COP 3502C Programming Assignment # 5

Binary Search Tree

Read all the pages before starting to write your code!

Objective:

To implement a binary search tree that handles strings with multiple fields, incorporating a range of functionalities for efficient data management and retrieval.

Deliverable:

Write all the code in a single main.c file and upload the main.c file. Please include the following commented lines in the beginning of your code to declare your authorship of the code:

```
/* COP 3502C Assignment 5
This program is written by: Your Full Name  */
```

Compliance with Rules: UCF Golden rules apply towards this assignment and submission. Assignment rules mentioned in syllabus, are also applied in this submission. The TA and Instructor can call any students for explaining any part of the code in order to better assess your authorship and for further clarification if needed.

Caution!!!

Sharing this assignment description (fully or partly) as well as your code (fully or partly) to anyone/anywhere is a violation of the policy. I may report to office of student conduct and an investigation can easily trace the student who shared/posted it. **Also, getting a part of code from anywhere other than class resources will be considered as cheating.**

Deadline:

See the deadline in Webcourses. An assignment submitted by email will not be graded and such emails will not be replied according to the course policy.

What to do if you need clarification on the problem?

Write an email to the TA and put the course teacher in the cc for clarification on the requirements. I will also create a discussion thread in webcourses, and I highly encourage you to ask your question in the discussion board. Maybe many students might have same question as you. Also, other students can reply, and you might get your answer faster.

How to get help if you are stuck?

According to the course policy, all the helps should be taken during office hours. There Occasionally, we might reply in email.

Parking Violation Tracker

Background Story

The Monster Campus Parking Authority is known for issuing tickets for various parking violations, including reverse parking, parking in restricted areas, and occupying reserved spaces. The campus has greatly benefited from the parking garage systems you developed in the past four assignments. Now, the Parking Authority is looking to build a new system to track parking tickets and fines issued to vehicle owners. The goal is to reduce traffic violations by recording every ticket issued and the associated fines. As you learned in class, storing data in a binary search tree (BST) can improve search efficiency, making this a great opportunity to apply that knowledge.

In the new system, vehicle owners can accumulate fines, pay them off partially, or check their current balance. Additionally, some owners may be removed from the tracking system if they no longer owe fines. The system should also support analytical queries, such as calculating the total and average fines.

In your binary search tree implementation, each node will store the vehicle owner's name and the amount of the fine they need to pay. The owner's name will serve as the key for the BST, with comparisons made based on alphabetical order. As you develop this application, you may also want to implement debugging queries to gain better insights into the structure of the tree.

Problem

Develop a program that processes input commands to manage the parking ticket fine system. The program should respond appropriately to each command, as outlined below:

- *Add a fine to a vehicle owner*
- *Deduct a fine from a vehicle owner*
- *Search for a vehicle owner's record*
- *Calculate the average fine amount per owner in the system*
- *Calculate the total amount of fines in the system*
- *Determine the balance of the tree in terms of height*
- *Calculate the total fine amount for vehicle owners whose names are alphabetically smaller than a given name*

Input (must be standard input using scanf (no file i/o is allowed))

The first line of input contains a single positive integers: ***n*** (***n*** ≤ 300,000), the number of commands to process.

The next **n** lines will each contain a single command. Note that all strings in this assignment are assumed to be single-word strings. Therefore, using scanf with %s should be sufficient to capture each string input. Below is the format for each of the possible input lines:

Command 1

`add <name> <fine>`

- `<name>` A lowercase alphabetic string containing no more than 25 characters.
- `<fine>` A positive integer, less than or equal to 100.

This command adds a vehicle owner with the specified name (`<name>`) to the tree. If the owner already exists in the system, the command will increase the owner's fine by the given amount `(<fine>)`.

Command 2

`deduct <name> <fine>`

- `<name>` A lowercase alphabetic string containing no more than 25 characters.
- `<fine>` A positive integer, less than or equal to 100.

