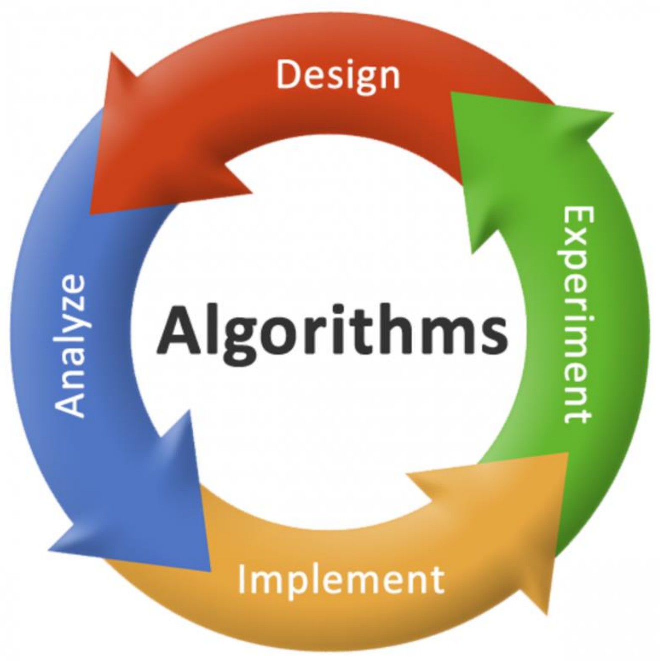
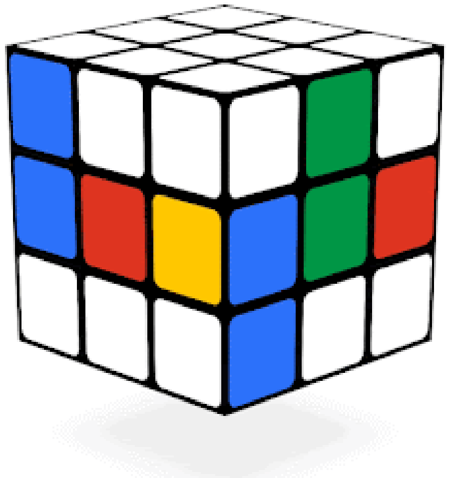
DSE 2256 DESIGN & ANALYSIS OF ALGORITHMS

Lecture 0 & 1 :

Introduction





Instructors:

Dr. Savitha G,
Assistant Professor, DSCA, MIT, Manipal

Dr. Abhilash K. Pai,
Assistant Professor, DSCA, MIT, Manipal

Overview

- Syllabus review
- Evaluation policy
- What is an algorithm?
- Why study algorithms?
- Algorithm requirements
- An example problem and the possible algorithms
- Algorithm design and analysis process
- Important problem types

DSE 2256 DAA [3 + 1 = 4 credits] : Detailed Syllabus

Introduction to DAA : What is Algorithm, Fundamentals of Algorithms, Important Problem Types.

Fundamentals of Analysis of Algorithms: Analysis Framework: Asymptotic Notations and Basic Efficiency Classes, Mathematical Analysis of Non recursive and Recursive Algorithms.

Brute force Techniques: Selection sort, Bubble sort, Sequential Search, Brute Force String Matching, Exhaustive Search.

Divide and Conquer Techniques: Merge Sort, Quick Sort, Binary Search, Binary Tree Traversals, Multiplication of large integers , Strassen's Matrix Multiplication.

Decrease and Conquer Techniques: Insertion Sort, Depth First Search, Breadth First Search, Topological Sorting.

Transform and Conquer Techniques: Presorting, Balanced Search Trees, Heapsort, Problem reduction.

DSE 2256 DAA [3 + 1 = 4 credits] : Detailed Syllabus (contd.)

Space and Time trade-offs: Sorting by counting, Input Enhancement in String Matching (Horspool algorithm, Boyer-Moore algorithm), Hashing.

