

LeetCode Practice

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Chapter 1

Math and Probability

1.1 Nim Game (E)

You are playing the following Nim Game with your friend: There is a heap of stones on the table, each time one of you take turns to remove 1 to 3 stones. The one who removes the last stone will be the winner. You will take the first turn to remove the stones.

Both of you are very clever and have optimal strategies for the game. Write a function to determine whether you can win the game given the number of stones in the heap.

For example, if there are 4 stones in the heap, then you will never win the game: no matter 1, 2, or 3 stones you remove, the last stone will always be removed by your friend.

```
class Solution {
public:
    bool canWinNim(int n) {
        if (n % 4 == 0)
            return false;
        else
            return true;
    }
};
```

1.2 Bulb Switcher (M)

There are n bulbs that are initially off. You first turn on all the bulbs. Then, you turn off every second bulb. On the third round, you toggle every third bulb (turning on if it's off or turning off if it's on). For the i th round, you toggle every i bulb. For the n th round, you only toggle the last bulb. Find how many bulbs are on after n rounds.

Example: Given $n = 3$.

At first, the three bulbs are [off, off, off].
After first round, the three bulbs are [on, on, on].
After second round, the three bulbs are [on, off, on].
After third round, the three bulbs are [on, off, off].
So you should return 1, because there is only one bulb is on.

```
class Solution {
public:
    int bulbSwitch(int n) {
        int res = 1;
        while (res * res <= n) ++res;
        return res - 1;
        // Or just simply use one line command: return sqrt(n);
    }
};
```

1.3 Find the Celebrity (M)

Suppose you are at a party with n people (labeled from 0 to $n - 1$) and among them, there may exist one celebrity. The definition of a celebrity is that all the other $n - 1$ people know him/her but he/she does not know any of them.

Now you want to find out who the celebrity is or verify that there is not one. The only thing you are allowed to do is to ask questions like: "Hi, A. Do you know B?" to get information of whether A knows B. You need to find out the celebrity (or verify there is not one) by asking as few questions as possible (in the asymptotic sense).

You are given a helper function `bool knows(a, b)` which tells you whether A knows B. Implement a function `int findCelebrity(n)`, your function should minimize the number of calls to `knows`.

Note: There will be exactly one celebrity if he/she is in the party. Return the celebrity's label if there is a celebrity in the party. If there is no celebrity, return -1.

```
# Space O(N)
def findCelebrity(n):
    candidate = [True for i in range(n)]
    for i in range(i):
        for j in range(j):
            if candidate[i] and i != j:
                if knows(i, j) or !know(j, i):
                    candidate[i] = False
                    break
```

```

        else:
            candidate[j] = False
            if candidate[i]: return i
    return -1

# Space O(1)
def findCelebrity(n):
    candidate = 0

    # find the possible candidate
    # note that the selected candidate i does not know anyone after the index i
    for i in range(n):
        if knows(candidate, i): candidate = i

    # if the selected candidate knows anyone or anyone does not know the candidate,
    # then the selected candidate is not celebrity
    for i in range(n):
        if candidate != i and (knows(candidate, i) or !know(i, candidate)):
            return -1

    # the above for loop can be optimized by checking two parts separately:
    # 1. before the selected candidate, check the same conditions as the above for
    #    loop
    # 2. only check if i knows the selected candidate, because it has been
    #    verified before that
    #    the selected candidate must know i
    for i in range(candidate):
        if knows(candidate, i) or !knows(i, candidate): return -1
    for i in range(i + 1, n):
        if !knows(i, candidate): return -1

    # otherwise the selected candidate is the celebrity
    return candidate

```

```

class Solution {
public:
    int findCelebrity(int n) {
        int res = 0;
        for (int i = 0; i < n; ++i) {
            // if res knows i, then res must not be celebrity and i could be
            // celebrity
            // update res to i and check the next i
            if (knows(res, i)) res = i;
        }
        for (int i = 0; i < n; ++i) {
            // if res knows i, or i doesn't know res,
            // then res must not be celebrity

```

```

        if (res != i && (knows(res, i) || !knows(i, res))) return -1;
    }
    return res;
}

};

class Solution {
public:
    int findCelebrity(int n) {
        for (int i = 0, j = 0; i < n; ++i) {
            for (j = 0; j < n; ++j) {
                // if i knows j or j doesn't know i,
                // then i is not celebrity
                if (i != j && (knows(i, j) || !knows(j, i))) break;
            }
            // if i does not know any j , but all j know i
            // then i is celebrity
            if (j == n) return i;
        }
        return -1;
    }
};

```

1.4 Water and Jug Problem (M)

You are given two jugs with capacities x and y liters. There is an infinite amount of water supply available. You need to determine whether it is possible to measure exactly z liters using these two jugs. If z liters of water is measurable, you must have z liters of water contained within one or both buckets by the end.

Operations allowed:

Fill any of the jugs completely with water.

Empty any of the jugs.

Pour water from one jug into another till the other jug is completely full or the first jug itself is empty.

Example 1: (From the famous "Die Hard" example)

Input: $x = 3$, $y = 5$, $z = 4$

Output: True

Example 2:

Input: $x = 2$, $y = 6$, $z = 5$

Output: False


```
// ax + by = z where z = gcd(x, y)
class Solution {
public:
    bool canMeasureWater(int x, int y, int z) {
        return z == 0 || (x + y >= z && z % gcd(x, y) == 0);
    }
    int gcd(int x, int y) {
        return y == 0 ? x : gcd(y, x % y);
    }
};
```

1.5 Factorial Trailing Zeroes (E)

Given an integer n, return the number of trailing zeroes in n!.

```
class Solution {
public:
    // All trailing 0 is from factors 5 * 2
    // In the n! operation, factors 2 is always ample.
    // So we just count how many 5 factors in all number from 1 to n.
    int trailingZeroes(int n) {
        if (n < 5)
            return 0;
        else
            return n/5 + trailingZeroes(n/5);
    }
};
```

1.6 Number of Digit One (H)

Given an integer n, count the total number of digit 1 appearing in all non-negative integers less than or equal to n.

For example: Given n = 13, Return 6, because digit 1 occurred in the following numbers: 1, 10, 11, 12, 13.

Hint: Beware of overflow.

```
class Solution {
public:
    int countDigitOne(int n) {
        int res = 0, a = 1, b = 1;
```

```

        while (n > 0) {
            res += (n + 8) / 10 * a + (n % 10 == 1) * b;
            b += n % 10 * a;
            a *= 10;
            n /= 10;
        }
        return res;
    }
};

```

1.7 Palindrome Number (E)

Determine whether an integer is a palindrome. Do this without extra space.

Python:

```

# Convert to string
class Solution(object):
    def isPalindrome(self, x):
        """
        :type x: int
        :rtype: bool
        """
        if x < 0: return False
        x_str = str(x)
        n = len(x_str)
        if n == 1: return True
        left, right = 0, n - 1
        while left < right:
            if x_str[left] != x_str[right]:
                return False
            left += 1
            right -= 1
        return True

# use module and div
class Solution(object):
    def isPalindrome(self, x):
        """
        :type x: int
        :rtype: bool
        """
        if x < 0: return False
        n = 1
        while x / n >= 10:
            n *= 10

```

```

while x > 0:
    left = x / n
    right = x % 10
    if left != right: return False
    x = (x % n) / 10
    n /= 100
return True

```

C++:

```

class Solution {
public:
    bool isPalindrome(int x) {
        if (x < 0) return false;
        int d = 1;
        while (x / d >= 10)
            d *= 10;           // get the initial divisor size
        while (x > 0) {
            int q = x / d;     // quotient as the first digit
            int r = x % 10;    // remainder as the last digit
            if (q != r) return false;
            x = x % d / 10;    // remove the first and the last digits
            d /= 100;         // reduce the divisor size
        }
        return true;
    }
};

```

1.8 Reverse Integer (E)

Reverse digits of an integer.

Example1: x = 123, return 321

Example2: x = -123, return -321

Python:

```

class Solution(object):
    def reverse(self, x):
        """
        :type x: int
        :rtype: int
        """
        res, sign = 0, 1
        if x < 0:
            sign = -1

```

```

        x *= sign
    while x != 0:
        res = res * 10 + x % 10
        if res > pow(2, 31) - 1:
            return 0
        x /= 10
    return sign * res

```

C++:

```

class Solution {
public:
    int reverse(int x) {
        if (x < INT_MIN || x > INT_MAX) return 0;

        long num, result = 0;

        if (x < 0)                // convert to positive if x is a negtive
            num = -x;
        else
            num = x;

        while (num != 0) {
            result = result * 10 + num % 10;
            num /= 10;
        }

        if (x < 0)                // convert result back if x is a negtive
            result = -result;

        if (result < INT_MIN || result > INT_MAX)
            return 0;
        else
            return result;
    }
};

```

1.9 Integer Break (M)

Given a positive integer n , break it into the sum of at least two positive integers and maximize the product of those integers. Return the maximum product you can get.

For example, given $n = 2$, return 1 ($2 = 1 + 1$); given $n = 10$, return 36 ($10 = 3 + 3 + 4$).

Note: You may assume that n is not less than 2 and not larger than 58.

Hint:

There is a simple $O(n)$ solution to this problem.

You may check the breaking results of n ranging from 7 to 10 to discover the regularities.

```
/** 2 = 1 + 1
 * 3 = 2 + 1
 * 4 = 2 + 2
 * 5 = 3 + 2
 * 6 = 3 + 3
 * 7 = 3 + 4
 * 8 = 3 + 3 + 2
 * 9 = 3 + 3 + 3
 * 10 = 3 + 3 + 4
 */
class Solution {
public:
    int integerBreak(int n) {
        if (n == 2 || n == 3) return n - 1;
        int res = 1;
        while (n > 4) {
            res *= 3;
            n -= 3;
        }
        return res * n;
    }
};
```

1.10 Integer Replacement (E)

Given a positive integer n and you can do operations as follow:

If n is even, replace n with $n/2$.

If n is odd, you can replace n with either $n + 1$ or $n - 1$.

What is the minimum number of replacements needed for n to become 1?

Example 1:

Input: 8

Output: 3

Explanation: 8 \rightarrow 4 \rightarrow 2 \rightarrow 1

Example 2:

Input: 7

Output: 4

Explanation: 7 \rightarrow 8 \rightarrow 4 \rightarrow 2 \rightarrow 1 or 7 \rightarrow 6 \rightarrow 3 \rightarrow 2 \rightarrow 1

```

class Solution {
public:
    int integerReplacement(int n) {
        if (n == 1) return 0;
        if (n % 2 == 0) {
            return 1 + integerReplacement(n/2);
        }
        else {
            long long t = n;
            return 2 + min(integerReplacement((t+1)/2),
                           integerReplacement((t-1)/2));
        }
    }
};

class Solution {
public:
    int integerReplacement(int n) {
        long long t = n;
        int cnt = 0;
        while (t > 1) {
            ++cnt;
            if (t & 1) {
                if ((t & 2) && (t != 3)) ++t;
                else --t;
            } else {
                t >>= 1;
            }
        }
        return cnt;
    }
};

```

1.11 Count Numbers with Unique Digits (M)

Given a non-negative integer n , count all numbers with unique digits, x , where $0 \leq x < 10^n$.

Example: Given $n = 2$, return 91. (The answer should be the total numbers in the range of $0 \leq x < 100$, excluding [11,22,33,44,55,66,77,88,99])

Hint:

A direct way is to use the backtracking approach.

Backtracking should contains three states which are (the current number, number of steps to get that number and a bitmask which represent which number is marked as visited so

far in the current number). Start with state (0,0,0) and count all valid number till we reach number of steps equals to 10n.

This problem can also be solved using a dynamic programming approach and some knowledge of combinatorics.

Let $f(k)$ = count of numbers with unique digits with length equals k.

$f(1) = 10$, ..., $f(k) = 9 * 9 * 8 * \dots (9 - k + 2)$ [The first factor is 9 because a number cannot start with 0].

```
// 1. Formula solution
class Solution {
public:
    int countNumbersWithUniqueDigits(int n) {
        if (n == 0) return 1;
        int res = 0;
        for (int i = 1; i <= n; ++i) {
            res += count(i);
        }
        return res;
    }

    int count(int k) {
        if (k == 1) return 10;
        int res = 1;
        for (int i = 9; i >= (9 - k + 2); --i) {
            res *= i;
        }
        return res * 9;
    }
};
```

```
// 2. Backtracking solution
class Solution {
public:
    int countNumbersWithUniqueDigits(int n) {
        int res = 1, max = pow(10, n), used = 0;
        for (int i = 1; i < 10; ++i) {
            used |= (1 << i);
            res += search(i, max, used);
            used &= ~(1 << i);
        }
        return res;
    }

    int search(int pre, int max, int used) {
        int res = 0;
        if (pre < max) ++res;
    }
};
```

```

        else return res;
    for (int i = 0; i < 10; ++i) {
        if (!(used & (1 << i))) {
            used |= (1 << i);
            int cur = 10 * pre + i;
            res += search(cur, max, used);
            used &= ~(1 << i);
        }
    }
    return res;
}
};

```

1.12 Lexicographical Numbers (M)

Given an integer n , return 1 - n in lexicographical order.

For example, given 13, return: [1,10,11,12,13,2,3,4,5,6,7,8,9].

Please optimize your algorithm to use less time and space. The input size may be as large as 5,000,000.

```

class Solution {
public:
    vector<int> lexicalOrder(int n) {
        vector<int> res(n);
        int cur = 1;
        for (int i = 0; i < n; ++i) {
            res[i] = cur;
            // traversal the number which is the 10 multiple of cur
            if (cur * 10 <= n) {
                cur *= 10;
            } else {
                if (cur >= n) cur /= 10;
                cur += 1; // traversal cur through increasing it by 1
                while (cur % 10 == 0) cur /= 10;
            }
        }
        return res;
    }
};

```

1.13 Fraction to Recurring Decimal (M)

Given two integers representing the numerator and denominator of a fraction, return the fraction in string format. If the fractional part is repeating, enclose the repeating part in parentheses.