Behavior:

- If the vehicle owner has a fine amount less than the specified deduction, the fine will be reduced to zero (or the owner's current fine if it's less than the specified amount).
- If the owner's fine becomes zero or negative after the deduction, the owner is removed from the tree.

This command ensures that if a deduction exceeds the current fine, the fine is set to zero and the owner is removed from the system if they no longer owe any fines.

Command 3

`search <name>`

- `<name>` A lowercase alphabetic string containing no more than 25 characters.

Behavior:

- This command searches for the vehicle owner with the specified name `<name>`) in the tree.
- If the owner is found, the command will report:
  - The remaining fine the owner still needs to pay.
  - The depth (or level) of the node in the tree that stores that owner's record.

The depth refers to the number of edges from the root node to the node storing the vehicle owner's record.

Command 4

`average`

This command calculates the average amount of fine per vehicle owner in the tree.

Command 5

`height_balance`

This command calculates and compares the heights of the left and right subtrees of the root node.

Behavior:

- The command will calculate the height of the left subtree starting from the left child of the root node.
- It will also calculate the height of the right subtree starting from the right child of the root node.
- If the heights of the left and right subtrees are the same, the command will output that the tree is "balanced."
- If the heights are different, the command will output that the tree is "not balanced."

Command 6

`calc_below <name>`

- `<name>` A lowercase alphabetic string containing no more than 25 characters.

Behavior:

- This command calculates the total amount of fines for all vehicle owners whose names come **alphabetically** before the specified <name>.
- The calculation includes only those owners whose names are lexicographically smaller than equal to <name>, based on alphabetical order.
- The command should sum up the fines of all such vehicle owners in the system and output the total amount.

Output (standard output. No file i/o allowed)

For each input command, output a single line as described below:

Commands 1

Print out a single line with the format:

```
<name> <fine> <depth>
```

The <name> refers to the vehicle owner's name who is being fined, <fine> represents the updated total fine they owe, and <depth> indicates the depth of the node in the tree where the owner's record is stored. If the vehicle owner does not already exist in the tree, the program should insert the owner and then display the message with the owner's name, their new fine, and the depth of the corresponding node in the tree.

Commands 2

Print out a single line with the format:

```
<name> <fine> <depth>
```

The `<name>` represents the vehicle owner's name whose fine has been deducted, `<fine>` is the updated total fine they now owe, and `<depth>` is the depth of the node where their record is stored. If the deduction causes the owner's total fine to reach zero or become negative, the owner should be removed from the tree, and the following message should be printed:

```
<name> removed
```

If the vehicle owner does not exist in the tree when the deduction command is executed, the program should print:

```
<name> not found
```

Important note: If the deduction results in deleting a vehicle owner from the tree, and the owner's node has two children, replace the deleted node with the maximum node from the left subtree. This ensures that there is a consistent and correct result for each test case.

Command 3

If the vehicle owner in question wasn't found in the binary search tree, output the following line:

```
<name> not found
```

If the name is found, output a line with the following format:

```
<name> <fine> <depth>
```

The `<name>` refers to the vehicle owner's name being searched for, `<fine>` is the total fine they owe, and `<depth>` indicates the depth of the node where their record is stored in the tree.

Command 4

Show the average up to two decimal places. Please use double data type for all fractional calculations and also make sure not to do int division by mistake.

```
<average>
```

where `<average>` is the average amount of fine per vehicle owner available in the tree.

Command 5
This command prints a line with the left height, right height and a message whether it is balanced or not.

```
left height = <lh> right height = <rh>  <balance status>
```

where `<lh>` is the height of the left subtree, `<rh>` is the height of the right subtree, and `<balance status>` is either “balanced” or “not balanced”.