Dynamic Programming: Computing a Binomial Coefficient, Warshall's and Floyd's Algorithms, The Knapsack Problem and Memory functions.

Greedy Techniques: Prim's, Kruskal's and Dijkstra's Algorithm, Huffman Trees.

Limitations of algorithmic power: P, NP, and NP-complete Problems.

Coping with the limitations of algorithmic power: Backtracking, n–Queens problem, Hamiltonian Circuit Problem, Subset–Sum Problem.

Branch and Bound: Assignment Problem, Knapsack Problem, Travelling Salesman Problem.

DSE 2256 DAA : References

1. **Anany Levitin**, *Introduction to the Design and Analysis of Algorithms*, (3e), Pearson Education, 2011.
2. **Ellis Horowitz and Sartaj Sahni**, *Computer Algorithms/C++*, (2e), University Press, 2007.
3. **Thomas H. Cormen, Charles E. Leiserson, Ronal L, Rivest, Clifford Stein**, *Introduction to Algorithms*, (2e), PHI, 2006.
4. **MIT OpenCourseWare:** https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-006-introduction-to-algorithms-spring-2020/lecture-videos/
5. **NPTEL Video Lectures:** https://nptel.ac.in/courses/106/106/106106131/

DSE 2256 DAA : Evaluation Policy (Tentative)

Assignment#1: 5 marks

Assignment#2: 5 marks

Assignment#3: 5 marks

Assignment#4: 5 marks

4 * 5 = 20 marks

Sessional Test#1: 15 marks

Sessional Test#2: 15 marks

2 * 15 = 30 marks

Internal Max. Marks = 50

End Semester Examination: 50 marks

DSE 2256 DAA : Prerequisites

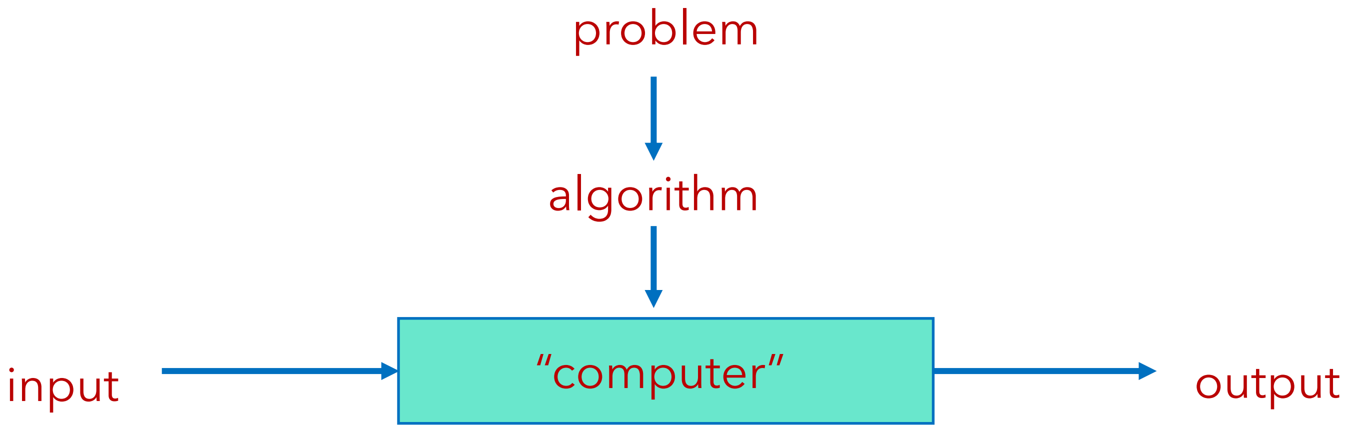
- Knowledge about fundamental data structures
- Recurrence relations
- Necessary summation formulas
- Calculus to some extent
- Basic programming knowledge

What is an Algorithm?

- An **algorithm** is a sequence of **unambiguous instructions**:
  - ❖ For solving a problem.

