: 0

Enter Base: 2

       0 in base 2:

      Enter option: A

      Enter N: 29

Enter Base: 2

       29 in base 2: 11101

      Enter option: a

      Enter N: 1.6

      Error: 1.6 was not a valid non-negative integer.

      Enter N: -5

      Error: -5 was not a valid non-negative integer.

      Enter N: 42

Enter Base: 12

      Error: 12 was not a valid integer between 2 and 10 inclusive.

      Enter Base: 1

      Error: 1 was not a valid integer between 2 and 10 inclusive.

      Enter Base: 10

       42 in base 10: 42

      Enter option: x
May the force be with you.
```

Test 3:

```
        .    .        .      .             . .     .        .          .
.
         .                 .                    .                .
  .              A long time ago in a galaxy far, far away...   .
              .   A terrible civil war burns throughout the  .        .     .
                 galaxy: a rag-tag group of freedom fighters   .  .
     .       .  has risen from beneath the dark shadow of the            .
.        .     evil monster the Galactic Empire has become.                 .
.
    .      Outnumbered and outgunned,  the Rebellion burns across the   .    .
.      vast reaches of space and a thousand-thousand worlds, with only     .
    . their great courage - and the mystical power known as the Force -
     flaming a fire of hope. a                                   .

              .------.
            .'::::::' `.
            |: __   __ |
            | <__] [__>|
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              | |==| |
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      \\  |  LS |    `.   |||||


  ~~ Your mission: Tatooine planet is under attack from stormtroopers,
                   and there is only one line of defense remaining
                   It is up to you to stop the invasion and save the planet~~



Please choose one of the options below:
             A. Convert a decimal number to another base system
             B. Convert decimal number from another base.
             C. Convert from one representation system to another.
             D. Display the sum of two binary numbers.
             E. Compress an image.
             U. Uncompress an image.
             M. Display the menu of options.
             X. Exit from the program.

      Enter option: b
```

```
      Enter string number S: 11

      Enter Base: 2

       11 in base 2: 3

      Enter option: B

      Enter string number S:

      Enter Base: 10

        in base 10: 0

      Enter option: b

      Enter string number S: 11

      Enter Base: 12

      Error: 12 was not a valid integer between 2 and 10 inclusive.

      Enter Base: 1

      Error: 1 was not a valid integer between 2 and 10 inclusive.

      Enter Base: 10

       11 in base 10: 11

      Enter option: x
May the force be with you.
```

Test 4:

```
        .    .        .      .             . .     .        .          .
.
         .                 .                    .                .
  .               A long time ago in a galaxy far, far away...   .
              .   A terrible civil war burns throughout the  .        .     .
                 galaxy: a rag-tag group of freedom fighters   .  .
     .       .  has risen from beneath the dark shadow of the            .
.        .     evil monster the Galactic Empire has become.                  .
.
    .      Outnumbered and outgunned,  the Rebellion burns across the   .    .
.      vast reaches of space and a thousand-thousand worlds, with only      .
    . their great courage - and the mystical power known as the Force -
     flaming a fire of hope. a                                   .

              .------.
            .'::::::' `.
            |: __   __ |
            | <__] [__>|
            `-.  __  .-'
              | |==| |
              | |==| |
           __.`-[..]-`\__
    _.--:``      ||   _``:::--._
   | |  |.      .:'  (o) ::|  | |
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    ===-|:``` // /.\       |-===
   |_| `:___//_|[ ]|_____.' |_| )
    l=l   |\V/_=======_==|   l=l/
  .-l=l   |`'==/=="======|  /|.:
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  `.l_l   |==============|   l_l
    [_]  [__][__]____[_]__]  [_]
    \\ .'.--.- --   --. .`. |||.
    \\| |  |    |    |  || ||||
     \\   .'    |    |  |`.||||
      \\  |  LS |    `.   |||||


  ~~ Your mission: Tatooine planet is under attack from stormtroopers,
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             U. Uncompress an image.
             M. Display the menu of options.
             X. Exit from the program.

      Enter option: c
```

```
      Enter base B1: 1

      Error: 1 was not a valid integer between 2 and 10 inclusive.

      Enter base B1: 12

      Error: 12 was not a valid integer between 2 and 10 inclusive.

      Enter base B1: 10

      Enter base B2: 1

      Error: 1 was not a valid integer between 2 and 10 inclusive.

      Enter base B2: 12

      Error: 12 was not a valid integer between 2 and 10 inclusive.

      Enter base B2: 2

      Enter string number S: 3

       3 in base 10 is 11 in base 2...

      Enter option: C

      Enter base B1: 10

      Enter base B2: 2

      Enter string number S: 0

       0 in base 10 is  in base 2...

      Enter option: x
May the force be with you.
```

Test 5:

```
        .    .        .      .             . .     .        .          .
.
         .                 .                    .                .
  .               A long time ago in a galaxy far, far away...   .
              .   A terrible civil war burns throughout the  .        .     .
                 galaxy: a rag-tag group of freedom fighters   .  .
     .       .  has risen from beneath the dark shadow of the            .
.        .     evil monster the Galactic Empire has become.                  .
.
    .      Outnumbered and outgunned,  the Rebellion burns across the   .    .
.      vast reaches of space and a thousand-thousand worlds, with only     .
    . their great courage - and the mystical power known as the Force -
     flaming a fire of hope. a                                   .

