Engineering

&

Computer Science

SOEN-6011

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https://github.com/Aruna-Pala/SOEN6011

Scientific Calculator - Power Function ab^x

supervised by

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Contents

1 Problem 1

1.1 Description

A power function is of the form:

$$f(x) = ab^x \tag{1}$$

where x is a real number, a and b are constants.

1.2 Domain

The domain is set of all real numbers, (- ∞,∞)

1.3 Co-domain

The co-domain is also set of all real numbers.

1.4 Characteristics of Power Function.

1. For any exponential function, the domain is the set of all real number, however range is bounded by the horizontal symptote of the graph of f(x).
2. The behaviour of power function effects the exponential growth and decay.
3. When b greater than 1, the graph accelerates towards y-axis contributing to exponential growth.
4. When b greater than 1 and less than 0, the graph decreases towards y-axis contributing to exponential decay.
5. When modeling real-world situations with an exponential function, the domain and range can be limited to numbers that make sense in the context. The domain and range can be stated using the inequalities for a continuous interval in these cases.

1.5 Context of use model

Developers:
The developers of the system use it frequently to check if the system is working as expected.

Testers:
The testers of the system test the functions are working correctly.

Assessing Team:
The assessor team will need to assess the project implementation.

Students and Peers:
Students and peers of the course may use the calculator to find the results of the value of ab^x. It can serve as a future reference.

Researchers and Other Academicians:
Researchers and other academicians can be interested in the system to calculate the result of the function ab^x. Identify differences in implementation, the behaviour of the system to compare and contrast.

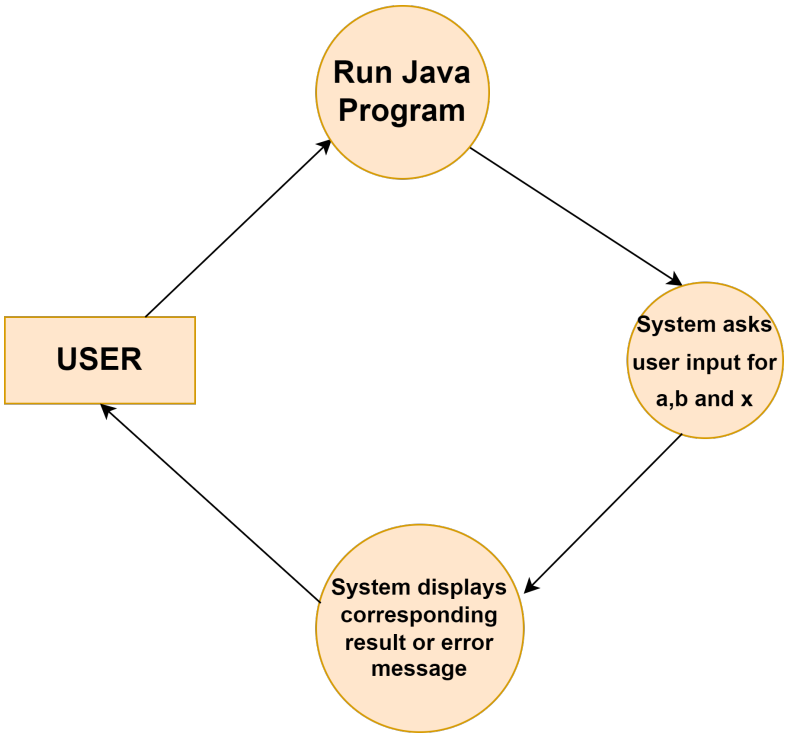


Figure 1: Context of Use model: Power Function ab^x

The key elements of use model are:

Boxes:
External entities that the main entity interacts with (organizations, departments, systems, or processes)

Connectors:
Interactions between entities

Flows:
Interactions are labelled to show the flow of data, physical objects between the entities.

2 Problem 2

2.1 Assumptions

- In function $f(x) = ab^x$, the output will always be in decimals.
- The output of the function will be greater than zero, if a and b constants are not equal to zero.
- The range for the values of x can be from -100000 $\leq$ x $\leq$ +100000.
- x can be negative but not in decimal.
- The value for a and b ranging from -100000 $\leq$ a $\leq$ 100000 and -100000 $\leq$ b $\leq$ 100000.
- a and b are constants, the calculator accepts the magical constants such as e.