OR

  - ❖ For obtaining a **required output** for any **legitimate input** in a **finite amount of time.**



Why study algorithms?

- **Practical importance**
  - A practitioner's toolkit of known algorithms
  - Framework for designing and analyzing algorithms for new problems

- **Theoretical importance**
  - The core of computer science

The study of algorithms is called **algorithmics**.

Algorithm requirements

- **Finiteness**
  - Terminates after a finite number of steps
- **Definiteness**
  - Each step must be clear and unambiguous
- **Clearly specified input**
  - Valid inputs are clearly specified
- **Clearly specified/expected output**
  - Can be proved to produce the correct output given a valid input
- **Effectiveness**
  - Steps are sufficiently simple and basic

Remember!!

- The same algorithm can be represented in different ways.
- Several algorithms for solving the same problem may exist.

Example : GCD of two numbers

Problem: Find **gcd(m,n),** the greatest common divisor of two nonnegative, not both zero integers m and n

Examples:

1. If m = 60 and n = 24,

   gcd(60,24) = 12

2. If m = 60 and n = 0,

   gcd(60,0) = 60

3. If m = 0 and n =0,

   gcd(0,0) = ?

Question:

1. What if m and n are prime numbers ?

2. What if m and n are co-prime or relatively prime numbers?

Euclid's Algorithm :

The logic: Euclid's algorithm is based on repeated application of following equality until the second number becomes 0 :

gcd(m,n) = gcd(n, m mod n)

Example:

gcd(60,24) = ?

gcd(60,24) = gcd(24, 60 mod 24)
= gcd(24,12)
= gcd(12, 24 mod 12)
= gcd(12,0)
= **12**

Two descriptions of Euclid's algorithm

#1

Euclid's algorithm for computing gcd(m,n)

Step 1 : If n = 0, return m and stop; otherwise go to Step 2.

Step 2 : Divide m by n and assign the value of the remainder to r.

Step 3 : Assign the value of n to m and the value of r to n. Go to Step 1.

#2

Algorithm Euclid(m,n)

```
//Computes gcd(m,n) by Euclid's algorithm
// Input: two nonnegative, not both zero integers m and n
//Output: Greatest common divisor of m and n
while n ≠ 0 do
        r ← m mod n
  m← n
  n ← r
return m
```

Pseudocode

Other algorithms to compute GCD - I

Consecutive integer checking algorithm for computing gcd(*m*, *n*)

Step 1 : Assign the value of **min{*m*, *n*} to *t*.**

Step 2 : **Divide *m* by *t***. If the remainder of this division is 0, go to Step 3; otherwise, go to Step 4.

Step 3 : **Divide *n* by *t***. If the remainder of this division is 0, return the value of *t* as the answer and stop; otherwise, proceed to Step 4.

Step 4 : **Decrease the value of *t* by 1**. Go to Step 2.

Is this slower than Euclid's algorithm?

Other algorithms to compute GCD - II

Middle-school procedure for computing gcd(m, n)

Step 1 : Find the prime factors of m.

Step 2 : Find the prime factors of n.