For example,

Given numerator = 1, denominator = 2, return "0.5".

Given numerator = 2, denominator = 1, return "2".

Given numerator = 2, denominator = 3, return "0.(6)".

Hint:

No scary math, just apply elementary math knowledge. Still remember how to perform a long division?

Try a long division on 4/9, the repeating part is obvious. Now try 4/333. Do you see a pattern?

Be wary of edge cases! List out as many test cases as you can think of and test your code thoroughly.

```
class Solution {
public:
    string fractionToDecimal(int numerator, int denominator) {
        int s1 = numerator >= 0 ? 1 : -1;
        int s2 = denominator >= 0 ? 1 : -1;
        long long num = abs( (long long)numerator );
        long long den = abs( (long long)denominator );
        long long out = num / den;
        long long rem = num % den;
        unordered_map<long long, int> m;
        string res = to_string(out);
        if (s1 * s2 == -1 && (out > 0 || rem > 0)) res = "-" + res;
        if (rem == 0) return res;
        res += ".";
        string s = "";
        int pos = 0;
        while (rem != 0) {
            if (m.find(rem) != m.end()) {
                s.insert(m[rem], "(");
                s += ")";
                return res + s;
            }
            m[rem] = pos;
            s += to_string((rem * 10) / den);
            rem = (rem * 10) % den;
            ++pos;
        }
    }
};
```

```

        return res + s;
    }
};

```

1.14 Elimination Game (M)

There is a list of sorted integers from 1 to n . Starting from left to right, remove the first number and every other number afterward until you reach the end of the list. Repeat the previous step again, but this time from right to left, remove the right most number and every other number from the remaining numbers. We keep repeating the steps again, alternating left to right and right to left, until a single number remains. Find the last number that remains starting with a list of length n .

Example:

Input: $n = 9$,
 1 2 3 4 5 6 7 8 9
 2 4 6 8
 2 6
 6
 Output: 6

```

class Solution {
public:
    int lastRemaining(int n) {
        return help(n, true);
    }
    int help(int n, bool left2right) {
        if (n == 1) return 1;
        if (left2right) {
            return 2 * help(n / 2, false);
        } else {
            return 2 * help(n / 2, true) - 1 + n % 2;
        }
    }
};

class Solution {
public:
    int lastRemaining(int n) {
        return n == 1 ? 1 : 2 * (1 + n / 2 - lastRemaining(n / 2));
    }
};

class Solution {
public:

```

```

int lastRemaining(int n) {
    int base = 1, res = 1;
    while (base * 2 <= n) {
        res += base;
        base *= 2;
        if (base * 2 > n) break;
        if ((n / base) % 2 == 1) res += base;
        base *= 2;
    }
    return res;
}
};

```

1.15 Rotate Function (E)

Given an array of integers A and let n to be its length. Assume Bk to be an array obtained by rotating the array A k positions clock-wise, we define a "rotation function" F on A as follow: $F(k) = 0 * Bk[0] + 1 * Bk[1] + \dots + (n-1) * Bk[n-1]$.

Calculate the maximum value of F(0), F(1), ..., F(n-1).

Note: n is guaranteed to be less than 105.

Example: A = [4, 3, 2, 6]

$F(0) = (0 * 4) + (1 * 3) + (2 * 2) + (3 * 6) = 0 + 3 + 4 + 18 = 25$

$F(1) = (0 * 6) + (1 * 4) + (2 * 3) + (3 * 2) = 0 + 4 + 6 + 6 = 16$

$F(2) = (0 * 2) + (1 * 6) + (2 * 4) + (3 * 3) = 0 + 6 + 8 + 9 = 23$

$F(3) = (0 * 3) + (1 * 2) + (2 * 6) + (3 * 4) = 0 + 2 + 12 + 12 = 26$

So the maximum value of F(0), F(1), F(2), F(3) is F(3) = 26.

```

/** F(0) = 0A + 1B + 2C + 3D
 * F(1) = 0D + 1A + 2B + 3C = F(0) + (1A+1B+1C+1D) - 4D
 * F(2) = 0C + 1D + 2A + 3B = F(1) + (1A+1B+1C+1D) - 4C
 * F(3) = 0B + 1C + 2D + 3A = F(2) + (1A+1B+1C+1D) - 4B
 * So, F(i) = F(i-1) + sum - n*A[n-i]
 */
class Solution {
public:
    int maxRotateFunction(vector<int>& A) {
        int F = 0, sum = 0, n = A.size();
        for (int i = 0; i < n; ++i) {
            sum += A[i];
            F += i * A[i];
        }
    }
}

```

```

    int res = F;
    for (int i = 1; i < n; ++i) {
        F = F + sum - n * A[n - i];
        res = max(res, F);
    }
    return res;
}
};

```

1.16 Plus One (E)

Given a non-negative number represented as an array of digits, plus one to the number. The digits are stored such that the most significant digit is at the head of the list.

```

class Solution {
public:
    vector<int> plusOne(vector<int>& digits) {
        int tmp = 1;

        for (int i = digits.size()-1; i >= 0; --i) {
            digits[i] += tmp;
            if (digits[i] == 10) {
                digits[i] = 0;
                tmp = 1;
            } else {
                tmp = 0;
            }
        }

        if (tmp == 1) {
            digits[0] = 1;
            digits.push_back(0);
        }

        return digits;
    }
};

```

1.17 Add Digits (E)

Given a non-negative integer num, repeatedly add all its digits until the result has only one digit.

For example: Given $\text{num} = 38$, the process is like: $3 + 8 = 11$, $1 + 1 = 2$. Since 2 has only one digit, return it.

Follow up: Could you do it without any loop/recursion in $O(1)$ runtime?

```
class Solution(object):
    def addDigits(self, num):
        """
        :type num: int
        :rtype: int
        """
        res = 0
        while num > 0:
            res += num % 10
            num /= 10
        if res < 10:
            return res
        else:
            return self.addDigits(res)
```

```
class Solution(object):
    def addDigits(self, num):
        """
        :type num: int
        :rtype: int
        """
        if num == 0:
            return 0
        else:
            return (num - 1) % 9 + 1
```

```
class Solution {
public:
    int addDigits(int num) {
        if (num < 10)
            return num;

        int sum = 0;
        while (num != 0) {
            sum += num % 10; // get the rightmost digit and add it up
            num /= 10; // get the new num after removing the rightmost digit
        }

        return addDigits(sum);
    }
};
```

1.18 Happy Number (E)

Write an algorithm to determine if a number is "happy".

A happy number is a number defined by the following process: Starting with any positive integer, replace the number by the sum of the squares of its digits, and repeat the process until the number equals 1 (where it will stay), or it loops endlessly in a cycle which does not include 1. Those numbers for which this process ends in 1 are happy numbers.

Example: 19 is a happy number

$$\begin{aligned}1^2 + 9^2 &= 82 \\8^2 + 2^2 &= 68 \\6^2 + 8^2 &= 100 \\1^2 + 0^2 + 0^2 &= 1\end{aligned}$$

```
class Solution(object):
    def isHappy(self, n):
        """
        :type n: int
        :rtype: bool
        """
        if n == 1: return True
        if n == 4: return False
        res = 0
        while n > 0:
            res += pow((n % 10), 2)
            n /= 10
        return self.isHappy(res)
```

```
class Solution {
public:
    bool isHappy(int n) {
        if (n == 1) return true;
        // All non-happy numbers follow sequences that reach the cycle: 4, 16,
        // 37, 58, 89, 145, 42, 20, 4, ...
        if (n == 4) return false;
        int digit = 0;
        while (n != 0) {
            digit += pow((n % 10), 2);
            n /= 10;
        }
        return isHappy(digit);
    }
};
```

1.19 Ugly Number (E)

Write a program to check whether a given number is an ugly number.

Ugly numbers are positive numbers whose prime factors only include 2, 3, 5. For example, 6, 8 are ugly while 14 is not ugly since it includes another prime factor 7.

Note that 1 is typically treated as an ugly number.

```
class Solution {
public:
    bool isUgly(int num) {
        if (num == 0) return false;
        while (num % 2 == 0) num /= 2;
        while (num % 3 == 0) num /= 3;
        while (num % 5 == 0) num /= 5;
        return num == 1;
    }
};
```

1.20 Ugly Number II (M)

Write a program to find the n-th ugly number.

Ugly numbers are positive numbers whose prime factors only include 2, 3, 5. For example, 1, 2, 3, 4, 5, 6, 8, 9, 10, 12 is the sequence of the first 10 ugly numbers.

Note that 1 is typically treated as an ugly number.

```
class Solution {
public:
    int nthUglyNumber(int n) {
        if (n <= 0) return 0;
        int idx2 = 0, idx3 = 0, idx5 = 0;
        vector<int> res(n);
        res[0] = 1;
        for (int i = 1; i < n; ++i) {
            res[i] = min(2 * res[idx2], min(3 * res[idx3], 5 * res[idx5]));
            if (res[i] == 2 * res[idx2]) ++idx2;
            if (res[i] == 3 * res[idx3]) ++idx3;
            if (res[i] == 5 * res[idx5]) ++idx5;
        }
        return res[n-1];
    }
};
```

```
};
```

1.21 Super Ugly Number (M)

Write a program to find the n-th super ugly number.

Super ugly numbers are positive numbers whose all prime factors are in the given prime list primes of size k. For example, [1, 2, 4, 7, 8, 13, 14, 16, 19, 26, 28, 32] is the sequence of the first 12 super ugly numbers given primes = [2, 7, 13, 19] of size 4.

Note: (1) 1 is a super ugly number for any given primes. (2) The given numbers in primes are in ascending order. (3) $0 < k \leq 100, 0 < n \leq 10^6, 0 < \text{primes}[i] < 1000$.

```
class Solution {
public:
    int nthSuperUglyNumber(int n, vector<int>& primes) {
        vector<int> res(n, INT_MAX);
        vector<int> index(primes.size(), 0);
        res[0] = 1;

        for (int i = 1; i < n; ++i) {
            for (int j = 0; j < primes.size(); ++j) {
                res[i] = min(res[i], primes[j] * res[index[j]]);
            }
            for (int j = 0; j < index.size(); ++j) {
                if (res[i] == primes[j] * res[index[j]]) {
                    ++index[j];
                }
            }
        }

        return res[n-1];
    }
};
```

1.22 Count Primes (E)

Count the number of prime numbers less than a non-negative number, n.

A prime number (or a prime) is a natural number greater than 1 that has no positive divisors other than 1 and itself.

```
class Solution(object):
```



```

def countPrimes(self, n):
    """
    :type n: int
    :rtype: int
    """
    if n <= 1: return 0
    isPrime = [True] * n
    res = 0
    # if i is a prime, then i*i, i*(i+1), i*(i+2), ... are not prime
    for i in range(2, n):
        if isPrime[i]:
            for j in range(i * i, n, i):
                isPrime[j] = False
    for p in isPrime:
        if p: res += 1
    return res - 2

```

```

class Solution {
public:
    int countPrimes(int n) {
        if (n <= 0) return 0;
        bool isPrime[n];
        for (int i = 2; i < n; ++i) isPrime[i] = true;
        // if i is a prime, then i*i, i*(i+1), i*(i+2), ... are not prime
        for (int i = 2; i * i < n; ++i) {
            if (isPrime[i] == false)
                continue;
            for (int j = i * i; j < n; j += i)
                isPrime[j] = false;
        }
        int cnt = 0;
        for (int i = 2; i < n; ++i){
            if (isPrime[i] == true) ++cnt;
        }
        return cnt;
    }
};

```

1.23 Pow(x, n) (M)

Implement pow(x, n).

```

class Solution(object):
    def myPow(self, x, n):

```

```

"""
:type x: float
:type n: int
:rtype: float
"""

# base case
if n == 0: return 1
# recursion case 3: n < 0
if n < 0: return 1 / self.myPow(x, -n)
# break the main problem
half = self.myPow(x, n/2)
# recursion case 1: n is even
if n % 2 == 0:
    return half * half
# recursion case 2: n is odd
else:
    return half * half * x

```

```

// x^n = x^(n/2) * x^(n/2) if n is even
// x^n = x * x^(n/2) * x^(n/2) if n is odd
class Solution {
public:
    double myPow(double x, int n) {
        if (n < 0) return 1 / power(x, -n);
        else return power(x, n);
    }
    double power(double x, int n) {
        if (n == 0) return 1;
        double half = power(x, n/2);
        if (n % 2 == 0) return half * half;
        else return x * half * half;
    }
};

```

1.24 Super Pow (M)

Your task is to calculate $ab \bmod 1337$ where a is a positive integer and b is an extremely large positive integer given in the form of an array.

Example1: $a = 2$ $b = [3]$ Result: 8

Example2: $a = 2$ $b = [1,0]$ Result: 1024

```
class Solution(object):
```

```
def mySqrt(self, x):
    """
    :type x: int
    :rtype: int
    """
    left, right = 1, x
    while left <= right:
        mid = left + (right - left) / 2
        if x == mid * mid:
            return mid
        elif x > mid * mid:
            left = mid + 1
        else:
            right = mid - 1
    return right
```

```
class Solution {
public:
    int superPow(int a, vector<int>& b) {
        long long res = 1;
        for (int i = 0; i < b.size(); ++i) {
            //e.g. 2^23 % 1337 = (2^2)^10 * 2^3 % 1337
            res = power(res, 10) * power(a, b[i]) % 1337;
        }
        return res;
    }
    int power(int x, int n) {
        if (n == 0) return 1;
        if (n == 1) return x % 1337;
        return power(x % 1337, n / 2) * power(x % 1337, n - n / 2) % 1337;
    }
};
```

1.25 Sqrt(x) (M)

Implement `int sqrt(int x)`. Compute and return the square root of `x`.

```
// Find a candidate sq and decide the search range based on sq and x
class Solution {
public:
    int mySqrt(int x) {
        long long left = 1, right = x;
        while (left <= right) {
            long long mid = left + (right - left) / 2;
```

```

        long long sq = mid * mid;
        if (x == sq) return mid;
        else if (x > sq) left = mid + 1;
        else right = mid - 1;
    }
    return right; // if x=0 or x=1, just return right
}
};

```

1.26 Valid Perfect Square (M)

Given a positive integer num, write a function which returns True if num is a perfect square else False. Note: Do not use any built-in library function such as sqrt.