2.2 Requirements

2.2.1 Functional requirements throughout development process

1. **Below table shows the Functional requirements at initial stage where it is categorized with priorities and since it is the one delivery project hence assigning version as 1.0.**
2. **Priority 1: Need to rethink scope if we don't have these. Use these to identify where to apply resources when problems/change occurs.**
3. **Priority 2: These are all the other requirements.**
4. **Priority 3: Flexible which can be added later-These priority requirements are negotiable or can be implemented later**

FR#	Difficulty	Priority	Description	Rationale
FR1	Easy	1	System shall take an input x as a real number.	The rationale behind this requirement is to calculate the function only for real numbers.
FR2	Easy	3	System shall output the value within the expected range.	The rationale behind this requirement is to get result in the range of the function.
FR3	Easy	1	System should validate the input.	The rationale behind this requirement is to check domain value for function.

Table 1: Functional Requirements at initial stage of development

In the initial development process have considered only the real numbers as input, User giving input through console and the rationale behind the result.

considered system expecting constants where I have implemented the exceptional algorithm which is clearly mentioned in program and also in problem 3

FR#	Difficulty	Priority	Description	Rationale
FR4	Medium	1	System should accept **e** as constant.	The rationale behind this requirement is the acceptability of the constants.
FR5	Easy	1	System should show relevant error messages or User readable messages if any.	The rationale behind this requirement is to handle error handling.
FR6	Medium	1	System should show relevant result when the exponential value is in decimals.	The rationale behind this requirement is to check whether output is accurate for Decimal real numbers.

Table 2: Functional Requirements at second stage of development

This is final stage where I have checked the Non-Functional requirements (NFR) of the complete function ab^x

FR#	Difficulty	Priority	Description	Rationale
NFR7	Easy	1	System shall show relevant success messages or confirmation results.	The rationale behind this requirement is to show relevant messages and contributes to usability.
NFR8	Medium	2	System shall complete the calculation on expected time.	The rationale behind this requirement is to have good performance of the calculator.

Table 3: Non Functional Requirements at Final stage of development

3 Problem 3

3.1 Algorithms Used and Pseudocode

Following are the algorithms used for function ab^x

1. Recursive approach

2. Iterative approach

3. Divide and Conquer approach

3.2 Algorithm Description

3.2.1 Algorithm 1 - Recursive approach

The details of algorithm 1 is given below:
Complexity = $O(logn), O(n)$
Space Complexity = $O(1)$
Approach = Recursion
Rationale = a and b are the constants, depending on the value of b the complexities is being calculated such that if b = any integer then powerfunction() will be called. So, the time complexity will be $O(logn)$ and space complexity to 1. If b = e then taylor series will execute calling exponential() resulting $O(n)$ time complexity and $O(1)$ space complexity.
Advantages

1. $O(logn)$ is the time complexity of the recursive algorithm. This recursive technique has tail recursive to avoid stack overflow issues and handle large inputs more efficiently.
2. Algorithm 1 has more readability and maintainable code which is easy to handle.

Disadvantages

1. It uses more memory because of the function calling itself and add to stack in each recursion and it stores the value until recursion completes.
2. Sometimes recursion can be slow if the function is not implemented properly. Analyzing recursion code is complex to solve a difficult problem to simpler way to solve.

3.2.2 Algorithm 2: Iterative approach

The details of algorithm 2 is given below:
Complexity = $O(n), \Omega(n)$
Space Complexity = $O(1)$
Approach = Iterative
Rationale = The a and b are the constants, depending on the value of b the complexities is being calculated such that if b = any integer then calling powerfunction(). So, the time complexity will be $O(n)$ and space complexity to 1. If b = e then taylor series will execute calling exponential() resulting $\Omega(n)$ time

Algorithm 1 Recursive Approach - ab^x

```
procedure function5(a, b, x)
    in:  String a, b, x
    out:  double result
    result = 0
    if ((a || b) == "0") then return result
    else
        if (b == "e") then
            result = a * exponential(x)
        else
            result = a * powerfunction(b,x)
        return result;

procedure exponential(n)
    in:  int n
    out:  double result
    sum = 1
    x = 10
    for i <= x − 1
    sum = 1 + n ∗ sum/i
    return sum

procedure powerfunction(x, n)
    in:  double x, int n
    out:  double result
    if ((n < 0) then
        return 1.0/powerHandler(x, Math.abs(n))
    else
        return powerHandler(x, n)

procedure powerHandler(x, n)
    in:  double x, int n
    out:  double result
    if (n == 0) then return 1
    if (n == 1) then return x
    if (nmod2 == 0) then
        return powerHandler(x ∗ x, n/2)
    else
        return x ∗ powerHandler(x ∗ x, n/2)
```