Command 6
```
<total>
```

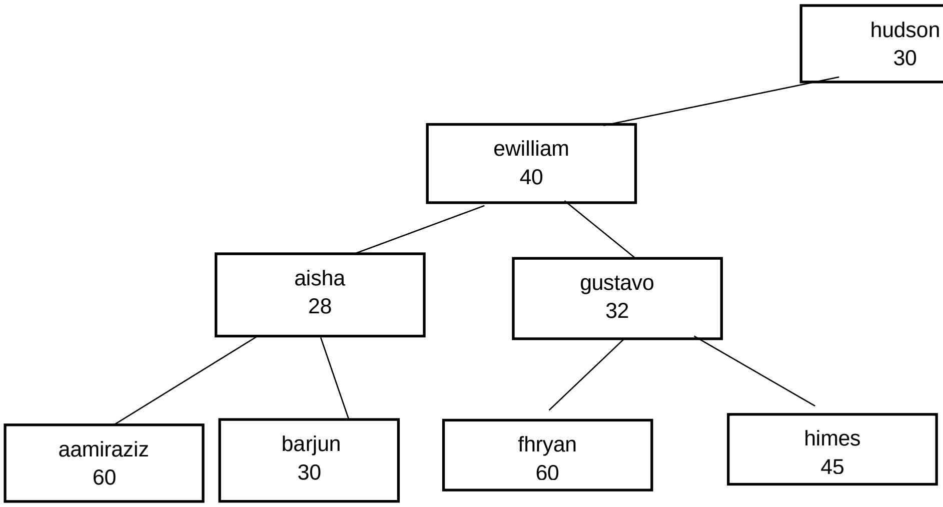
Where `<total>` is the total amount of fines for the vehicle owners whose names are **lexicographically less than or equal to** the name provided in the command. Note that the name entered in the command **does not necessarily have to be present in the tree**. The total should include fines for all owners whose names come before or are the same as the given name in alphabetical order.