Example 1: Input: 16 Returns: True

Example 2: Input: 14 Returns: False

```

class Solution {
public:
    bool isPerfectSquare(int num) {
        long long left = 1, right = num;
        while (left <= right) {
            long long mid = left + (right - left) / 2;
            long long sq = mid * mid;
            if (num == sq) return true;
            else if (num > sq) left = mid + 1;
            else right = mid - 1;
        }
        return false;
    }
};

```

1.27 Rectangle Area (E)

Find the total area covered by two rectilinear rectangles in a 2D plane. Each rectangle is defined by its bottom left corner and top right corner as shown in the figure.

```

class Solution(object):
    def computeArea(self, A, B, C, D, E, F, G, H):
        """
        :type A: int

```

```

        :type B: int
        :type C: int
        :type D: int
        :type E: int
        :type F: int
        :type G: int
        :type H: int
        :rtype: int
        """
        width = max(min(C, G) - max(A, E), 0)
        height = max(min(D, H) - max(B, F), 0)
        overlap = width * height
        area1 = (C - A) * (D - B)
        area2 = (G - E) * (H - F)
        return area1 + area2 - overlap

```

```

class Solution {
public:
    int computeArea(int A, int B, int C, int D, int E, int F, int G, int H) {
        int areaA = (C-A) * (D-B);
        int areaB = (G-E) * (H-F);

        int left = max(A,E);
        int right = min(C,G);
        int top = min(D,H);
        int bottom = max(B,F);

        int overlap = 0;
        if (right > left && top > bottom)
            overlap = (right - left) * (top - bottom);

        return areaA + areaB - overlap;
    }
};

```

1.28 Rectangle Overlap (M)

A rectangle is represented as a list $[x1, y1, x2, y2]$, where $(x1, y1)$ are the coordinates of its bottom-left corner, and $(x2, y2)$ are the coordinates of its top-right corner.

Two rectangles overlap if the area of their intersection is positive. To be clear, two rectangles that only touch at the corner or edges do not overlap.

Given two (axis-aligned) rectangles, return whether they overlap.

```
class Solution(object):
    def isRectangleOverlap(self, rec1, rec2):
        """
        :type rec1: List[int]
        :type rec2: List[int]
        :rtype: bool
        """
        return rec1[0] < rec2[2] and rec2[0] < rec1[2] and \
            rec1[1] < rec2[3] and rec2[1] < rec1[3]
```

1.29 Container With Most Water (M)

Given n non-negative integers a_1, a_2, \dots, a_n , where each represents a point at coordinate (i, a_i) . n vertical lines are drawn such that the two endpoints of line i is at (i, a_i) and $(i, 0)$. Find two lines, which together with x-axis forms a container, such that the container contains the most water.

Note: You may not slant the container.

```
class Solution {
public:
    int maxArea(vector<int> &height) {
        int left = 0, right = height.size()-1, res = 0;
        while (left <= right) {
            res = max(res, min(height[left], height[right]) * (right - left));
            if (height[left] < height[right]) ++left;
            else --right;
        }
        return res;
    }
};
```

1.30 Trapping Rain Water (H)

Given n non-negative integers representing an elevation map where the width of each bar is 1, compute how much water it is able to trap after raining.

For example, Given $[0,1,0,2,1,0,1,3,2,1,2,1]$, return 6.

```
class Solution(object):
    def trap(self, height):
```

```

"""
:type height: List[int]
:rtype: int
"""
n = len(height)
left, right = 0, n - 1
res = 0
while left < right:
    min_bar = min(height[left], height[right])
    if min_bar == height[left]:
        left += 1
        while left < right and height[left] < min_bar:
            res += min_bar - height[left]
            left += 1
    else:
        right -= 1
        while left < right and height[right] < min_bar:
            res += min_bar - height[right]
            right -= 1
return res

```

```

class Solution {
public:
    int trap(vector<int>& height) {
        int res = 0, left = 0, right = height.size() - 1;
        while (left < right) {
            int mn = min(height[left], height[right]);
            if (height[left] == mn) { // scan from left to right
                ++left;
                while (left < right && height[left] < mn) {
                    res += (mn - height[left]);
                    ++left;
                }
            } else { // scan from right to left
                --right;
                while (left < right && height[right] < mn) {
                    res += (mn - height[right]);
                    --right;
                }
            }
        }
        return res;
    }
};

```

1.31 Largest Rectangle in Histogram (H)

Given n non-negative integers representing the histogram's bar height where the width of each bar is 1, find the area of largest rectangle in the histogram.

For example, Given heights = [2,1,5,6,2,3], return 10.

```
class Solution(object):
    def largestRectangleArea(self, heights):
        """
        :type heights: List[int]
        :rtype: int
        """
        res = 0
        n = len(heights)
        for i in range(n):
            if i + 1 < n and heights[i] <= heights[i + 1]: continue
            min_h = heights[i]
            for j in range(i, -1, -1):
                min_h = min(min_h, heights[j])
                area = min_h * (i - j + 1)
                res = max(res, area)
        return res
```

```
class Solution {
public:
    int largestRectangleArea(vector<int> &height) {
        int res = 0;
        for (int i = 0; i < height.size(); ++i) {
            if (i + 1 < height.size() && height[i] <= height[i + 1]) {
                continue; // find the local maximum height
            }
            int minH = height[i];
            // find the minimum height back from j to 0
            for (int j = i; j >= 0; --j) {
                minH = min(minH, height[j]); // save the minimum height
                int area = minH * (i - j + 1); // compute the area
                res = max(res, area); // save the maximum area
            }
        }
        return res;
    }
};
```

1.32 Line Reflection (M)

Given n points on a 2D plane, find if there is such a line parallel to y-axis that reflect the given set of points.

Example 1: Given points = $[[1,1],[-1,1]]$, return true.

Example 2: Given points = $[[1,1],[-1,-1]]$, return false.

Follow up: Could you do better than $O(n^2)$?

Hint:

Find the smallest and largest x-value for all points.

If there is a line then it should be at $y = (\min X + \max X) / 2$.

For each point, make sure that it has a reflected point in the opposite side.

```
class Solution {
public:
    bool isReflected(vector<pair<int, int>>& points) {
        unordered_map<int, set<int>> m;
        int mx = INT_MIN, mn = INT_MAX;
        for (auto a : points) {
            mx = max(mx, a.first);
            mn = min(mn, a.first);
            m[a.first].insert(a.second);
        }
        double y = (double)(mx + mn) / 2;
        for (auto a : points) {
            // find the reflection point
            // note that y = (a.first + t) / 2
            int t = 2 * y - a.first;
            // if t and a.first are reflect point,
            // t should be in m, and the y-coordinate related to t should equal
            // to a.second
            if (!m.count(t) || !m[t].count(a.second)) {
                return false;
            }
        }
        return true;
    }
};
```

1.33 Max Points on a Line (H)

Given n points on a 2D plane, find the maximum number of points that lie on the same straight line.

```
/**
 * Definition for a point.
 * struct Point {
 *     int x;
 *     int y;
 *     Point() : x(0), y(0) {}
 *     Point(int a, int b) : x(a), y(b) {}
 * };
 */
class Solution {
public:
    int maxPoints(vector<Point>& points) {
        int res = 0;
        unordered_map<float, int> m;
        for (int i = 0; i < points.size(); ++i) {
            m.clear();
            m[INT_MIN] = 0;
            int duplicate = 1;
            for (int j = 0; j < points.size(); ++j) {
                if (j == i) continue;
                if (points[i].x == points[j].x && points[i].y == points[j].y) {
                    ++duplicate;
                    continue;
                }
                float slope = (points[i].x == points[j].x) ? INT_MAX :
                    (float)(points[j].y - points[i].y) / (points[j].x -
                    points[i].x);
                ++m[slope];
            }
            for (unordered_map<float, int>::iterator it = m.begin(); it !=
                m.end(); ++it) {
                res = max(res, it->second + duplicate);
            }
        }
        return res;
    }
};
```

1.34 Perfect Rectangle (H)

Given N axis-aligned rectangles where $N > 0$, determine if they all together form an exact cover of a rectangular region. Each rectangle is represented as a bottom-left point and a top-right point. For example, a unit square is represented as [1,1,2,2]. (coordinate of bottom-left point is (1, 1) and top-right point is (2, 2)).

```
class Solution {
public:
    bool isRectangleCover(vector<vector<int>>& rectangles) {
        unordered_map<string, int> m;
        int min_x = INT_MAX, min_y = INT_MAX, max_x = INT_MIN, max_y = INT_MIN,
            area = 0, cnt = 0;
        for (auto rect : rectangles) {
            min_x = min(min_x, rect[0]);
            min_y = min(min_y, rect[1]);
            max_x = max(max_x, rect[2]);
            max_y = max(max_y, rect[3]);
            area += (rect[2] - rect[0]) * (rect[3] - rect[1]);
            if (!isValid(m, to_string(rect[0]) + "_" + to_string(rect[1]), 1))
                return false; // bottom-left
            if (!isValid(m, to_string(rect[0]) + "_" + to_string(rect[3]), 2))
                return false; // top-left
            if (!isValid(m, to_string(rect[2]) + "_" + to_string(rect[3]), 4))
                return false; // top-right
            if (!isValid(m, to_string(rect[2]) + "_" + to_string(rect[1]), 8))
                return false; // bottom-right
        }
        for (auto it = m.begin(); it != m.end(); ++it) {
            int t = it->second;
            if (t != 15 && t != 12 && t != 10 && t != 9 && t != 6 && t != 5 &&
                t != 3) {
                ++cnt;
            }
        }
        return cnt == 4 && area == (max_x - min_x) * (max_y - min_y);
    }
    bool isValid(unordered_map<string, int>& m, string corner, int type) {
        int& val = m[corner];
        if (val & type) return false;
        val |= type;
        return true;
    }
};

class Solution {
public:
```

```

bool isRectangleCover(vector<vector<int>>& rectangles) {
    set<string> st;
    int min_x = INT_MAX, min_y = INT_MAX, max_x = INT_MIN, max_y = INT_MIN,
        area = 0;
    for (auto rect : rectangles) {
        min_x = min(min_x, rect[0]);
        min_y = min(min_y, rect[1]);
        max_x = max(max_x, rect[2]);
        max_y = max(max_y, rect[3]);
        area += (rect[2] - rect[0]) * (rect[3] - rect[1]);
        string s1 = to_string(rect[0]) + "_" + to_string(rect[1]); //
            bottom-left
        string s2 = to_string(rect[0]) + "_" + to_string(rect[3]); // top-left
        string s3 = to_string(rect[2]) + "_" + to_string(rect[3]); //
            top-right
        string s4 = to_string(rect[2]) + "_" + to_string(rect[1]); //
            bottom-right
        if (st.count(s1)) st.erase(s1);
        else st.insert(s1);
        if (st.count(s2)) st.erase(s2);
        else st.insert(s2);
        if (st.count(s3)) st.erase(s3);
        else st.insert(s3);
        if (st.count(s4)) st.erase(s4);
        else st.insert(s4);
    }
    string t1 = to_string(min_x) + "_" + to_string(min_y);
    string t2 = to_string(min_x) + "_" + to_string(max_y);
    string t3 = to_string(max_x) + "_" + to_string(max_y);
    string t4 = to_string(max_x) + "_" + to_string(min_y);
    if (!st.count(t1) || !st.count(t2) || !st.count(t3) || !st.count(t4) ||
        st.size() != 4) return false;
    return area == (max_x - min_x) * (max_y - min_y);
}
};

```

1.35 Random Pick Index (M)

Given an array of integers with possible duplicates, randomly output the index of a given target number. You can assume that the given target number must exist in the array.

Note: The array size can be very large. Solution that uses too much extra space will not pass the judge.

```

class Solution(object):

```

```

def __init__(self, nums):
    """
    :type nums: List[int]
    """
    self.nums = nums

def pick(self, target):
    """
    :type target: int
    :rtype: int
    """
    res = None
    cnt = 0
    for i, x in enumerate(self.nums):
        if x == target:
            cnt += 1
            chance = random.randint(1, cnt)
            if chance == cnt: res = i
    return res

# Your Solution object will be instantiated and called as such:
# obj = Solution(nums)
# param_1 = obj.pick(target)

```

1.36 Shuffle an Array (M)

Shuffle a set of numbers without duplicates.