Algorithm 2 Iterative Approach - ab^x

```
procedure function5(a, b, x)
    in: String a, b, x
    out: double result
    result = 0
    if ((a || b) == "0") then return result
    else
        if (b == "e") then
            sum = 1
            m = 1 and i = 1
            for i <= x − 1
            sum = 1 + m ∗ sum/i
            end
            return a*sum
        else
            if (x == 0) then return 1
            if (x == 1) then return a*x
            else
                i = 1andpow = 1
                for i <= n
                pow = pow ∗ x
                end
                return a*sum
```

complexity and $O(1)$ space complexity.

Advantages

1. Because all operations are performed on the heap, iterative algorithms which avoid stack overflow.
2. Space complexity is $O(1)$.

Disadvantages

1. The complexity is $O(n)$.
2. The algorithm is not efficient.
3. The algorithm has poor readability and maintainability.

3.2.3 Algorithm 3 : Divide and Conquer

The details of algorithm 3 is given below:
Complexity = $O(n), \Omega(n)$
Space Complexity = $O(1)$
Approach = Divide and Conquer
Rationale = a and b are the constants, depending on the value of b the complexities is being calculated such that if b = any integer then powerfunction() will

Algorithm 3 Divide and Conquer Approach - ab^x

```
procedure Function5(a, b, x)
    in:  String a, b, x
    out:  double result
    result = 0
    if ((a || b) == "0") then return result
    else
        if (b == "e") then
            sum = 1
            m = 1 and i = 1
            for i <= x − 1
            sum = 1 + m ∗ sum/i
            end
            return a*sum
        else
            if (x == 0) then return 1
            if (x == 1) then return a*x
            else
                return a*powerHandler(b,x)

procedure powerHandler(b, x)
    in:  double b, int x
    out:  double result
    if (x == 1) then
        return 1
    else if (x mod 2 == 0) then
        return powerHandler(b, x/2) ∗ powerHandler(b, x/2)
    else
        return b ∗ powerHandler(b, x/2) ∗ powerHandler(b, x/2)
```

be called. So, the time complexity will be $O(n)$ and space complexity to 1. If b = e then taylor series will execute calling exponential() resulting $\Omega(n)$ time complexity and $O(1)$ space complexity.

Advantages

1. The problem has been solved in divide and conquer approach may result in robustness.
2. Space complexity is $O(1)$.

Disadvantages

1. The complexity is $O(n)$.
2. The constant allocation of memory space, which leads to a stack overflow, has a substantial impact on efficiency.