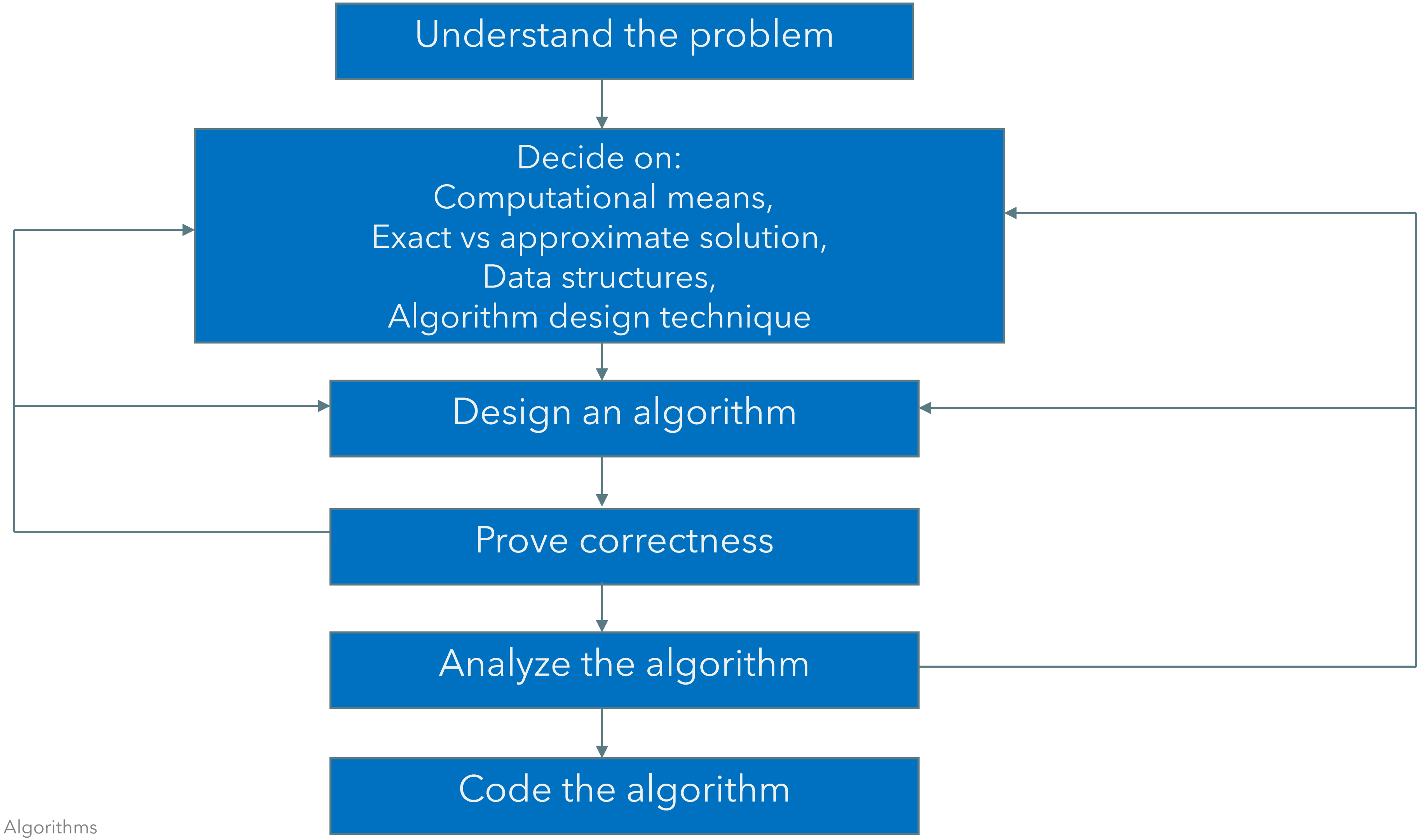
Step 3 : Identify all the common factors in the two prime expansions found in Step 1 and Step 2 (If p is a common factor occurring p_m and p_n times in m and n, respectively, it should be repeated $\min\{p_m, p_n\}$ times).

Step 4 : Compute the product of all the common factors and return it as the GCD of the numbers given.

Basic Issues Related to Algorithms

- How to design algorithms
- How to express algorithms
- Proving correctness
- Efficiency (or complexity) analysis
    - Theoretical analysis
    - Empirical analysis
- Optimality

Algorithm design and analysis process



Analysis of Algorithms

- How good is the algorithm?
    - Correctness
    - Time efficiency
    - Space efficiency

- Other Characteristics
    - Simplicity
    - Generality

- Does there exist a better algorithm?
    - Lower bounds
    - Optimality

Important problem types

- Sorting
- Searching
- String processing
- Graph problems
- Combinatorial problems
- Geometric problems
- Numerical problems