Example:

```

// Init an array with set 1, 2, and 3. int[] nums = {1,2,3}; Solution solution = new Solution(nums);
// Shuffle the array [1,2,3] and return its result. Any permutation of [1,2,3] must equally likely to be returned. solution.shuffle();
// Resets the array back to its original configuration [1,2,3]. solution.reset();
// Returns the random shuffling of array [1,2,3]. solution.shuffle();

```

```

class Solution(object):

    def __init__(self, nums):
        """
        :type nums: List[int]
        """
        self.original = list(nums)
        self.array = nums

    def reset(self):

```

```

    """
    Resets the array to its original configuration and return it.
    :rtype: List[int]
    """
    self.array = self.original
    self.original = list(self.array)
    return self.array

def shuffle(self):
    """
    Returns a random shuffling of the array.
    :rtype: List[int]
    """
    n = len(self.array)
    for i in range(n):
        # randomly select an idx from i to n
        swap_idx = random.randrange(i, n)
        # swap idx and i, idx could also be i
        self.array[i], self.array[swap_idx] = self.array[swap_idx],
            self.array[i]
    return self.array

# Your Solution object will be instantiated and called as such:
# obj = Solution(nums)
# param_1 = obj.reset()
# param_2 = obj.shuffle()

```

1.37 Reservoir Sampling (FB high frequency)

Reservoir sampling is a family of randomized algorithms for randomly choosing k samples from a list of n items, where n is either a very large or unknown number. Typically n is large enough that the list doesn't fit into main memory. For example, a list of search queries in Google and Facebook.

```

# A function to randomly select k items from stream[0..n-1].
def selectKItems(stream, n, k):
    # index for elements in stream[]
    i=0;

    # reservoir[] is the output array.
    # Initialize it with first k elements from stream[]
    reservoir = [0]*k;
    for i in range(k):
        reservoir[i] = stream[i];

```

```
# Iterate from the (k+1)th element to nth element in stream[]
while(i < n):
    # Pick a random index from 0 to i.
    j = random.randrange(i+1);

    # If the randomly picked index is smaller than k,
    # then replace the element present at the index j with new element
    # from stream i
    # otherwise we keep reservoir[] as the same
    if(j < k):
        reservoir[j] = stream[i];
    # we keep increasing i until all n items in stream[] are checked
    i+=1;
```

Chapter 2

Bit Manipulation

2.1 Sum of Two Integers (E)

Calculate the sum of two integers a and b, but you are not allowed to use the operator + and -.

Example:

Given a = 1 and b = 2, return 3.

```
class Solution {
public:
    int getSum(int a, int b) {
        int sum = a;
        while (b != 0) {
            sum = a ^ b; // use ^ to find different bits
            b = (a & b) << 1; // use & to find carry, then shift one position left
            a = sum;
        }
        return sum;
    }
};
```

2.2 Divide Two Integers (M)

Divide two integers without using multiplication, division and mod operator. If it is overflow, return MAXINT.

```
class Solution {
public:
    int divide(int dividend, int divisor) {
        if (divisor == 0 || (dividend == INT_MIN && divisor == -1)) return
            INT_MAX;
    }
};
```

```

    long long m = abs((long long)dividend), n = abs((long long)divisor), res
        = 0;
    int sign = ((dividend < 0) ^ (divisor < 0)) ? -1 : 1;
    if (n == 1) return sign == 1 ? m : -m;
    while (m >= n) {
        long long t = n, p = 1;
        while (m >= (t << 1)) {
            t <<= 1;
            p <<= 1;
        }
        res += p;
        m -= t;
    }
    return sign == 1 ? res : -res;
}
};

```

2.3 Bitwise AND of Numbers Range (M)

Given a range $[m, n]$ where $0 \leq m \leq n \leq 2147483647$, return the bitwise AND of all numbers in this range, inclusive.

For example, given the range $[5, 7]$, you should return 4.

```

class Solution {
public:
    int rangeBitwiseAnd(int m, int n) {
        int count = 0;
        while (m != n) {
            m >>= 1;
            n >>= 1;
            ++count;
        }
        return m << count;
    }
};

```

2.4 Grey Code (M)

The gray code is a binary numeral system where two successive values differ in only one bit.

Given a non-negative integer n representing the total number of bits in the code, print the sequence of gray code. A gray code sequence must begin with 0.

For example, given $n = 2$, return $[0,1,3,2]$. Its gray code sequence is:

00 - 0

01 - 1

11 - 3

10 - 2

```
// Binary to grey code
class Solution {
public:
    vector<int> grayCode(int n) {
        vector<int> res;
        for (int i = 0; i < pow(2,n); ++i) {
            res.push_back((i >> 1) ^ i);
        }
        return res;
    }
};
```

2.5 Repeated DNA Sequences (M)

All DNA is composed of a series of nucleotides abbreviated as A, C, G, and T, for example: "ACGAATTCG". When studying DNA, it is sometimes useful to identify repeated sequences within the DNA.

Write a function to find all the 10-letter-long sequences (substrings) that occur more than once in a DNA molecule.

For example, Given $s = \text{"AAAAACCCCCAAAAACCCCCCAAAAAGGGTTT"}$, Return: $[\text{"AAAAACCCCC"}, \text{"CCCCCAAAAA"}]$.

```
// A: 0100 0001 C: 0100 0011 G: 0100 0111 T: 0101 0100
// Only use the last 3 bits to represent DNAs
class Solution {
public:
    vector<string> findRepeatedDnaSequences(string s) {
        vector<string> res;
        if (s.size() <= 10) return res;
        int mask = 0x7fffffff;
        unordered_map<int, int> m;
        int cur = 0, i = 0;
        while (i < 9) { // save 9 letters in DNA to cur
            cur = (cur << 3) | (s[i++] & 7); // only use the last 3 bits
```

```

    }
    while (i < s.size()) {
        cur = ((cur & mask) << 3) | (s[i++] & 7);
        if (m.find(cur) != m.end()) {
            // appear more than once
            if (m[cur] == 1) res.push_back(s.substr(i - 10, 10));
            ++m[cur];
        } else {
            m[cur] = 1;
        }
    }
    return res;
}
};

```

2.6 Power of Two (E)

Given an integer, write a function to determine if it is a power of two.

```

class Solution(object):
    def isPowerOfTwo(self, n):
        """
        :type n: int
        :rtype: bool
        """
        return (n > 0) and (n & n-1 == 0)

```

A general solution for power of K

```

class Solution(object):
    def isPowerOfK(self, n, k):
        """
        :type n: int
        :rtype: bool
        """
        if n <= 0: return False
        while n % k == 0:
            n /= k
        return n == 1

```

```

class Solution {
public:
    bool isPowerOfTwo(int n) {    // 2^x = n
        return (n > 0) && (n & (n-1)) == 0;
    }
}

```

```
};
```

2.7 Power of Three (E)

Given an integer, write a function to determine if it is a power of three.

```
class Solution(object):
    def isPowerOfThree(self, n):
        """
        :type n: int
        :rtype: bool
        """
        if n <= 0: return False
        while n % 3 == 0:
            n /= 3
        return n == 1
```

```
class Solution {
public:
    bool isPowerOfThree(int n) {
        if (n <= 0) return false;
        while(n % 3 == 0) n /= 3;
        return n == 1;
    }
};
```

2.8 Power of Four (E)

Given an integer (signed 32 bits), write a function to check whether it is a power of 4.

```
class Solution(object):
    def isPowerOfFour(self, num):
        """
        :type num: int
        :rtype: bool
        """
        if num <= 0: return False
        while num % 4 == 0:
            num /= 4
        return num == 1
```

```

class Solution {
public:
    bool isPowerOfFour(int num) {
        return (num > 0) && ((num & (num - 1)) == 0) && ((num & 0x55555555) ==
            num);
    }
};

```

2.9 Number of 1 Bits (E)

Write a function that takes an unsigned integer and returns the number of "1" bits it has (also known as the Hamming weight).

For example, the 32-bit integer "11" has binary representation 00000000000000000000000000001011, so the function should return 3.

```

class Solution(object):
    def hammingWeight(self, n):
        """
        :type n: int
        :rtype: int
        """
        cnt = 0
        while n:
            cnt += n & 1
            n >>= 1
        return cnt

```

```

class Solution {
public:
    int hammingWeight(uint32_t n) {
        int res = 0;
        while (n != 0) {
            if (n & 1 == 1) ++res;
            n = n >> 1;
        }
        return res;
    }
};

```

2.10 Counting Bits (M)

Given a non negative integer number *num*. For every numbers *i* in the range $0 \leq i \leq num$ calculate the number of 1's in their binary representation and return them as an array.

Example:

For *num* = 5 you should return [0,1,1,2,1,2].

```
class Solution {
public:
    vector<int> countBits(int num) {
        vector<int> res = {0};
        int offset = 2;

        for (int i = 1; i <= num; ++i) {
            if (i >= offset)
                offset *= 2;
            res.push_back(res[i - offset/2] + 1);    // dp[index] = dp[index -
                                                    offset] + 1;
        }

        return res;
    }
};
```

2.11 Reverse Bits (E)

Reverse bits of a given 32 bits unsigned integer.

For example, given input 43261596 (represented in binary as 00000010100101000001111010011100), return 964176192 (represented in binary as 00111001011110000010100101000000).

Follow up:

If this function is called many times, how would you optimize it?

```
class Solution {
public:
    uint32_t reverseBits(uint32_t n) {
        int res = 0;
        for (int i = 0; i < 32; ++i){
            res += n & 1;    // assign the right most bit of n to res
            n >>= 1;        // remove the assigned bit from n
            if (i < 31)
```

```

        res <<= 1;    // move the assigned bit in res to left for
                      reversing
    }
    return res;
}
};

```

2.12 Single Number (E)

Given an array of integers, every element appears twice except for one. Find that single one.

Note: Your algorithm should have a linear runtime complexity. Could you implement it without using extra memory?

```

class Solution {
public:
    int singleNumber(vector<int>& nums) {
        int result = 0;
        for (int i = 0; i < nums.size(); ++i)
            result ^= nums[i];
        return result;
    }
};

```

2.13 Single Number II (M)

Given an array of integers, every element appears three times except for one. Find that single one.

Note: Your algorithm should have a linear runtime complexity. Could you implement it without using extra memory?

```

class Solution {
public:
    int singleNumber(vector<int>& nums) {
        int x1 = 0;
        int x2 = 0;
        int mask = 0;
        for (int i = 0; i < nums.size(); ++i) {
            x2 ^= x1 & nums[i];
            x1 ^= nums[i];
            mask = ~(x1 & x2);
        }
    }
};

```

```

        x2 &= mask;
        x1 &= mask;
    }
    return x1;
}
};

```

2.14 Single Number III (M)

Given an array of numbers `nums`, in which exactly two elements appear only once and all the other elements appear exactly twice. Find the two elements that appear only once.

For example: Given `nums = [1, 2, 1, 3, 2, 5]`, return `[3, 5]`.

Note: The order of the result is not important. So in the above example, `[5, 3]` is also correct. Your algorithm should run in linear runtime complexity. Could you implement it using only constant space complexity?

```

class Solution {
public:
    vector<int> singleNumber(vector<int>& nums) {
        int r = 0, n = nums.size(), i = 0, last = 0;
        vector<int> ret(2, 0);
        for (i = 0; i < n; ++i) r ^= nums[i]; // r = A ^ B
        last = r & ~(r - 1); // get the last '1'
        for (i = 0; i < n; ++i)
        {
            if ((last & nums[i]) != 0)
                ret[0] ^= nums[i];           // group with the same position of '1'
            else
                ret[1] ^= nums[i];           // group without the same position of '1'
        }

        return ret;
    }
};

```

2.15 UTF-8 Validation (M)

A character in UTF8 can be from 1 to 4 bytes long, subjected to the following rules:

For 1-byte character, the first bit is a 0, followed by its unicode code.

For n-bytes character, the first n-bits are all one's, the n+1 bit is 0, followed by n-1 bytes

with most significant 2 bits being 10.

This is how the UTF-8 encoding would work:
Char. number range — UTF-8 octet sequence
(hexadecimal) — (binary)

0000 0000-0000 007F — 0xxxxxxx
0000 0080-0000 07FF — 110xxxxx 10xxxxxx
0000 0800-0000 FFFF — 1110xxxx 10xxxxxx 10xxxxxx
0001 0000-0010 FFFF — 11110xxx 10xxxxxx 10xxxxxx 10xxxxxx

Given an array of integers representing the data, return whether it is a valid utf-8 encoding.

Note: The input is an array of integers. Only the least significant 8 bits of each integer is used to store the data. This means each integer represents only 1 byte of data.

Example 1:

data = [197, 130, 1], which represents the octet sequence: 11000101 10000010 00000001.
Return true.

It is a valid utf-8 encoding for a 2-bytes character followed by a 1-byte character.

Example 2:

data = [235, 140, 4], which represented the octet sequence: 11101011 10001100 00000100.
Return false.

The first 3 bits are all one's and the 4th bit is 0 means it is a 3-bytes character.

The next byte is a continuation byte which starts with 10 and that's correct.

But the second continuation byte does not start with 10, so it is invalid.

```
class Solution {
public:
    bool validUtf8(vector<int>& data) {
        for (int i = 0; i < data.size(); ++i) {
            if (data[i] < 0b10000000) {
                continue;
            } else {
                int cnt = 0, val = data[i];
                for (int j = 7; j >= 1; --j) {
                    if (val >= pow(2, j)) ++cnt;
                    else break;
                    val -= pow(2, j);
                }
                if (cnt == 1) return false;
                for (int j = i + 1; j < i + cnt; ++j) {
                    if (data[j] > 0b10111111 || data[j] < 0b10000000) return false;
                }
            }
        }
    }
};
```

```

        i += cnt - 1;
    }
}
return true;
}
};

class Solution {
public:
    bool validUtf8(vector<int>& data) {
        int cnt = 0;
        for (int d : data) {
            if (cnt == 0) {
                if ((d >> 5) == 0b110) cnt = 1;
                else if ((d >> 4) == 0b1110) cnt = 2;
                else if ((d >> 3) == 0b11110) cnt = 3;
                else if (d >> 7) return false;
            } else {
                if ((d >> 6) != 0b10) return false;
                --cnt;
            }
        }
        return cnt == 0;
    }
};

```

2.16 Binary Clock (Google phone screen 2016.8.15)

Suppose you have a binary clock that consists of two rows of LEDs. The first row has four LEDs representing four binary digits to indicate the hour. The bottom row has six LEDs to represent six binary digits indicating the minute. Write a program to list all the times that consist of exactly three lights being on, and the rest being off. List the times in human readable form.

```

class BinaryClock {
public:
    void clockTime() {
        vector<string> res;
        for (int h = 0; h <= 12; ++h) {
            for (int m = 0; m < 60; ++m) {
                if (countBits(h) + countBits(m) == 3) {
                    res.push_back(to_string(h) + ':' + to_string(m));
                }
            }
        }
    }
};

```

```

    }
    int countBits(int value){
        int mask = 1;
        int cnt = 0;
        for(int i = 0; i < 6; i++) {
            if((value & mask) == 1) ++cnt; // find 1, increase cnt
            mask <<= 1; // shift left to find all 1's in value
        }
        return cnt;
    }
};

```

2.17 Hamming Distance (E)

The Hamming distance between two integers is the number of positions at which the corresponding bits are different.