Sample input/output on the next page

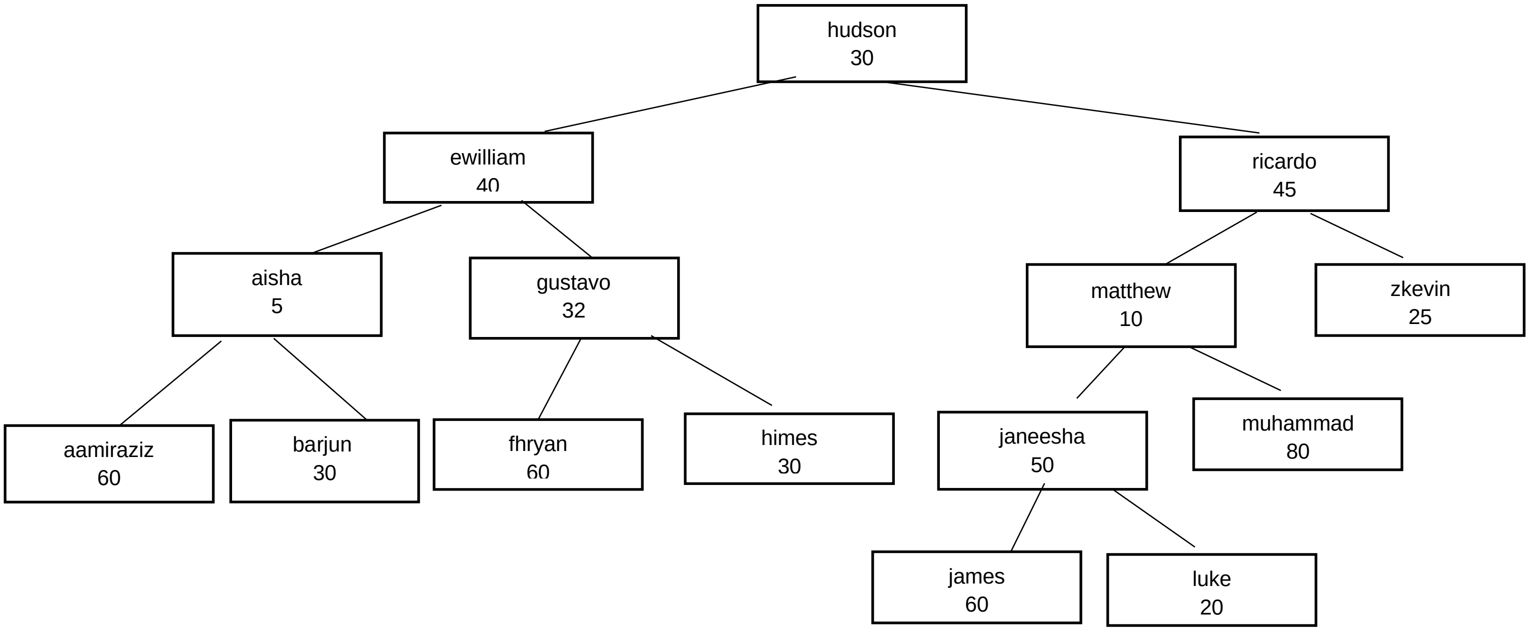
Line	Sample Input	Sample Output
1	46	
2	add hudson 30	hudson 30 0
3	add ewillam 40	ewillam 40 1
4	add gustavo 32	gustavo 32 2
5	add aisha 28	aisha 28 2
6	add fhryan 60	fhryan 60 3
7	add himes 45	himes 45 3
8	add aamiraziz 60	aamiraziz 60 3
9	add barjun 30	barjun 30 3
10	height_balance	left height = 2 right height = -1 not balanced
11	calc_below happy	250
12	average	40.62
13	deduct aisha 23	aisha 5 2
14	deduct himes 15	himes 30 3
15	add gustavo 8	gustavo 40 2
16	add ricardo 20	ricardo 20 1
17	add zkevin 25	zkevin 25 2
18	add matthew 10	matthew 10 2
19	add janeesha 50	janeesha 50 3
20	add muhammad 80	muhammad 80 3
21	height_balance	left height = 2 right height = 2 balanced
22	add james 60	james 60 4
23	height_balance	left height = 2 right height = 3 not balanced
24	add luke 20	luke 20 4
25	calc_below ricardo	535
26	calc_below muhammad	515
27	average	37.33
28	deduct muhammad 80	muhammad removed
29	search matthew	matthew 10 2
30	search muhammad	muhammad not found
31	deduct matthew 15	matthew removed
32	height_balance	left height = 2 right height = 2 balanced
33	search janeesha	janeesha 50 2
34	deduct ewillam 41	ewillam removed
35	search barjun	barjun 30 1
36	height_balance	left height = 2 right height = 2 balanced
37	deduct barjun 30	barjun removed
38	height_balance	left height = 2 right height = 2 balanced
39	search aisha	aisha 5 1
40	search fhryan	fhryan 60 3
41	deduct ewillam 20	ewillam not found
42	search gustavo	gustavo 40 2
43	deduct hudson 30	hudson removed
44	search zkevin	zkevin 25 2
45	search himes	himes 30 0
46	calc_below himes	195
47	calc_below aamiraziz	60