3.2.4 Mindmap for decising Pseudocode

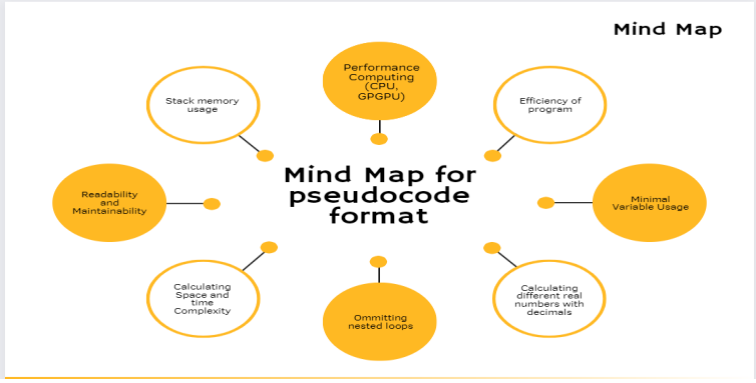


Figure 2: Snapshot that shows which constraints are used to decide pseudocode

```
def expo {
   def exponent(double p)
      exp_temp, exp_pow, exp_frac, exp_intg, exp_logn;
      exp_temp = p;
      exp_frac = exp_temp;
      exp_pow = (1.0 + exp_temp);
      exp_intg = 1.0;

      do
         exp_intg++;
         exp_frac *= (exp_temp / exp_intg);
         exp_logn = exp_pow;
         exp_pow += exp_frac;
      while (exp_logn != exp_pow);

      return exp_pow;
   def getLog(double b) {

      exp_res, exp_base, exp_left, exp_right, exp_temp, exp_value;
      exp_value = 2.71828182845905;
```

```
    exp_base = b;
    exp_res = 0.0;
    // This speeds up the convergence by calculating the integral
    while (exp_base >= exp_value)
       exp_base /= exp_value;
       exp_res++;

    exp_res += (exp_base / exp_value);
    exp_base = b;
    counter = 0;
    do
       counter++;
       exp_temp = exp_res;
       exp_left = (exp_base / (exponent(exp_res - 1.0)));
       exp_right = ((exp_res - 1.0) * exp_value);
       exp_res = ((exp_left + exp_right) / exp_value);
       if (counter == 5)
          break;
    while (exp_res != exp_temp);

    return exp_res;


def powerHandler(double b, double x)
    res = 1;

    if (b % 1 == 0 && x % 1 == 0)

       x_int = (int) Math.floor(Math.abs(x));
       for (int i = 0; i < x_int; i++)
          res = res * b;

       if (x < 0)
          return 1 / res;
       else
          return res;
     else
       logRes = getLog(b);
       exp = x * logRes;
       res = exponent(exp) * 1;
       return res;
```

Listing 1: Pseudocode for Exponential function

3.3 Conclusion

By computing power(b, x/2) only once and storing it, the algorithm 2, algorithm 3 can be optimized to $O(logn)$. The approach used in algorithm1 stores power at once. Also algorithm1 avoids stack overflow while calculating the input which is one of the advantage for choosing algorithm 1 over other two.

4 Problem 4

4.1 Standard Guidelines

The source code review is based on the standard practices that a developer has used while writing the code. The coverage of all standard guidelines on which the report has generated is listed below.

1. The code should eliminate nested if statement.
2. The code should follow a coding style guide.
3. The code should have meaningful method and variable names.
4. The author should annotate the comments not exceeding 10 to 20 lines.
5. The class program should not import unnecessary packages.
6. The code should have low coupling and high cohesion.
7. The code should avoid the global scoping for common variables and functions.
8. The code should avoid memory leakage.
9. The code should narrow the variable scope as far as possible in the code.
10. Usage of mutable variable over creating new variables in object oriented language.

4.2 Programming style

Standard programming style used		
S.No.	Description	Result
1	No Error found in the code	Pass
2	No deadlock encountered	Pass
3	Use of annotation in the code	Pass
4	No usage of nested ifs statement	Pass
5	No Warning found in the code	Pass
6	No unnecessary package is included in the code	Pass
7	Usage of meaningful method and variable names	Pass
8	Not exceeding source line of code	Pass
9	No unused variable found	Pass
10	No memory leakage	Pass

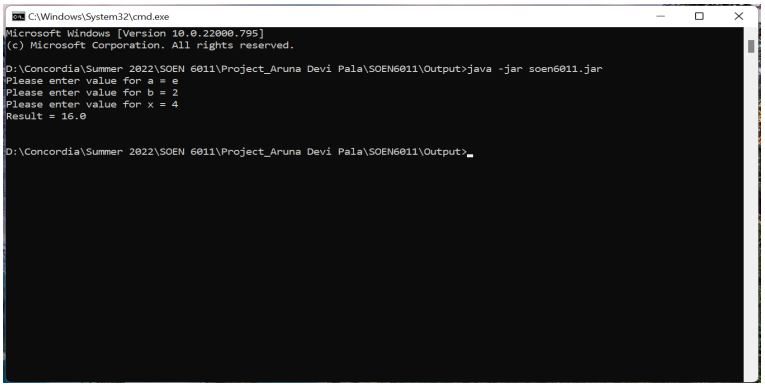
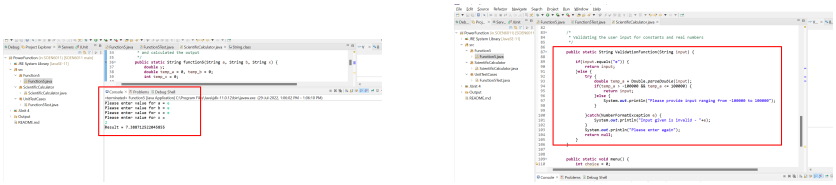


Figure 3: Snapshot of Running Program using Command Prompt

Program submitted doesn't depend on any particular tool or IDE to compile. You can run and compile the program using **.jar** file using *java -jar soen6011.jar* as shown below:

1. **Textual Interface** is being used in the program by which user gets to know if input given is valid/Invalid
2.After system gets input from the user it calculates the output and display to the user for the function given which is ab^x
3. Below figure shows the exact Interface how it looks like while running program
4. Error handling: Below figure shows in which stage error handling is done. Here have done validation of error messages and throwing the error messages which are human readable.
5. Used exception handling for whole function.Figure shows the error handling



(a) Textual Inteface (b) Error Handling

Figure 4: Snapshot of Interface Error-handling

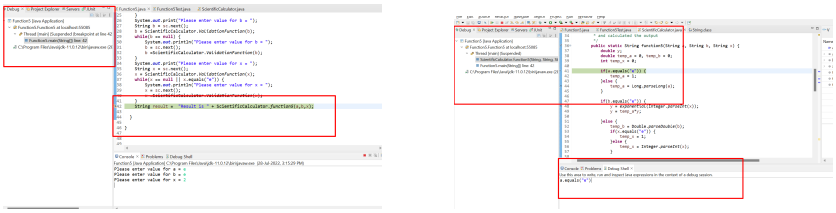
4.3 Eclipse Debugger

Debugging is the process of finding defects and fixing faults, flaws, and anomalies in software. It's an important tool for any Java developer because it aims in the detection of minor bugs that aren't obvious during code reviews or only occur when a specific condition is met.

Debugger Used : Inbuilt debugger offered by Eclipse Java Development Tools (JDT).

Following are the advantages and disadvantages of using debugger in the program.

Readable Error messages:
Whenever user enters a values that are out of range then he/she is provided with



(a) Debugger on Function5

(b) Debugger on ScientificCalculator

Figure 6: Eclipse Built-in Debugger

message which is useful and let user reenter again with valid input.Below Screenshot shows the exact view of messages:

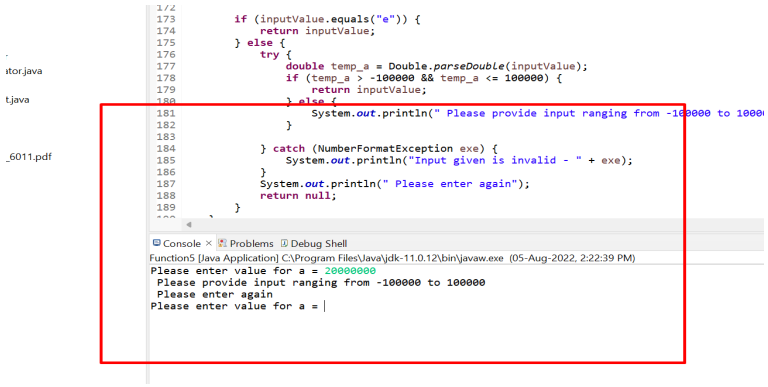


Figure 5: Snapshot of Error messages

Advantages

- Debugger promptly reports an erroneous state. This allows for earlier fault detection and makes the software development process stress-free and trouble-free.
- Using inbuilt debugger developer can step into code/out of/over code based on whether or not you think it matters.
- Debugging aids the developer in eliminating redundant and unwanted data.
- Debugging allows developers to avoid writing complex one-time testing code, which reduces resources and time during software development.

Disadvantages

- When the execution is halted inside an invariant, the debugger isn't particularly useful.
- If you use any of the previously unsupported expressions in a breakpoint condition, the condition will always return True since the evaluation is failing. In this instance, the debugger will come to a halt.

4.4 Achieved Quality Attributes

4.4.1 Robustness

- Usage of exception for exceptional test cases.
- Narrowed the variable scope as far as possible in the code.
- Error handling done on the code.
- Usage of mutable variable over creating new variables.

4.4.2 Maintainability

- Common practices has been adapted within the implemented function5 to avoid ambiguities.
- Useful comments added in the code where it is required.
- Avoided global scoping for common variables and functions.
- Refactored code wherever possible and merged to the github branch.

4.4.3 Usable

- Simple console interface provided for user input.
- Error messages are given in wrong input.
- Success messages are given for results.
- Suggestions are given when user encountered any difficulties while using to calculate ab^x.

4.4.4 Correctness

- Coding standards is followed.
- Proper testing practices has been done on the function assigned.
- JUnit Testing has implemented to check the correctness of eacj function the program by adding negative and positive testcases.

4.4.5 Efficiency

- The main focus on readability is given to the code.
- The program takes not less than two or three nanoseconds.