              .------.
            .':::::' `.
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            `-.  __  .-'
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  .-l=l   |`'==/=="======|  /|.:
  | l l   |=="======\=_==| `-T l
  `.l_l   |==============|   l_l
    [_]  [__][__]____[_]__]  [_]
    \\ .'.--.- --   --. .`. |||.
    \\| |  |    |    |  || ||||
     \\   .'    |    |  |`.||||
      \\  |  LS |    `.   |||||



  ~~ Your mission: Tatooine planet is under attack from stormtroopers,
                   and there is only one line of defense remaining
                   It is up to you to stop the invasion and save the planet~~



Please choose one of the options below:
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             E. Compress an image.
             U. Uncompress an image.
             M. Display the menu of options.
             X. Exit from the program.

      Enter option: d

      Enter the first string number: 110

      Enter the second string number: 11

      The sum:  1001

      Enter option: D

      Enter the first string number: 11100

      Enter the second string number: 11110

      The sum:  111010

      Enter option: x
May the force be with you.
```

Test 6:

```
        .    .        .      .             . .     .        .          .
.
         .                 .                    .                .
  .               A long time ago in a galaxy far, far away...   .
              .   A terrible civil war burns throughout the  .        .     .
                 galaxy: a rag-tag group of freedom fighters   .  .
     .       .  has risen from beneath the dark shadow of the            .
.        .     evil monster the Galactic Empire has become.                  .
.
    .      Outnumbered and outgunned,  the Rebellion burns across the   .    .
.      vast reaches of space and a thousand-thousand worlds, with only     .
    . their great courage - and the mystical power known as the Force -
     flaming a fire of hope. a                                   .

              .------.
            .':::::' `.
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            | <__] [__>|
            `-.  __  .-'
              | |==| |
              | |==| |
           __.`-[..]-`\__
    _.--:``      ||   _``:::--._
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   |_|  |::..  // _       :|  |_|
    ===-|:``` // /.\       |-===
   |_| `:___//_|[ ]|_____.' |_| )
    l=l   |\V/_=======_==|   l=l/
  .-l=l   |`'==/=="======|  /|.:
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  `.l_l   |==============|   l_l
    [_]  [__][__]____[_]__]  [_]
    \\ .'.--.- --   --. .`. |||.
    \\| |  |    |    |  || ||||
     \\   .'    |    |  |`.||||
      \\  |  LS |    `.   |||||


  ~~ Your mission: Tatooine planet is under attack from stormtroopers,
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             E. Compress an image.
             U. Uncompress an image.
             M. Display the menu of options.
             X. Exit from the program.

      Enter option: e
```

```
      Enter a binary string of an image: 11111

       Original image: 11111

       Run-length encoded image: 10000101

      Enter option: E

      Enter a binary string of an image: 00000000000000000000000000000000

       Original image: 00000000000000000000000000000000

       Run-length encoded image: 00100000

      Enter option: X
May the force be with you.
```

Test 7:

```
        .    .        .      .             . .     .        .          .
.
         .                 .                    .                .
  .               A long time ago in a galaxy far, far away...   .
              .   A terrible civil war burns throughout the  .        .     .
                 galaxy: a rag-tag group of freedom fighters   .  .
     .       .  has risen from beneath the dark shadow of the            .
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.
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.      vast reaches of space and a thousand-thousand worlds, with only     .
    . their great courage - and the mystical power known as the Force -
     flaming a fire of hope. a                                   .

              .------.
            .'::::::' `.
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     \\   .'    |    |  |`.||||
      \\  |  LS |    `.   |||||
```

```
  ~~ Your mission: Tatooine planet is under attack from stormtroopers,
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             E. Compress an image.
             U. Uncompress an image.
             M. Display the menu of options.
             X. Exit from the program.

      Enter option: u

      Enter a run-length encoded string of an image: 00100000

       Run-length encoded image: 00100000

       Original image: 00000000000000000000000000000000

      Enter option: U

      Enter a run-length encoded string of an image: 10000101

       Run-length encoded image: 10000101

       Original image: 11111

      Enter option: X
May the force be with you.
```

Grading Rubric

```
Computer Project #04                            Scoring Summary
General Requirements:
  ( 4 pts) Coding Standard 1-9
      (descriptive comments, function headers, mnemonic identifiers,
      format, etc...)

Implementation:
 ( 4 pts)  numtobase() function

 ( 4 pts)  basetonum() function

 ( 2 pts)  basetobase() function

 ( 4 pts)  addbinary() function

 ( 4 pts)  compress() function

 ( 4 pts)  uncompress() function

 ( 4 pts)  Test 1

 ( 2 pts)  Test 2

 ( 2 pts)  Test 3

 ( 3 pts)  Test 4

 ( 1 pts)  Test 5

 ( 1 pts)  Test 6

 ( 1 pts)  Test 7

Note: hard coding an answer earns zero points for the whole project
-10 points for not using main()
```