Given two integers x and y, calculate the Hamming distance.

```

class Solution(object):
    def hammingDistance(self, x, y):
        """
        :type x: int
        :type y: int
        :rtype: int
        """
        res = 0
        # %: get the lower bit
        # /: remove the lower bit
        # ^: xor
        while x or y:
            res += (x % 2) ^ (y % 2)
            x /= 2
            y /= 2
        return res

```

2.18 Total Hamming Distance (M)

The Hamming distance between two integers is the number of positions at which the corresponding bits are different.

Now your job is to find the total Hamming distance between all pairs of the given numbers.

Example:

Input: 4, 14, 2

Output: 6

Explanation: In binary representation, the 4 is 0100, 14 is 1110, and 2 is 0010 (just showing the four bits relevant in this case). So the answer will be: $\text{HammingDistance}(4, 14) + \text{HammingDistance}(4, 2) + \text{HammingDistance}(14, 2) = 2 + 2 + 2 = 6$.

```
# O(M^2 * N)
class Solution(object):
    def totalHammingDistance(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        n = len(nums)
        res = 0
        for i in range(n-1):
            for j in range(i+1, n):
                res += self.hammingDistance(nums[i], nums[j])
        return res
    def hammingDistance(self, x, y):
        res = 0
        while x or y:
            res += (x % 2) ^ (y % 2)
            x /= 2
            y /= 2
        return res

# O(MN): M is the number of nums, N is the length of the longest binary num
class Solution(object):
    def totalHammingDistance(self, nums):
        if not nums or len(nums) == 1: return 0
        n = len(nums)
        mx = max(nums)
        res = 0
        m = 1 # mask to count the number of ones
        while m <= mx:
            ones = 0
            # count the number of ones in current bit for all nums
            for num in nums:
                if m & num: ones += 1
            # count the number of zeros in current bit for all nums
            zeros = n - ones
            # hamming dist for current bit is ones * zeros
            res += ones * zeros
            # check the next higher bit
            m <<= 1
        return res
```

Chapter 3

Linked List

3.1 Intersection of Two Linked Lists (E)

Write a program to find the node at which the intersection of two singly linked lists begins.

Notes:

If the two linked lists have no intersection at all, return null.

The linked lists must retain their original structure after the function returns.

You may assume there are no cycles anywhere in the entire linked structure.

Your code should preferably run in $O(n)$ time and use only $O(1)$ memory.

```
# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None

class Solution(object):
    def getIntersectionNode(self, headA, headB):
        """
        :type head1, head1: ListNode
        :rtype: ListNode
        """
        if not headA or not headB: return None
        p1, p2 = headA, headB
        while p1 != p2:
            p1 = p1.next
            p2 = p2.next
            if p1 == p2:
                return p1
            if not p1:
                p1 = headB
            if not p2:
                p2 = headA
```

```

        p2 = headA
    return p1
}



---


/**
 * Definition for singly-linked list.
 * struct ListNode {
 *     int val;
 *     ListNode *next;
 *     ListNode(int x) : val(x), next(NULL) {}
 * };
 */

class Solution {
public:
    ListNode *getIntersectionNode(ListNode *headA, ListNode *headB) {
        if (!headA || !headB) return NULL;

        ListNode *p1 = headA;
        ListNode *p2 = headB;

        while (p1 && p2 && p1 != p2) {
            p1 = p1->next;
            p2 = p2->next;

            if (p1 == p2) return p1;

            if (!p1) p1 = headB;
            if (!p2) p2 = headA;
        }

        return p1;
    }
};

```

3.2 Add Two Numbers (M)

You are given two linked lists representing two non-negative numbers. The digits are stored in reverse order and each of their nodes contain a single digit. Add the two numbers and return it as a linked list.

Input: (2 → 4 → 3) + (5 → 6 → 4)

Output: 7 → 0 → 8

Python:

```

# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None

# O(max(m,n))
class Solution(object):
    def addTwoNumbers(self, l1, l2):
        """
        :type l1: ListNode
        :type l2: ListNode
        :rtype: ListNode
        """
        carry = 0
        # dummy head
        head = curr = ListNode(0)
        while l1 or l2:
            val = carry
            if l1:
                val += l1.val
                l1 = l1.next
            if l2:
                val += l2.val
                l2 = l2.next
            curr.next = ListNode(val % 10)
            curr = curr.next
            carry = val / 10
        if carry > 0:
            curr.next = ListNode(carry)
        return head.next

```

C++:

```

class Solution {
public:
    ListNode *addTwoNumbers(ListNode *l1, ListNode *l2) {
        ListNode *res = new ListNode(0);
        ListNode *cur = res;
        int carry = 0;
        while (l1 || l2) {
            int n1 = l1 ? l1->val : 0;
            int n2 = l2 ? l2->val : 0;
            int sum = n1 + n2 + carry;
            carry = sum / 10;
            cur->next = new ListNode(sum % 10);
            cur = cur->next;
            if (l1) l1 = l1->next;

```

```

        if (l2) l2 = l2->next;
    }
    if (carry) cur->next = new ListNode(1);
    return res->next;
}
};

```

3.3 Add Two Numbers II (M)

You are given two non-empty linked lists representing two non-negative integers. The most significant digit comes first and each of their nodes contain a single digit. Add the two numbers and return it as a linked list.

You may assume the two numbers do not contain any leading zero, except the number 0 itself.

Follow up: What if you cannot modify the input lists? In other words, reversing the lists is not allowed.

Input: (7 → 2 → 4 → 3) + (5 → 6 → 4)

Output: 7 → 8 → 0 → 7

Python:

```

# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None

class Solution(object):
    def addTwoNumbers(self, l1, l2):
        """
        :type l1: ListNode
        :type l2: ListNode
        :rtype: ListNode
        """
        s1, s2 = [], []
        while l1:
            s1.append(l1.val)
            l1 = l1.next
        while l2:
            s2.append(l2.val)
            l2 = l2.next
        carry = 0
        curr = ListNode(0)

```



```

while s1 or s2:
    val = carry
    if s1: val += s1.pop()
    if s2: val += s2.pop()
    curr.val = val % 10
    carry = val / 10
    head = ListNode(0)
    head.next = curr
    curr = head
if carry > 0:
    curr.val = carry
    return curr
else:
    return curr.next

```

3.4 Plus One Linked List (E)

Given a non-negative number represented as a singly linked list of digits, plus one to the number. The digits are stored such that the most significant digit is at the head of the list.

Example:

Input: 1 → 2 → 3

Output: 1 → 2 → 4

```

class Solution {
public:
    ListNode *plusOne(ListNode *head) {
        if (!head) return head;
        int carry = 1;
        ListNode *rev_head = reverse(head), *p = rev_head;

        while (p) {
            int sum = p->val + carry;
            if (sum == 10) {
                p->val = 0;
                carry = 1;
                p = p->next;
            } else {
                carry = 0;
                break;
            }
        }

        if (carry == 1) {
            p->next = new ListNode(1);
        }
    }
};

```

```

    }

    return reverse(rev_head);
}

ListNode *reverse(ListNode *head) {
    ListNode *p1 = head->next, *p2;
    head->next = NULL;

    while (p1->next) {
        p2 = p1->next;
        p1->next = head;
        head = p1;
        p1 = p2;
    }

    return head;
}
};

```

3.5 Palindrome Linked List (E)

Given a singly linked list, determine if it is a palindrome.

Python:

```

# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None

# stack
class Solution(object):
    def isPalindrome(self, head):
        """
        :type head: ListNode
        :rtype: bool
        """
        s = []
        x = head
        while x:
            s.append(x.val)
            x = x.next
        while s:
            tmp = s.pop()

```

```

        if tmp != head.val: return False
        head = head.next
    return True

# stack with slow and fast pointers
class Solution(object):
    def isPalindrome(self, head):
        """
        :type head: ListNode
        :rtype: bool
        """
        if not head: return True
        s = []
        slow, fast = head, head
        s.append(head.val)
        while fast.next and fast.next.next:
            slow = slow.next
            fast = fast.next.next
            s.append(slow.val)
        if not fast.next: s.pop()
        while slow.next:
            slow = slow.next
            if s.pop() != slow.val: return False
        return True

```

C++:

```

// reverse the right half list and compare it to the left half list
class Solution {
public:
    bool isPalindrome(ListNode *head) {
        if (!head || !head->next) return true;

        ListNode *slow = head, *fast = head;
        while (fast->next && fast->next->next) {
            slow = slow->next;
            fast = fast->next->next;
        }

        slow->next = reverseList(slow->next);
        slow = slow->next;

        while (slow) {
            if (head->val != slow->val) return false;
            head = head->next;
            slow = slow->next;
        }
    }
}

```

```

        return true;
    }

    ListNode *reverseList(ListNode *head) {
        ListNode *p1 = head->next, *p2;
        head->next = NULL;

        while (p1) {
            p2 = p1->next;
            p1->next = head;
            head = p1;
            p1 = p2;
        }

        return head;
    }
};

```

3.6 Swap Nodes in Pairs (E)

Given a linked list, swap every two adjacent nodes and return its head.

For example, Given 1 → 2 → 3 → 4, you should return the list as 2 → 1 → 4 → 3.

Your algorithm should use only constant space. You may not modify the values in the list, only nodes itself can be changed.

```

# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None

# Iteration
class Solution(object):
    def swapPairs(self, head):
        """
        :type head: ListNode
        :rtype: ListNode
        """
        dummy = ListNode(0)
        dummy.next = head
        p = dummy
        while p.next and p.next.next:
            t = p.next.next

```

```

        p.next.next = t.next
        t.next = p.next
        p.next = t
        p = t.next
    return dummy.next

# Recursion
class Solution(object):
    def swapPairs(self, head):
        """
        :type head: ListNode
        :rtype: ListNode
        """
        if not head or not head.next:
            return head
        t = head.next
        head.next = self.swapPairs(head.next.next)
        t.next = head
        return t

```

```

// iterative
class Solution {
public:
    ListNode *swapPairs(ListNode *head) {
        ListNode *new_head = new ListNode(0);
        new_head->next = head;
        ListNode *prev = new_head, *cur = head;

        while(cur && cur->next) {
            prev->next = cur->next;
            cur->next = cur->next->next;
            prev->next->next = cur;
            prev = cur;
            cur = cur->next;
        }

        return new_head->next;
    }
};

```

```

// recursive
class Solution {
public:
    ListNode* swapPairs(ListNode* head) {
        if (head == NULL || head->next == NULL)
            return head;

```

```

        ListNode *p = head->next;
        head->next = swapPairs(p->next);
        p->next = head;

        return p;
    }
};

```

3.7 Reverse Linked List (E)

Reverse a singly linked list.

```

# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None

# iteration with stack
class Solution(object):
    def reverseList(self, head):
        """
        :type head: ListNode
        :rtype: ListNode
        """
        s = []
        p = head
        while p:
            s.append(p.val)
            p = p.next
        dummy = ListNode(0)
        p = dummy
        while s:
            p.next = ListNode(s.pop())
            p = p.next
        return dummy.next

# iteration by inserting nodes after new head
class Solution(object):
    def reverseList(self, head):
        """
        :type head: ListNode
        :rtype: ListNode
        """
        newhead = None

```

```

        while head:
            t = head.next
            head.next = newhead
            newhead = head
            head = t
        return newhead

# recursive
class Solution(object):
    def reverseList(self, head):
        """
        :type head: ListNode
        :rtype: ListNode
        """
        if not head or not head.next: return head
        newhead = self.reverseList(head.next)
        head.next.next = head
        head.next = None
        return newhead

```

```

// recursive solution
class Solution {
public:
    ListNode* reverseList(ListNode* head) {
        if (!head || !(head -> next))
            return head;
        ListNode* node = reverseList(head -> next);
        head -> next -> next = head;
        head -> next = NULL;
        return node;
    }
};

// iterative solution
class Solution {
public:
    ListNode* reverseList(ListNode* head) {
        if (head == NULL || head->next == NULL)
            return head;

        ListNode *p1 = head->next, *p2;
        head->next = NULL;
        while (p1 != NULL) {
            p2 = p1->next;
            p1->next = head;
            head = p1;
            p1 = p2;
        }
    }
};

```

```

    }

    return head;
}
};

```

3.8 Reverse Linked List II (M)

Reverse a linked list from position m to n . Do it in-place and in one-pass.

For example: Given $1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \rightarrow NULL$, $m = 2$ and $n = 4$, return $1 \rightarrow 4 \rightarrow 3 \rightarrow 2 \rightarrow 5 \rightarrow NULL$.

Note: Given m , n satisfy the following condition: $1 \leq m \leq n \leq \text{length of list}$.

```

# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None

class Solution(object):
    def reverseBetween(self, head, m, n):
        """
        :type head: ListNode
        :type m: int
        :type n: int
        :rtype: ListNode
        """
        dummy = ListNode(0)
        dummy.next = head
        prev = dummy
        for i in range(m-1):
            prev = prev.next
        curr = prev.next
        for i in range(m, n):
            t = curr.next
            curr.next = t.next
            t.next = prev.next
            prev.next = t
        return dummy.next

```

```

class Solution {
public:

```



```

ListNode* reverseBetween(ListNode* head, int m, int n) {
    if (!head || m >= n) return head;
    ListNode *new_head = new ListNode(0);
    new_head->next = head;
    ListNode *pre = new_head;
    for (int i = 1; i < m; ++i) pre = pre->next;
    ListNode *cur = pre->next; // start of the mth node
    for (int i = 1; i <= n - m; ++i) {
        ListNode *tmp = cur->next;
        cur->next = tmp->next;
        tmp->next = pre->next;
        pre->next = tmp;
    }

    return new_head->next;
}
};

```

3.9 Rotate Linked List (M)

Given a list, rotate the list to the right by k places, where k is non-negative.