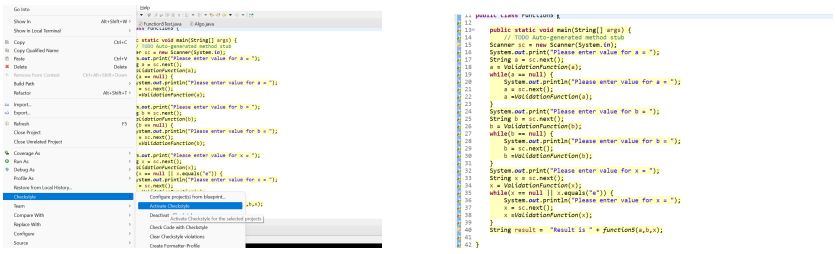
4.4.6 Portability

- The main focus is used to run the program on different platforms.Java Program is Platform independent hence have achieved portable.
- Program submitted is unlike most other programming languages, where a different version of a program must be made for each variety of computer,

and an executable program that runs on one type of computer will not run on another.

4.5 Quality Check of Source Code

It's a programming tool that helps programmers write Java code that follows a set of rules. It automates the process of inspecting Java code, saving humans the time and effort of doing so. It's ideal for projects that want to enforce a coding standard.



(a) Activating checkstyle (b) checkstyle on code

Figure 7: Snapshot of Checkstyle

Advantages

- The checkstyle is portable between different IDEs.
- Easily integrate as a pre-commit hook or into your build tool into your Software Configuration Management.
- Checkstyle is a stand-alone framework, integrating it with your other tools is considerably easier.
- ability of creating user own rules. Eclipse defines a large set of styles, but checkstyle has more, and you can add your own custom rules.

Disadvantages

- Checkstyle is a static analysis tool for a single file.
- Checkstyle cannot properly handle a file's binary Byte Order Mark (BOM), like UTF8's Unicode.

4.6 Review Approach

Used Approach - Lightweight Code Review

- Walk-through the code.
- Executed the code in run time environment and also used debugger.
- Inspection on comment length, Checking dependencies among the components, Check on unused variables.
- Observing global scoping of the functions and variables.

4.7 Conclusion

Overall, the code is well-structured and well-written. It is clear from the code that readability is a developer's primary focus. The only suggestion I have is to retain logs because they can help with debugging.

5 Problem 5

5.1 Implemented Unit Test

- Unit Testing Framework Used: JUnit
- The sample practice used in the test cases are as follows:

  ID = TC1
  Test Case = description about the test case.
  Function Used = name of the function used in the test case.
  Functional Requirement ID Used = FRn

5.2 Results

No.	Description	Result	FR #
1	Validating the input given by user	PASS	FR1
2	System should accept a and b as constant e	PASS	FR4
3	System should output the value for input provided	PASS	FR2
4	System should validate the negative/Positive	PASS	FR3
5	System should show relavant error messages which are readable	PASS	FR5
6	System should show the relavant output	PASS	NFR7
7	Test on checking input within range	PASS	FR5
8	Test cases follows assumptions	Not Applicable	NA
9	System validating real number as Decimal numbers	PASS	FR6

Testcases Tracebility:
Above table with their respective Function requirements ID is given which shows each and every test case is traceable back to the Function requirements are problem 2.

5.3 Standard Guidelines

The following are the guidelines implemented in the unit testing for function 5 :