Sample Explanation

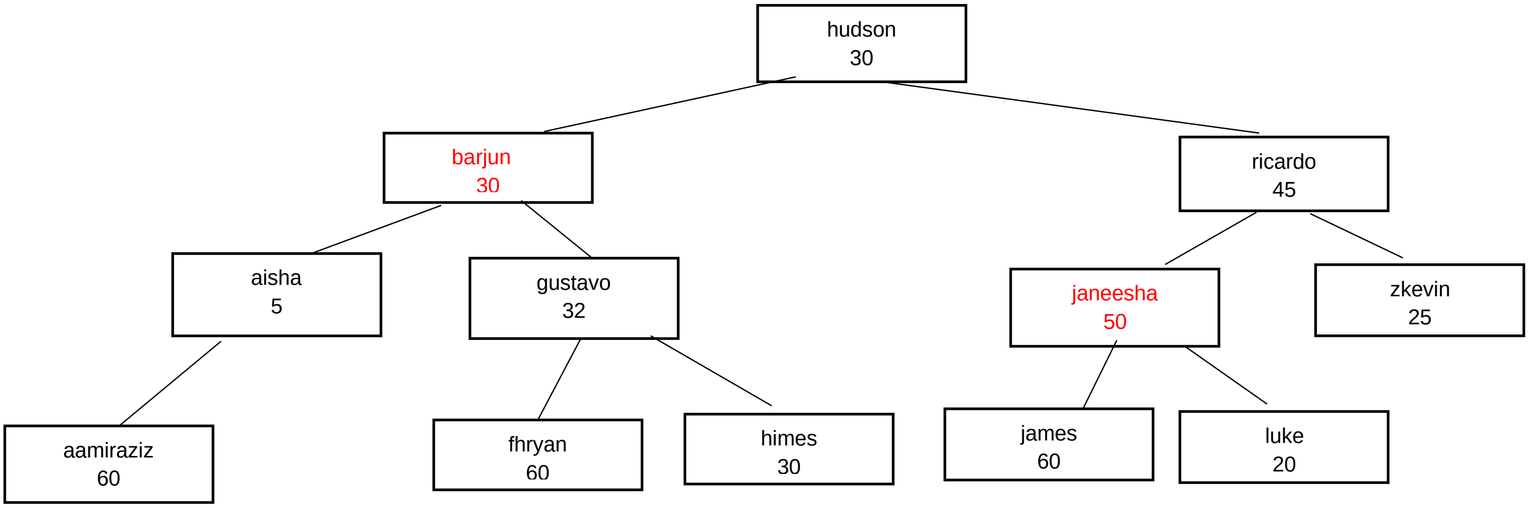
Right before the first deduct command (line 13), here is a picture of the tree (without all information stored in each node). The left height is 2 (as the height of the tree starting from ewillam is 2) and right height is -1 as there is no right subtree of root of the main tree. Also, “calc_below of happy” is calculated by summing up all the fines except hudson and himes as they are not alphabetically smaller or equal to “happy”:



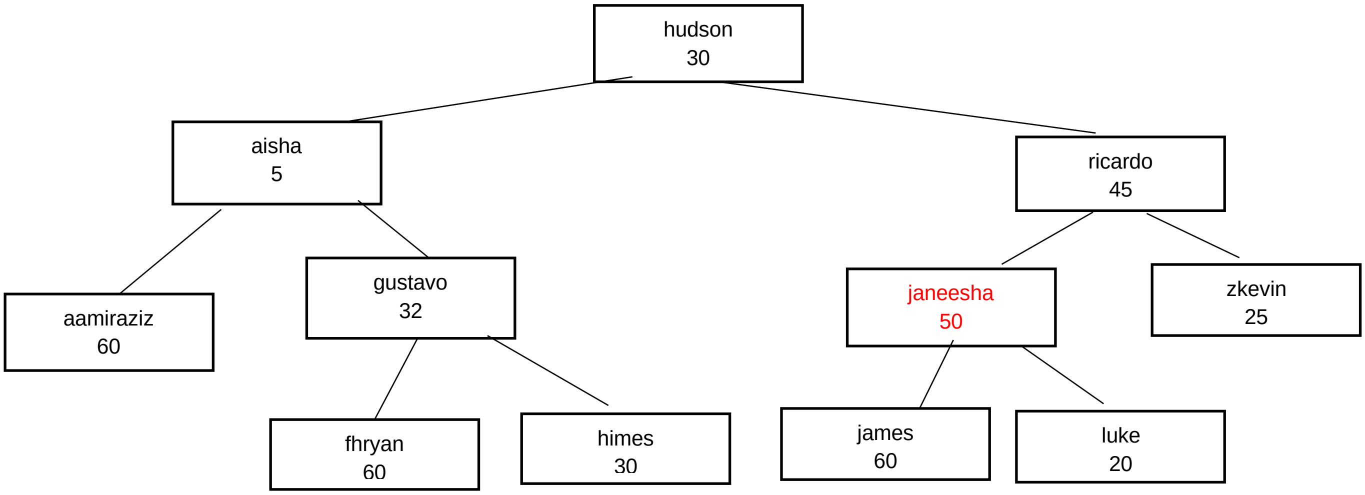
Next, after deducting 23 from aisha, 15 from himes, adding 8 to gustavo, and adding some more vehicle owners until the deduct command of muhammad (line 28), our tree becomes like the following. During this time, we have calculated height_balance multiple times to see the status as we keep updating the tree. Also, “*calc_below ricardo*” gave the sum of all the fines except *zkevin* from the following tree. Also, “*calc_below muhammad*” gave the sum all the fines except *ricardo* and *zkevin* :