For example:

Given 1- > 2- > 3- > 4- > 5- > *NULL* and k = 2, return 4- > 5- > 1- > 2- > 3- > *NULL*.

```

# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None

class Solution(object):
    def rotateRight(self, head, k):
        """
        :type head: ListNode
        :type k: int
        :rtype: ListNode
        """
        if not head: return None
        n = 1
        cur = head
        while cur.next:
            cur = cur.next
            n += 1

```

```

    # make a cycle list
    cur.next = head
    # locate the element before the newhead after rotation
    m = n - k % n
    for i in range(m):
        cur = cur.next
    newhead = cur.next
    cur.next = None
    return newhead

```

```

class Solution {
public:
    ListNode* rotateRight(ListNode* head, int k) {
        if (!head || k <= 0) return head;
        ListNode *p = head;
        int n = 1;
        while (p->next){           // get the length of list
            p = p->next;
            ++n;
        }
        p->next = head;           // make a circle list
        k = k % n;                // get the correct k
        for(int i = 0; i < n - k; ++i) // move p to the correct position
            p = p->next;
        head = p->next;
        p->next = NULL;
        return head;
    }
};

```

3.10 Reorder List (M)

Given a singly linked list L : $L_0 \rightarrow L_1 \rightarrow \dots \rightarrow L_{n-1} \rightarrow L_n$, reorder it to: $L_0 \rightarrow L_{n-1} \rightarrow L_1 \rightarrow L_{n-2} \rightarrow L_2 \rightarrow L_{n-3} \rightarrow \dots$. You must do this in-place without altering the nodes' values.

For example, Given 1,2,3,4, reorder it to 1,4,2,3.

```

// 1. Break the list to two lists from center
// 2. Reverse the second list
// 3. Insert the second list to the first list alternatively
class Solution {
public:
    void reorderList(ListNode* head) {

```

```

    if (!head || !head->next || !head->next->next) return;
    ListNode *slow = head, *fast = head;
    // step 1
    while (fast->next && fast->next->next) {
        slow = slow->next;
        fast = fast->next->next;
    }
    ListNode *mid = slow->next;
    slow->next = NULL;
    // step 2
    ListNode *new_head = reverseList(mid);
    // step 3
    while (head && new_head) {
        ListNode *tmp = head->next;
        head->next = new_head;
        new_head = new_head->next;
        head->next->next = tmp;
        head = tmp;
    }
}
ListNode *reverseList(ListNode *head) {
    ListNode *p1 = head->next, *p2;
    head->next = NULL;
    while (p1) {
        p2 = p1->next;
        p1->next = head;
        head = p1;
        p1 = p2;
    }
    return head;
}
};

```

3.11 Partition List (M)

Given a linked list and a value x , partition it such that all nodes less than x come before nodes greater than or equal to x . You should preserve the original relative order of the nodes in each of the two partitions.

For example, Given $1 \rightarrow 4 \rightarrow 3 \rightarrow 2 \rightarrow 5 \rightarrow 2$ and $x = 3$, return $1 \rightarrow 2 \rightarrow 2 \rightarrow 4 \rightarrow 3 \rightarrow 5$.

```

# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):

```

```

#         self.val = x
#         self.next = None

class Solution(object):
    def partition(self, head, x):
        """
        :type head: ListNode
        :type x: int
        :rtype: ListNode
        """
        if not head: return head
        dummy1, dummy2 = ListNode(0), ListNode(0)
        dummy1.next = head
        p1, p2 = dummy1, dummy2
        while p1.next:
            if p1.next.val < x:
                p2.next = p1.next
                p1.next = p1.next.next
                p2 = p2.next
            else:
                p1 = p1.next
        p2.next = dummy1.next
        return dummy2.next

```

```

class Solution {
public:
    ListNode* partition(ListNode* head, int x) {
        ListNode *head1 = new ListNode(0);
        ListNode *head2 = new ListNode(0);
        ListNode *p1 = head1;
        ListNode *p2 = head2;
        while (head) {
            if (head->val < x) {
                p1->next = head;
                p1 = p1->next;
            } else {
                p2->next = head;
                p2 = p2->next;
            }
            head = head->next;
        }
        p2->next = NULL;
        p1->next = head2->next;
        return head1->next;
    }
};

```

3.12 Odd Even Linked List (M)

Given a singly linked list, group all odd nodes together followed by the even nodes. Please note here we are talking about the node number and not the value in the nodes.

You should try to do it in place. The program should run in $O(1)$ space complexity and $O(\text{nodes})$ time complexity.

Example: Given $1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \rightarrow \text{NULL}$, return $1 \rightarrow 3 \rightarrow 5 \rightarrow 2 \rightarrow 4 \rightarrow \text{NULL}$.

Note: The relative order inside both the even and odd groups should remain as it was in the input. The first node is considered odd, the second node even and so on ...

```
class Solution {
public:
    ListNode* oddEvenList(ListNode* head) {
        if (!head || !head->next) return head;
        ListNode *odd = head, *even = head->next;
        while (even && even->next) {
            ListNode *tmp = odd->next; // must store odd->next as tmp
            odd->next = even->next;
            even->next = even->next->next;
            odd->next->next = tmp; // update odd->next->next to tmp but not the
                                // current even
            even = even->next;
            odd = odd->next;
        }
        return head;
    }
};
```

```
class Solution {
public:
    ListNode* oddEvenList(ListNode* head) {
        if (!head || !head->next) return head;
        ListNode *odd = head, *even = head->next, *even_head = even;
        while (even && even->next) {
            odd->next = even->next;
            odd = even->next;
            even->next = odd->next;
            even = odd->next;
        }
        odd->next = even_head;
        return head;
    }
};
```

```
};
```

3.13 Linked List Random Node (M)

Given a singly linked list, return a random node's value from the linked list. Each node must have the same probability of being chosen.

Follow up: What if the linked list is extremely large and its length is unknown to you? Could you solve this efficiently without using extra space?

Example:

```
// Init a singly linked list [1,2,3].
ListNode head = new ListNode(1);
head.next = new ListNode(2);
head.next.next = new ListNode(3);
Solution solution = new Solution(head);
```

```
// getRandom() should return either 1, 2, or 3 randomly. Each element should have equal
probability of returning.
solution.getRandom();
```

```
// 1. Regular solution
class Solution {
public:
    /** @param head The linked list's head.
        Note that the head is guaranteed to be not null, so it contains at least
        one node. */
    Solution(ListNode* head) {
        n = 0;
        ListNode *p = head;
        this->head = head;
        while (p) {
            ++n; // get the length of list
            p = p->next;
        }
    }

    /** Returns a random node's value. */
    int getRandom() {
        int idx = rand() % n;
        ListNode *p = head;
        while (idx) {
```

```

        p = p->next;
        --idx;
    }
    return p->val;
}

private:
    int n;
    ListNode *head;
};

// 2. Reservoir sampling
class Solution {
public:
    /** @param head The linked list's head. Note that the head is guaranteed to
        be not null, so it contains at least one node. */
    Solution(ListNode* head) {
        this->head = head;
    }

    /** Returns a random node's value. */
    int getRandom() {
        int res = head->val, i = 2;
        ListNode *cur = head->next;
        while (cur) {
            int j = rand() % i; // get a number from [0, i-1]
            if (j == 0) res = cur->val; // if j = 0, the random value is cur->val
            ++i;
            cur = cur->next;
        }
        return res;
    }
private:
    ListNode *head;
};

/**
 * Your Solution object will be instantiated and called as such:
 * Solution obj = new Solution(head);
 * int param_1 = obj.getRandom();
 */

```

3.14 Delete Node in a Linked List (E)

Write a function to delete a node (except the tail) in a singly linked list, given only access to that node.

Supposed the linked list is 1-2-3-4 and you are given the third node with value 3, the linked list should become 1-2-4 after calling your function.

```
# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None

class Solution(object):
    def deleteNode(self, node):
        """
        :type node: ListNode
        :rtype: void Do not return anything, modify node in-place instead.
        """
        node.val = node.next.val
        t = node.next
        node.next = t.next
        del t
```

```
class Solution {
public:
    void deleteNode(ListNode* node) {
        ListNode *tmp = node->next;
        *node = *tmp;
        delete tmp;
    }
};
```

3.15 Remove Linked List Elements (E)

Remove all elements from a linked list of integers that have value val.

Example:

Given: 1-2-6-3-4-5-6, val = 6

Return: 1-2-3-4-5

```
# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None
```



```

class Solution(object):
    def removeElements(self, head, val):
        """
        :type head: ListNode
        :type val: int
        :rtype: ListNode
        """
        dummy = ListNode(0)
        dummy.next = head
        prev, curr = dummy, head
        while curr:
            if curr.val == val:
                prev.next = curr.next
                t = curr
                curr = curr.next
                del t
            else:
                prev = prev.next
                curr = curr.next
        return dummy.next

```

```

class Solution {
public:
    ListNode* removeElements(ListNode* head, int val) {
        while (head != NULL && head->val == val)
            head = head->next;

        if (head == NULL)
            return head;

        ListNode *p1 = head, *p2 = head->next;
        while (p2 != NULL) {
            if (p2->val == val) {
                p1->next = p2->next;
            } else {
                p1 = p2;
            }
            p2 = p2->next;
        }

        return head;
    }
};

```

3.16 Remove Nth Node From End of List (E)

Given a linked list, remove the nth node from the end of list and return its head.

For example,

Given linked list: 1 → 2 → 3 → 4 → 5, and n = 2.

After removing the second node from the end, the linked list becomes 1 → 2 → 3 → 5.

```
# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None

class Solution(object):
    def removeNthFromEnd(self, head, n):
        """
        :type head: ListNode
        :type n: int
        :rtype: ListNode
        """
        dummy = ListNode(0)
        dummy.next = head
        p1, p2 = head, head
        for i in range(n):
            p2 = p2.next
        if not p2:
            return p1.next
        while p2.next:
            p1 = p1.next
            p2 = p2.next
        p1.next = p1.next.next
        return dummy.next
```

```
class Solution {
public:
    ListNode* removeNthFromEnd(ListNode* head, int n) {
        ListNode* slow = head;
        ListNode* fast = head;

        for (int i = 1; i <= n; ++i)
            fast = fast->next;

        if (!fast) return head->next;

        while (fast->next) {
```

```

        slow = slow->next;
        fast = fast->next;
    }
    slow->next = slow->next->next;    // remove the n-th node

    return head;
}
};

```

3.17 Remove Duplicates from Sorted List (E)

Given a sorted linked list, delete all duplicates such that each element appear only once.

For example:

Given 1-1-2, return 1-2.

Given 1-1-2-3-3, return 1-2-3.

```

class Solution {
public:
    ListNode* deleteDuplicates(ListNode* head) {
        if (head == NULL || head->next == NULL)
            return head;

        ListNode *p1 = head, *p2 = head->next;

        while (p2 != NULL) {
            if (p1->val == p2->val) {
                p1->next = p2->next;
            } else {
                p1 = p2;
            }
            p2 = p2->next;
        }

        return head;
    }
};

```

3.18 Remove Duplicates from Sorted List II (M)

Given a sorted linked list, delete all nodes that have duplicate numbers, leaving only distinct numbers from the original list.

For example,
Given 1-2-3-3-4-4-5, return 1-2-5.
Given 1-1-1-2-3, return 2-3.

```
class Solution {
public:
    ListNode* deleteDuplicates(ListNode* head) {
        if (head == NULL || head->next == NULL)
            return head;

        ListNode *new_head = new ListNode(0); // define a new head
        new_head->next = head;
        ListNode *p1 = new_head, *p2 = head;

        while(p2 != NULL) {
            while (p2->next != NULL && p2->val == p2->next->val) // set p2 to
                the last node of duplicates
                p2 = p2->next;

            if (p1->next == p2) {
                p1 = p1->next;           // no duplicate
            } else {
                p1->next = p2->next;     // skip all duplicates
            }

            p2 = p2->next;
        }

        return new_head->next;
    }
};
```

3.19 Linked List Cycle (E)

Given a linked list, determine if it has a cycle in it.

```
# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None

class Solution(object):
```

```

def hasCycle(self, head):
    """
    :type head: ListNode
    :rtype: bool
    """
    slow, fast = head, head
    while fast and fast.next:
        slow = slow.next
        fast = fast.next.next
        if slow == fast: return True
    return False

```

```

class Solution {
public:
    bool hasCycle(ListNode *head) {
        if (head == NULL)
            return false;

        ListNode *slow = head, *fast = head;
        while (fast->next != NULL && fast->next->next != NULL) {
            slow = slow->next;
            fast = fast->next->next;
            if (slow == fast)
                return true;
        }

        return false;
    }
};

```

3.20 Linked List Cycle II (M)

Given a linked list, return the node where the cycle begins. If there is no cycle, return null.

```

# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None

class Solution(object):
    def detectCycle(self, head):
        """
        :type head: ListNode

```

```

:rtype: ListNode
"""
slow, fast = head, head
while fast and fast.next:
    slow = slow.next
    fast = fast.next.next
    if slow == fast: break
if not fast or not fast.next: return None
slow = head
while slow != fast:
    slow = slow.next
    fast = fast.next
return slow