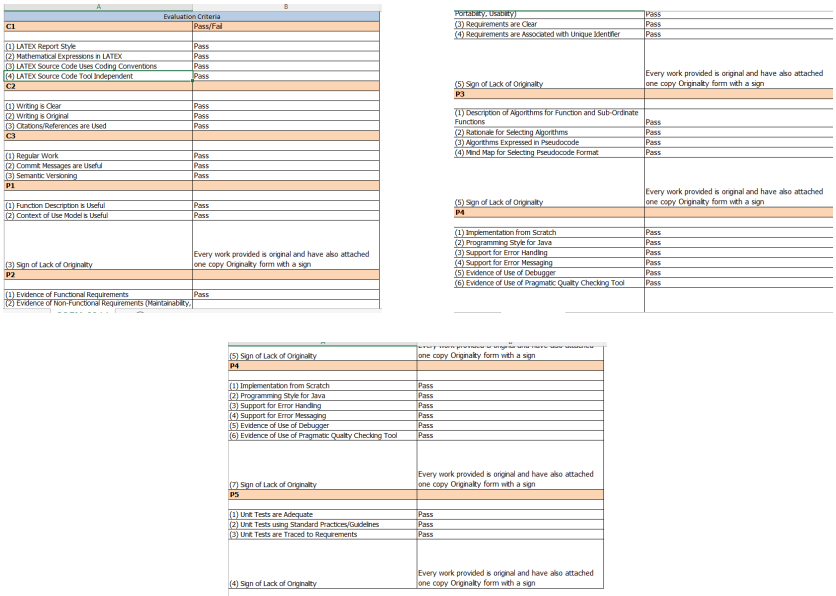
$$f(x) = ab^x \tag{2}$$

- Each test case should given a test case id.
- Each test should contains the unit test of each function involved in the implementation of function 5.

- Each test case is followed by one line statement justifying it's description.
- Each test case contains the function name used in the unit test case.
- Test case shall cover all the cases expected.
- Test Case should mention a expected value and actual value.
- Atleast one test case should be consider into a delta precision values.
- Each test case should show message or log for the sake of readability.
- Each test case should be traceable.
- Test case should map to the functional requirement.

5.4 Conclusion

Almost all the methods of function5 have been tested and confirmed to be effective and corrective. During the testing process, no major mistakes were discovered. All of the requirements given in Problem 2 has been covered in the mentioned test cases. Furthermore, all the test cases are to the point and covered all possibilities.



Evaluation Criteria	
C1	Pass/Fail
(1) LATEX Report Style	Pass
(2) Mathematical Expressions in LATEX	Pass
(3) LATEX Source Code Uses Coding Conventions	Pass
(4) LATEX Source Code Tool Independent	Pass
C2	
(1) Writing is Clear	Pass
(2) Writing is Original	Pass
(3) Citations/References are Used	Pass
C3	
(1) Regular Work	Pass
(2) Commit Messages are Useful	Pass
(3) Semantic Versioning	Pass
P1	
(1) Function Description is Useful	Pass
(2) Context of Use Model is Useful	Pass
(3) Sign of Lack of Originality	Every work provided is original and have also attached one copy Originality form with a sign
P2	
(1) Evidence of Functional Requirements	Pass
(2) Evidence of Non-Functional Requirements (Maintainability,	

Portability, Usability)	Pass
(3) Requirements are Clear	Pass
(4) Requirements are Associated with Unique Identifier	Pass
(5) Sign of Lack of Originality	Every work provided is original and have also attached one copy Originality form with a sign
P3	
(1) Description of Algorithms for Function and Sub-Ordinate Functions	Pass
(2) Rationale for Selecting Algorithms	Pass
(3) Algorithms Expressed in Pseudocode	Pass
(4) Mind Map for Selecting Pseudocode Format	Pass
(5) Sign of Lack of Originality	Every work provided is original and have also attached one copy Originality form with a sign
P4	
(1) Implementation from Scratch	Pass
(2) Programming Style for Java	Pass
(3) Support for Error Handling	Pass
(4) Support for Error Messaging	Pass
(5) Evidence of Use of Debugger	Pass
(6) Evidence of Use of Pragmatic Quality Checking Tool	Pass

(5) Sign of Lack of Originality	one copy Originality form with a sign
P4	
(1) Implementation from Scratch	Pass
(2) Programming Style for Java	Pass
(3) Support for Error Handling	Pass
(4) Support for Error Messaging	Pass
(5) Evidence of Use of Debugger	Pass
(6) Evidence of Use of Pragmatic Quality Checking Tool	Pass
(7) Sign of Lack of Originality	Every work provided is original and have also attached one copy Originality form with a sign
P5	
(1) Unit Tests are Adequate	Pass
(2) Unit Tests using Standard Practices/Guidelines	Pass
(3) Unit Tests are Traced to Requirements	Pass
(4) Sign of Lack of Originality	Every work provided is original and have also attached one copy Originality form with a sign

Figure 8: Evaluation Criteria

References

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https://en.wikipedia.org/wiki/Exponential_function
[2] Geeksforgeeks: Power Function,
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[4] Understanding context: Context use model,
https://users.encs.concordia.ca/ kamthan/courses/soen-6011/understand
[5]$Recursivealgorithm$: $SpaceandTimeComplexities$,
https://www.enjoyalgorithms.com/blog/time-complexity-analysis-of-recu