Important problem types I

- **Sorting**
- Searching
- String processing
- Graph problems
- Combinatorial problems
- Geometric problems
- Numerical problems

8 5 3 1 4 7 9

Important problem types II

- Sorting
- **Searching**
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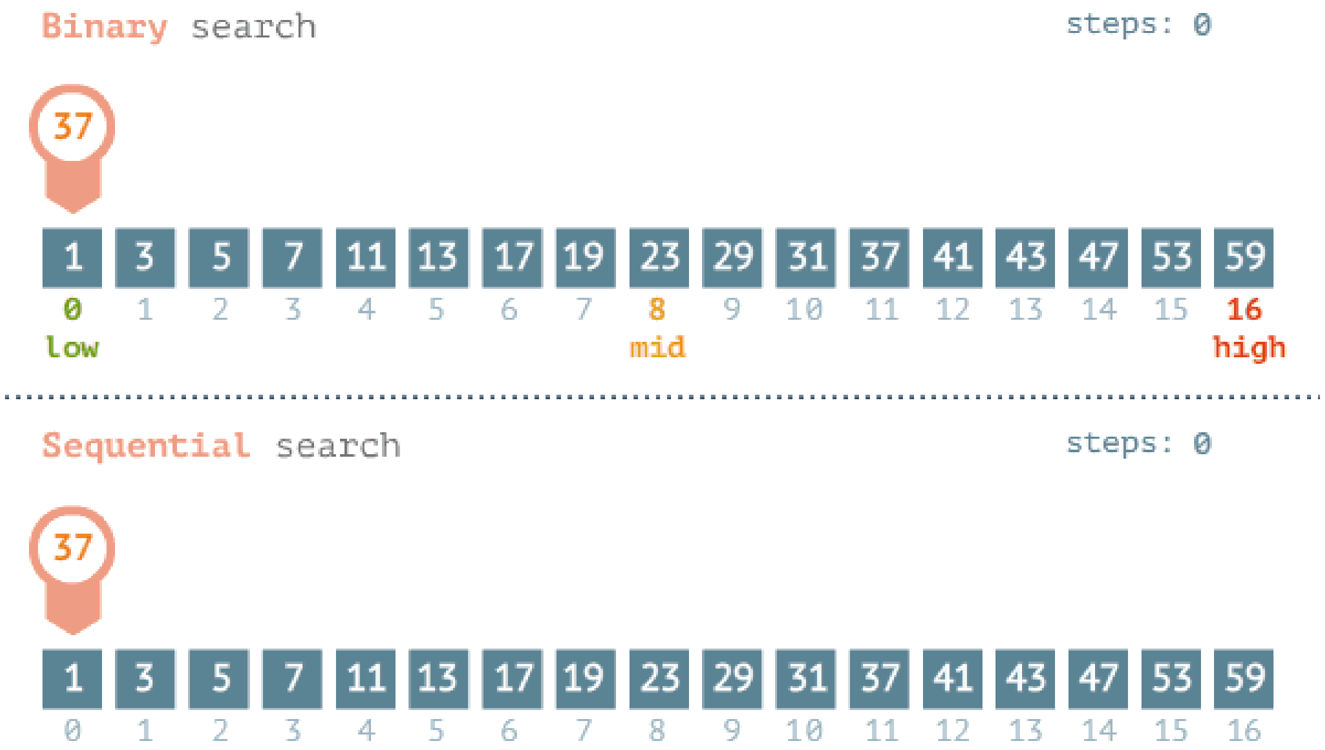
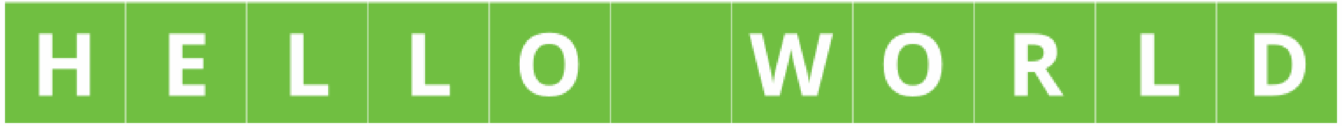
- Numerical problems