```

```

/**
 * len: length of the linked list
 * a: length of the head to the node where the cycle begins
 * b: length of the node where the cycle begins to the node where the slow and
    fast meet
 * r: length of the cycle
 * s: length of the slow moved
 *  $s = a + b$ ,  $2s = s + kr$ ;  $\rightarrow a + b = kr = (k-1)r + r$ ,  $r = \text{len} - a$ ;  $\rightarrow a =$ 
     $(k-1)r + \text{len} - a - b$ 
 */
class Solution {
public:
    ListNode *detectCycle(ListNode *head) {
        if (head == NULL)
            return NULL;

        ListNode *slow = head, *fast = head;

        while (fast->next != NULL && fast->next->next != NULL) {
            slow = slow->next;
            fast = fast->next->next;
            if (slow == fast) {
                fast = head;
                while (slow != fast) {
                    slow = slow->next;
                    fast = fast->next;
                }
                return slow;
            }
        }

        return NULL;
    }
}

```

```
};
```

3.21 Merge Two Sorted Lists (E)

Merge two sorted linked lists and return it as a new list. The new list should be made by splicing together the nodes of the first two lists.

```
# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None
```

```
class Solution(object):
    def mergeTwoLists(self, l1, l2):
        """
        :type l1: ListNode
        :type l2: ListNode
        :rtype: ListNode
        """
        dummy = ListNode(0)
        p = dummy
        while l1 and l2:
            if l1.val <= l2.val:
                p.next = l1
                l1 = l1.next
            else:
                p.next = l2
                l2 = l2.next
            p = p.next
        if l1: p.next = l1
        if l2: p.next = l2
        return dummy.next
```

```
class Solution {
public:
    ListNode* mergeTwoLists(ListNode* l1, ListNode* l2) {
        if (l1 == NULL) return l2;
        if (l2 == NULL) return l1;

        if (l1->val < l2->val) {
            l1->next = mergeTwoLists(l1->next, l2);
            return l1;
        } else {
```

```

        l2->next = mergeTwoLists(l2->next, l1);
        return l2;
    }
}
};

```

3.22 Merge k Sorted Lists (H)

Merge k sorted linked lists and return it as one sorted list. Analyze and describe its complexity.

```

# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None

# BF: Time - O(NlogN) Space - O(N)
class Solution(object):
    def mergeKLists(self, lists):
        """
        :type lists: List[ListNode]
        :rtype: ListNode
        """
        p = dummy = ListNode(0)
        nodes = []
        for l in lists:
            while l:
                nodes.append(l.val)
                l = l.next
        for x in sorted(nodes):
            p.next = ListNode(x)
            p = p.next
        return dummy.next

# Priority queue: Time - O(NlogK), K is the number of linked lists
#                 Space - O(N)
from Queue import PriorityQueue
class Solution(object):
    def mergeKLists(self, lists):
        """
        :type lists: List[ListNode]
        :rtype: ListNode
        """
        p = dummy = ListNode(0)

```



```

pq = PriorityQueue()
# for each sublist, only save the first node to pq,
# so the comparison complexity can be maintained as logK
# for insertion and pop.
for l in lists:
    if l:
        pq.put((l.val, l))
while not pq.empty():
    val, node = pq.get()
    p.next = ListNode(val)
    p = p.next
    node = node.next
    if node:
        pq.put((node.val, node))
return dummy.next

```

```

// Divide & Conquer
// Suppose initially each list is of average length n, then:  $k/2 \cdot (2n) + k/4 \cdot (4n) + k/8 \cdot (8n) \dots = \log k \cdot (kn)$ 
class Solution {
public:
    ListNode *mergeKLists(vector<ListNode *> &lists) {
        if(lists.empty()) return NULL;

        while(lists.size() > 1){
            lists.push_back(mergeTwoLists(lists[0], lists[1]));
            lists.erase(lists.begin());
            lists.erase(lists.begin());
        }
        return lists.front();
    }

    ListNode* mergeTwoLists(ListNode* l1, ListNode* l2) {
        if (l1 == NULL) return l2;
        if (l2 == NULL) return l1;

        if (l1->val < l2->val) {
            l1->next = mergeTwoLists(l1->next, l2);
            return l1;
        } else {
            l2->next = mergeTwoLists(l2->next, l1);
            return l2;
        }
    }
};

```

Chapter 4

Stack and Queue

4.1 Implement Stack using Queues (E)

Implement the following operations of a stack using queues.

push(x) – Push element x onto stack.

pop() – Removes the element on top of the stack.

top() – Get the top element.

empty() – Return whether the stack is empty.

```
class MyStack(object):

    def __init__(self):
        """
        Initialize your data structure here.
        """
        self.queue = []

    def push(self, x):
        """
        Push element x onto stack.
        :type x: int
        :rtype: None
        """
        self.queue.insert(0, x)
        n = len(self.queue)
        for i in range(1, n):
            self.queue.insert(0, self.queue[-1])
            self.queue.pop()

    def pop(self):
        """
```

```

        Removes the element on top of the stack and returns that element.
        :rtype: int
        """
        return self.queue.pop()

def top(self):
    """
    Get the top element.
    :rtype: int
    """
    return self.queue[-1]

def empty(self):
    """
    Returns whether the stack is empty.
    :rtype: bool
    """
    return not self.queue

# Your MyStack object will be instantiated and called as such:
# obj = MyStack()
# obj.push(x)
# param_2 = obj.pop()
# param_3 = obj.top()
# param_4 = obj.empty()

```

```

class Stack {
queue<int> que;
public:
    // Push element x onto stack.
    void push(int x) {
        que.push(x);                // push x to tail
        for (int i = 1; i < que.size(); ++i) { // repeat until x is the head
            que.push(que.front());          // push head to tail
            que.pop();                      // pop the old head
        }
    }

    // Removes the element on top of the stack.
    void pop() {
        que.pop();
    }

    // Get the top element.

```

```

int top() {
    return que.front();
}

// Return whether the stack is empty.
bool empty() {
    return que.empty();
}
};

```

4.2 Implement Queue using Stacks (E)

Implement the following operations of a queue using stacks.

push(x) – Push element x to the back of queue.

pop() – Removes the element from in front of queue.

peek() – Get the front element.

empty() – Return whether the queue is empty.

```

class MyQueue(object):

    def __init__(self):
        """
        Initialize your data structure here.
        """
        self.s1 = []
        self.s2 = []

    def push(self, x):
        """
        Push element x to the back of queue.
        :type x: int
        :rtype: None
        """
        while self.s1:
            self.s2.append(self.s1.pop())
        self.s1.append(x)
        while self.s2:
            self.s1.append(self.s2.pop())

    def pop(self):
        """
        Removes the element from in front of queue and returns that element.

```

```

        :rtype: int
        """
        return self.s1.pop()

def peek(self):
    """
    Get the front element.
    :rtype: int
    """
    return self.s1[-1]

def empty(self):
    """
    Returns whether the queue is empty.
    :rtype: bool
    """
    return not self.s1

# Your MyQueue object will be instantiated and called as such:
# obj = MyQueue()
# obj.push(x)
# param_2 = obj.pop()
# param_3 = obj.peek()
# param_4 = obj.empty()

```

```

class Queue {
stack<int> s1, s2;
public:
    // Push element x to the back of queue.
    void push(int x) {
        while (!s2.empty()){
            s1.push(s2.top());
            s2.pop();
        }
        s1.push(x);
    }

    // Removes the element from in front of queue.
    void pop(void) {
        while (!s1.empty()) {
            s2.push(s1.top());
            s1.pop();
        }
        s2.pop();
    }
}

```

```

// Get the front element.
int peek(void) {
    while (!s1.empty()) {
        s2.push(s1.top());
        s1.pop();
    }
    return s2.top();
}

// Return whether the queue is empty.
bool empty(void) {
    return s1.empty() && s2.empty();
}
};

```

4.3 Min Stack (E)

Design a stack that supports push, pop, top, and retrieving the minimum element in constant time.

push(x) – Push element x onto stack.
 pop() – Removes the element on top of the stack.
 top() – Get the top element.
 getMin() – Retrieve the minimum element in the stack.

Example:

```

MinStack minStack = new MinStack();
minStack.push(-2);
minStack.push(0);
minStack.push(-3);
minStack.getMin(); – > Returns -3.
minStack.pop();
minStack.top(); – > Returns 0.
minStack.getMin(); – > Returns -2.

```

```

class MinStack {
public:
    stack<int> s;
    stack<int> s_min;                // use a new stack to store minimum
    numbers

    void push(int x) {
        s.push(x);
    }

```

```

        if (s_min.empty() || x <= getMin()) // make a copy of a min value to s_min
            s_min.push(x);
    }

    void pop() {
        if (s.top() == getMin()) // update s_min if the min value is popped
            s_min.pop();
        s.pop();
    }

    int top() {
        return s.top();
    }

    int getMin() {
        return s_min.top();
    }
};

```

4.4 Moving Average from Data Stream (E)

Given a stream of integers and a window size, calculate the moving average of all integers in the sliding window.

For example,

MovingAverage m = new MovingAverage(3);

m.next(1) = 1

m.next(10) = (1 + 10) / 2

m.next(3) = (1 + 10 + 3) / 3

m.next(5) = (10 + 3 + 5) / 3

```

class MovingAverage {
public:
    MovingAverage(int size) {
        this->size = size;
        sum = 0;
    }

    double next(int val) {
        if (q.size() >= size) {
            sum -= q.front();
            q.pop();
        }
        q.push(val);
    }
};

```

```

        sum += val;
        return sum / q.size();
    }

private:
    queue<int> q;
    int size;
    double sum;
};

```

4.5 Evaluate Reverse Polish Notation (M)

Evaluate the value of an arithmetic expression in Reverse Polish Notation. Valid operators are +, -, *, /. Each operand may be an integer or another expression.

Some examples:

["2", "1", "+", "3", "*"] → ((2 + 1) * 3) → 9
 ["4", "13", "5", "/", "+"] → (4 + (13/5)) → 6

```

// atoi: string to integer
// c_str(): Returns a pointer to a null-terminated character array with data
//          equivalent to those stored in the string
class Solution {
public:
    int evalRPN(vector<string> &tokens) {
        if (tokens.size() == 1) return atoi(tokens[0].c_str());
        stack<int> s;
        for (int i = 0; i < tokens.size(); ++i) {
            if (tokens[i] != "+" && tokens[i] != "-" && tokens[i] != "*" &&
                tokens[i] != "/") {
                s.push(atoi(tokens[i].c_str()));
            } else {
                int m = s.top();
                s.pop();
                int n = s.top();
                s.pop();
                if (tokens[i] == "+") s.push(n + m);
                if (tokens[i] == "-") s.push(n - m);
                if (tokens[i] == "*") s.push(n * m);
                if (tokens[i] == "/") s.push(n / m);
            }
        }
        return s.top();
    }
};

```

4.6 Remove K Digits (M)

Given a non-negative integer num represented as a string, remove k digits from the number so that the new number is the smallest possible.

Note:

The length of num is less than 10002 and will be $\geq k$.
The given num does not contain any leading zero.

Example 1:

Input: num = "1432219", k = 3

Output: "1219"

Explanation: Remove the three digits 4, 3, and 2 to form the new number 1219 which is the smallest.

Example 2:

Input: num = "10200", k = 1

Output: "200"

Explanation: Remove the leading 1 and the number is 200. Note that the output must not contain leading zeroes.

Example 3:

Input: num = "10", k = 2

Output: "0"

Explanation: Remove all the digits from the number and it is left with nothing which is 0.

```
class Solution(object):
    def removeKdigits(self, num, k):
        """
        :type num: str
        :type k: int
        :rtype: str
        """
        res = []
        # only leave the small digits in res
        for n in num:
            while k > 0 and res and res[-1] > n:
                res.pop()
                k -= 1
            res.append(n)
        # make sure exact k digits are removed
```

```

while k > 0 and res:
    res.pop()
    k -= 1
# remove leading 0s
while res and res[0] == '0':
    res.pop(0)
# join list to resume str
if res:
    return ''.join(res)
else:
    return '0'

```

4.7 Kth Largest Element in an Array (M)

Find the kth largest element in an unsorted array. Note that it is the kth largest element in the sorted order, not the kth distinct element.

For example, Given [3,2,1,5,6,4] and k = 2, return 5.

Note: You may assume k is always valid, $1 \leq k \leq \text{array's length}$.

```

# O(NlogN)
class Solution(object):
    def findKthLargest(self, nums, k):
        """
        :type nums: List[int]
        :type k: int
        :rtype: int
        """
        nums.sort()
        return nums[len(nums)-k]

```

```

# O(Nlogk)
from Queue import PriorityQueue
class Solution(object):
    def findKthLargest(self, nums, k):
        """
        :type nums: List[int]
        :type k: int
        :rtype: int
        """
        pq = PriorityQueue()
        # O(Nlogk)
        for num in nums:
            pq.put(num)

```

```
        if pq.qsize() == k + 1: pq.get()
    return pq.get()
```

4.8 Top K Frequent Elements (M)

Given a non-empty array of integers, return the k most frequent elements.

For example, Given [1,1,1,2,2,3] and k = 2, return [1,2].

Note: You may assume k is always valid, $1 \leq k \leq$ number of unique elements.

Your algorithm's time complexity must be better than $O(n \log n)$, where n is the array's size.

```
from Queue import PriorityQueue
class Solution(object):
    def topKFrequent(self, nums, k):
        """
        :type nums: List[int]
        :type k: int
        :rtype: List[int]
        """
        pq = PriorityQueue()
        n = len(nums)
        freq_map, res = {}, []
        # O(N)
        for i in range(n):
            if nums[i] in freq_map:
                freq_map[nums[i]] += 1
            else:
                freq_map.update({nums[i]: 1})
        # O(Mlogk), M is the number of element in freq_map
        for num, freq in freq_map.items():
            pq.put((freq, num))
            if pq.qsize() == k + 1: pq.get()
        # O(klogk)
        for i in range(k):
            freq, num = pq.get()
            res.append(num)
        return res
```

```
class Solution {
public:
    vector<int> topKFrequent(vector<int>& nums, int k) {
        unordered_map<int, int> m;
        // Priority queues are a type of container adaptors, specifically
```

```

        designed such that its first element is always the greatest of the
        elements it contains, according to some strict weak ordering criterion.
priority_queue<pair<int, int>> q;
vector<int> res;
for (auto a : nums) {
    ++m[a];
}
for (auto it : m) {
    q.push({it.second, it.first});
}
for (int i = 0; i < k; ++i) {
    res.push_back(q.top().second);
    q.pop();
}
return res;
}
};

```

4.9 Kth Smallest Element in a Sorted Matrix (M)

Given a $n \times n$ matrix where each of the rows and columns are sorted in ascending order, find the k th smallest element in the matrix.