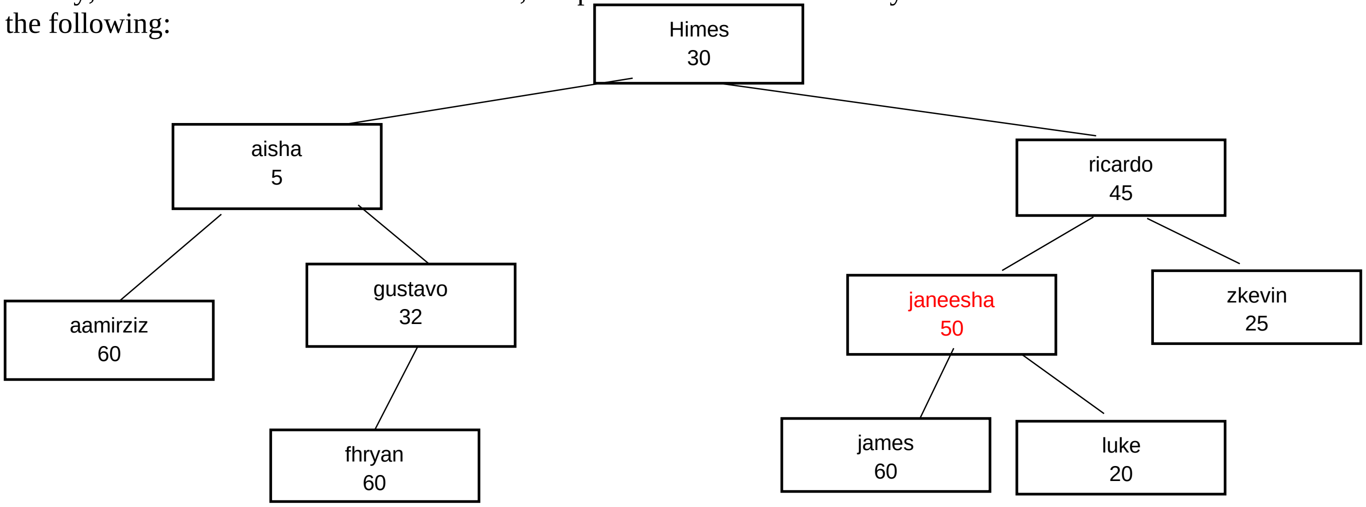
Next, on the deduct command for muhammad (line 28), matthew (line 31), and ewillam (line 34), their values became less than or equal to zero and as a result they were removed from the tree. The updated tree is shown below. If you see, after deleing ewillam, the place is taken by barjun as the he is the max from the left subtree of ewilliam. During this time, we have also performed multiple height balance and search operations to see the status of the updated tree. :



Then, on line 37 of the inputs, the deduct command for barjun results in removing barjun from the tree and as a result aisha took the place of barjun as aisha is the max in the left subtree of barjun.