Courtesy: www.penjee.com

Important problem types III

- Sorting
- Searching
- **String processing**
- Graph problems
- Combinatorial problems
- Geometric problems
- Numerical problems



Courtesy: www.raywenderlich.com

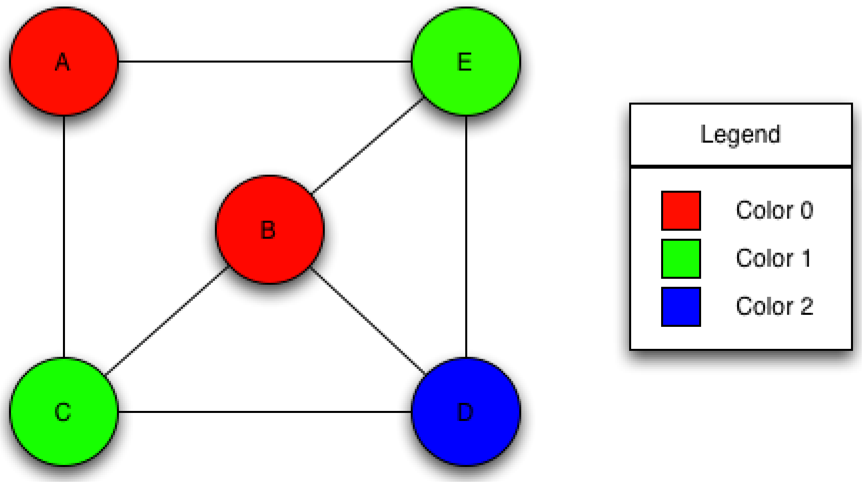
Important problem types IV

- Sorting
- Searching
- String processing
- **Graph problems**
- Combinatorial problems
- Geometric problems
- Numerical problems

Courtesy: www.manipal.pure.elsevier.com

Important problem types V

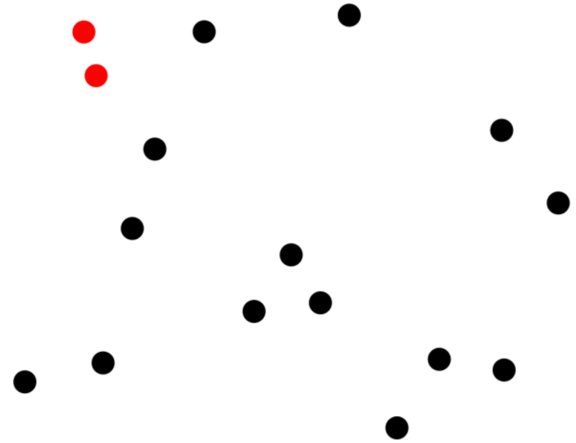
- Sorting
- Searching
- String processing
- Graph problems
- **Combinatorial problems**
- Geometric problems
- Numerical problems



Courtesy: www.boost.org

Important problem types VI

- Sorting
- Searching
- String processing
- Graph problems
- Combinatorial problems
- **Geometric problems**
- Numerical problems



Important problem types VII

- Sorting
- Searching
- String processing
- Graph problems
- Combinatorial problems
- Geometric problems
- **Numerical problems**

$$e^x \approx 1 + x + \frac{x^2}{2!} + \cdots + \frac{x^n}{n!}.$$

Summary

- An algorithm is sequence of **unambiguous instructions** for obtaining a required output from any **legitimate input** in a **finite amount of time**.

- An algorithm can be written using **English like language** or using **pseudocodes** or **a mix of both**.

- The **same algorithm** can be represented in **different ways** and **several algorithms** for the **same problem** may exist.

- The **best algorithm** for a given problem **must generate legitimate outputs** for **all specified range of inputs**, must **utilize less memory space** and **is faster than all other algorithms** for the same problem.

Thank you!

Any queries?