Finally, after deduct and deletion of hudson, the place of the root is taken by himes and the tree will become like the following:



Implementation Requirements/Run Time Requirements

1. Declare a node structure for binary search tree and store all the required items inside the node. Do not use any malloc to store the name of a vehicle owner. Use static size array for the name with appropriate size based on the max length.

2. The run-time for processing add, deduct, search, and height_balance commands should be O(h), where h is the current height of the tree.

3. You must use the delete function we have discussed in our class/recording and modify the code to fulfill the requirements of this assignment. It is fine to update the list of parameters and few logic inside the function. However, the logic of dealing with 3 cases must be handled in the exact same way discussed in the coding explanation. Not doing this will result in 50% penalty in your assignment.

4. Implement an insert function

5. Implement a search function

6. Implement a Height function

6. You should free all the memory to receive full credit

7. Your code must compile and execute on the Codegrade system.

8. You are not allowed to use any global varaible.

Few Important Hints:

- Carefully go through the sample input and output and understand the problem clearly based on the explanation
- Use **strcmp function** to compare strings and decide which string comes first alphabetically.
- Work for one command at a time and test it. Obviously, start with search and insertion and after inserting each vehicle owner, print them in in-order traversal to check whether they are inserted properly or not
- As you need **search function** during deletion as well as regular search and insertion, a good idea would be returning the node containing the name. Also, you need to calculate depth as you keep searching. A good idea would be using a pointer and pass a reference of a variable initialized with zero and keep updating the value through pointer as you keep traversing the tree while searching.
- For height, you can modify the code you have learned in the lab. But, note that the definition of height is a bit different in the lab than regular height definition.
- For avg, you can easily use the technique of sum of node function we have discussed in the class. Feek free tow write two functions for this purpose
- For calc_below, use similar strategy of sum of node, but selectively sum them!

Some Steps to check your output AUTOMATICALLY in a command line in repl.it or other system:

You can run the following commands to check whether your output is exactly matching with the sample output or not.

Step1: Copy the sample output to sample_out.txt file and move it to the server

Step2: compile your code using typical gcc and other commands.

//if you use math.h library, use the -lm option with the gcc command. Also, note that scanf function returns a value depending on the number of inputs. If you do not use the returned value of the scanf, gcc command may show warning to all of the scanf. In that case you can use “-Wno-unused-result” option with the gcc command to ignore those warning. So the command for compiling your code would be:

```
# gcc main.c leak_detector_c.c -Wno-unused-result -lm
```

Step3: **Execute your code and pass the sample input file as a input and generate the output into another file with the following command**

```
$ ./a.out < sample_in.txt > out.txt
```

Step4: Run the following command to compare your out.txt file with the sample output file

```
$cmp out.txt sample_out.txt
```

The command will not produce any output if the files contain exactly same data. Otherwise, it will tell you the first mismatched byte with the line number.

Step4(Alternative): Run the following command to compare your out.txt file with the sample output file

```
$diff -y out.txt sample_out.txt
```

The command will not produce any output if the files contain exactly same data. Otherwise, it will tell you the all the mismatches with more details compared to cmp command.

```
# diff -c myout1.txt sample_out1.txt  //this command will show ! symbol to the unmatched lines.
```

Tentative rubric (subject to change):

- Penalty section:
    - If code does not compile on codegrade: you may get zero
    - If any result hard-coded: -150%
    - Poorly indented code: -10%
    - Missing header comment: -20%
    - Missing comment onimportant block of code: -10%
    - Not fulfilling delete restriction: -50%
    - Not fulfilling any other implementation restriction: -40%
- Grade section:
    - Coding part: 40%
        - This part includes taking inputs properly, writing various functions properly, processing commands properly, etc.
    - Freeing all memory: 10%
    - Code output testing: 50%
        - There will be various test cases and the output format must match exactly to receive credit.