Note that it is the k th smallest element in the sorted order, not the k th distinct element.

Example:

matrix = [[1, 5, 9], [10, 11, 13], [12, 13, 15]],
 $k = 8$, return 13.

Note: You may assume k is always valid, $1 \leq k \leq n^2$.

```

from Queue import PriorityQueue
class Solution(object):
    def kthSmallest(self, matrix, k):
        """
        :type matrix: List[List[int]]
        :type k: int
        :rtype: int
        """
        pq = PriorityQueue()
        m, n = len(matrix), len(matrix[0])
        res = []
        for i in range(m):
            for j in range(n):
                pq.put(matrix[i][j])

```

```

        for i in range(m * n):
            num = pq.get()
            res.append(num)
        return res[k-1]

```

```

// 1. Binary search
class Solution {
public:
    int kthSmallest(vector<vector<int>>& matrix, int k) {
        int left = matrix[0][0], right = matrix.back().back();
        while (left < right) {
            int mid = left + (right - left) / 2, cnt = 0;
            // upper_bound(): Returns an iterator pointing to the first element
            // in the range [first,last) which compares greater than val.
            for (int i = 0; i < matrix.size(); ++i) {
                // get the position of upper_bound compared to mid
                cnt += upper_bound(matrix[i].begin(), matrix[i].end(), mid) -
                    matrix[i].begin();
            }
            if (cnt < k) left = mid + 1;
            else right = mid;
        }
        return left;
    }
};

// 2. Heap
class Solution {
public:
    int kthSmallest(vector<vector<int>>& matrix, int k) {
        priority_queue<int, vector<int>> q;
        for (int i = 0; i < matrix.size(); ++i) {
            for (int j = 0; j < matrix[i].size(); ++j) {
                q.emplace(matrix[i][j]);
                if (q.size() > k) q.pop();
            }
        }
        return q.top();
    }
};

```

4.10 K Closest Points to Origin (M)

We have a list of points on the plane. Find the K closest points to the origin (0, 0). (Here, the distance between two points on a plane is the Euclidean distance.)

You may return the answer in any order. The answer is guaranteed to be unique (except for the order that it is in.)

Example 1:

Input: points = [[1,3],[-2,2]], K = 1 Output: [[-2,2]] Explanation: The distance between (1, 3) and the origin is $\sqrt{10}$. The distance between (-2, 2) and the origin is $\sqrt{8}$. Since $\sqrt{8} < \sqrt{10}$, (-2, 2) is closer to the origin. We only want the closest K = 1 points from the origin, so the answer is just [[-2,2]].

Example 2:

Input: points = [[3,3],[5,-1],[-2,4]], K = 2 Output: [[3,3],[-2,4]] (The answer [[-2,4],[3,3]] would also be accepted.)

Note:

1 ≤ K ≤ points.length ≤ 10000 -10000 ≤ points[i][0] ≤ 10000 -10000 ≤ points[i][1] ≤ 10000

```
from Queue import PriorityQueue
import math
class Solution(object):
    def kClosest(self, points, K):
        """
        :type points: List[List[int]]
        :type K: int
        :rtype: List[List[int]]
        """
        res = []
        pq = PriorityQueue()
        for p in points:
            d = math.sqrt(p[0]**2 + p[1]**2)
            pq.put((d, p))
        for i in range(K):
            dist, point = pq.get()
            res.append(point)
        return res
```

Chapter 5

Array

5.1 Bulls and Cows (E)

You are playing the following Bulls and Cows game with your friend: You write down a number and ask your friend to guess what the number is. Each time your friend makes a guess, you provide a hint that indicates how many digits in said guess match your secret number exactly in both digit and position (called "bulls") and how many digits match the secret number but locate in the wrong position (called "cows"). Your friend will use successive guesses and hints to eventually derive the secret number.

For example:

Secret number: "1807"

Friend's guess: "7810"

Hint: 1 bull and 3 cows. (The bull is 8, the cows are 0, 1 and 7.)

Please note that both secret number and friend's guess may contain duplicate digits, for example:

Secret number: "1123"

Friend's guess: "0111"

In this case, the 1st 1 in friend's guess is a bull, the 2nd or 3rd 1 is a cow, and your function should return "1A1B".

```
class Solution {
public:
    string getHint(string secret, string guess) {
        int bull = 0, cow = 0;
        int set1[10] = {0};
        int set2[10] = {0};
        int len = secret.size();

        for (int i = 0; i < len; ++i) {
            if (secret[i] == guess[i]) {
                ++bull;
            }
        }
    }
};
```

```

        } else {
            ++set1[secret[i] - '0'];
            ++set2[guess[i] - '0'];
        }
    }

    for (int i = 0; i < 10; ++i) {
        if (set1[i] != 0 && set2[i] != 0)
            cow += min(set1[i], set2[i]);
    }

    return to_string(bull) + 'A' + to_string(cow) + 'B';
}
};

```

5.2 Rotate Array (E)

Rotate an array of n elements to the right by k steps.

For example, with $n = 7$ and $k = 3$, the array $[1,2,3,4,5,6,7]$ is rotated to $[5,6,7,1,2,3,4]$.

```

class Solution(object):
    def rotate(self, nums, k):
        """
        :type nums: List[int]
        :type k: int
        :rtype: None Do not return anything, modify nums in-place instead.
        """
        for i in range(k):
            nums.insert(0, nums[-1])
            nums.pop()

class Solution(object):
    def rotate(self, nums, k):
        """
        :type nums: List[int]
        :type k: int
        :rtype: None Do not return anything, modify nums in-place instead.
        """
        n = len(nums)
        nums[:n-k] = reversed(nums[:n-k])
        nums[n-k:] = reversed(nums[n-k:])
        nums.reverse()

```

```

class Solution {
public:
    void rotate(vector<int> &nums, int k) {
        if (k == 0) return;
        int n = nums.size();
        k = k % n;           // get the correct k if k > n

        reverse(nums, 0, n-1);
        reverse(nums, 0, k-1);
        reverse(nums, k, n-1);
    }

    void reverse(vector<int> &nums, int start, int end) {
        int tmp;
        while (start < end) {
            tmp = nums[start];
            nums[start++] = nums[end];
            nums[end--] = tmp;
        }
    }
};

```

5.3 Move Zeros (E)

Given an array `nums`, write a function to move all 0's to the end of it while maintaining the relative order of the non-zero elements.

For example, given `nums = [0, 1, 0, 3, 12]`, after calling your function, `nums` should be `[1, 3, 12, 0, 0]`.

Note:

You must do this in-place without making a copy of the array.

Minimize the total number of operations.

```

class Solution(object):
    def moveZeroes(self, nums):
        """
        :type nums: List[int]
        :rtype: None Do not return anything, modify nums in-place instead.
        """
        idx = 0
        for i in range(len(nums)):
            if nums[i] != 0:
                nums[idx] = nums[i]

```

```

        idx += 1
    for i in range(idx, len(nums)):
        nums[i] = 0

```

```

class Solution {
public:
    void moveZeroes(vector<int>& nums) {
        int index = 0;
        for (int i = 0; i < nums.size(); ++i) {
            if (nums[i] != 0)
                nums[index++] = nums[i];
        }
        for (int i = index; i < nums.size(); ++i)
            nums[i] = 0;
    }
};

```

5.4 Remove Element (E)

Given an array and a value, remove all instances of that value in place and return the new length. Do not allocate extra space for another array, you must do this in place with constant memory. The order of elements can be changed. It doesn't matter what you leave beyond the new length.

Example:

Given input array `nums = [3,2,2,3]`, `val = 3`, Your function should return `length = 2`, with the first two elements of `nums` being 2.

```

class Solution(object):
    def removeElement(self, nums, val):
        """
        :type nums: List[int]
        :type val: int
        :rtype: int
        """
        idx = 0
        for i in range(len(nums)):
            if nums[i] != val:
                nums[idx] = nums[i]
                idx += 1
        return idx

```

```

class Solution {

```

```

public:
    int removeElement(vector<int>& nums, int val) {
        int index = 0;
        for (int i = 0; i < nums.size(); ++i) {
            if (nums[i] != val)
                nums[index++] = nums[i];
        }
        return index;
    }
};

```

5.5 Remove Duplicates from Sorted Array (E)

Given a sorted array, remove the duplicates in place such that each element appear only once and return the new length. Do not allocate extra space for another array, you must do this in place with constant memory.

For example,

Given input array `nums = [1,1,2]`, your function should return `length = 2`, with the first two elements of `nums` being 1 and 2 respectively. It doesn't matter what you leave beyond the new length.

```

class Solution(object):
    def removeDuplicates(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        idx = 0
        for i in range(1, len(nums)):
            if nums[idx] != nums[i]:
                idx += 1
                nums[idx] = nums[i]
        return idx + 1

```

```

class Solution {
public:
    int removeDuplicates(vector<int>& nums) {
        if (nums.empty()) return 0;

        int index = 0;
        for (int i = 1; i < nums.size(); ++i) {
            if (nums[index] != nums[i])
                nums[++index] = nums[i];
        }
    }
};

```

```

    }
    return index + 1;
}
};

```

5.6 Remove Duplicates from Sorted Array II (M)

Given a sorted array `nums`, remove the duplicates in-place such that duplicates appeared at most twice and return the new length.

Do not allocate extra space for another array, you must do this by modifying the input array in-place with $O(1)$ extra memory.

```

class Solution(object):
    def removeDuplicates(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        # if the duplicates appeared at most k times
        k = 2
        idx = k
        for i in range(k, len(nums)):
            if nums[idx-k] != nums[i]:
                nums[idx] = nums[i]
                idx += 1
        return idx

```

5.7 Find K Pairs with Smallest Sums (M)

You are given two integer arrays `nums1` and `nums2` sorted in ascending order and an integer `k`. Define a pair (u,v) which consists of one element from the first array and one element from the second array. Find the `k` pairs $(u_1,v_1), (u_2,v_2) \dots (u_k,v_k)$ with the smallest sums.

Example 1:

Given `nums1 = [1,7,11]`, `nums2 = [2,4,6]`, `k = 3`

Return: `[1,2],[1,4],[1,6]`

The first 3 pairs are returned from the sequence: `[1,2],[1,4],[1,6],[7,2],[7,4],[11,2],[7,6],[11,4],[11,6]`

Example 2:

Given `nums1 = [1,1,2]`, `nums2 = [1,2,3]`, `k = 2`

Return: `[1,1],[1,1]`

The first 2 pairs are returned from the sequence: [1,1],[1,1],[1,2],[2,1],[1,2],[2,2],[1,3],[1,3],[2,3]

Example 3:

Given nums1 = [1,2], nums2 = [3], k = 3

Return: [1,3],[2,3]

All possible pairs are returned from the sequence: [1,3],[2,3]

```
class Solution {
public:
    vector<pair<int, int>> kSmallestPairs(vector<int>& nums1, vector<int>& nums2,
        int k) {
        vector<pair<int, int>> res;
        for (int i = 0; i < min((int)nums1.size(), k); ++i) {
            for (int j = 0; j < min((int)nums2.size(), k); ++j) {
                res.push_back({nums1[i], nums2[j]}); // find all combinations
            }
        }
        // sort res
        sort(res.begin(), res.end(),
            [](pair<int, int> &a, pair<int, int> &b){return a.first + a.second <
                b.first + b.second;});
        if (res.size() > k) res.erase(res.begin() + k, res.end()); // erase
            results from k+1 to end
        return res;
    }
};
```

```
class Solution {
public:
    vector<pair<int, int>> kSmallestPairs(vector<int>& nums1, vector<int>& nums2,
        int k) {
        vector<pair<int, int>> res;
        int size = min(k, (int)(nums1.size() * nums2.size()));
        vector<int> idx(nums1.size(), 0);
        for (int i = 0; i < size; ++i) {
            int t = 0, sum = INT_MAX;
            for (int j = 0; j < nums1.size(); ++j) {
                if (idx[j] < nums2.size() && sum >= nums1[j] + nums2[idx[j]]) {
                    t = j;
                    sum = nums1[j] + nums2[idx[j]];
                }
            }
            res.push_back({nums1[t], nums2[idx[t]]});
            ++idx[t];
        }
        return res;
    }
```

```
    }  
};
```

5.8 Shuffle an Array (M)

Shuffle a set of numbers without duplicates.

Example:

```
// Init an array with set 1, 2, and 3.
```

```
int[] nums = {1,2,3};
```

```
Solution solution = new Solution(nums);
```

```
// Shuffle the array [1,2,3] and return its result. Any permutation of [1,2,3] must equally  
likely to be returned.
```

```
solution.shuffle();
```

```
// Resets the array back to its original configuration [1,2,3].
```

```
solution.reset();
```

```
// Returns the random shuffling of array [1,2,3].
```

```
solution.shuffle();
```

```
class Solution {  
public:  
    Solution(vector<int> nums): v(nums) {}  
  
    /** Resets the array to its original configuration and return it. */  
    vector<int> reset() {  
        return v;  
    }  
  
    /** Returns a random shuffling of the array. */  
    // Reservoir sampling  
    vector<int> shuffle() {  
        vector<int> res = v;  
        for (int i = 0; i < res.size(); ++i) {  
            int t = rand() % res.size(); // randomly select a value from [0,  
                res.size()-1]  
            swap(res[i], res[t]); // swap for random shuffling  
        }  
        return res;  
    }  
private:
```

```

        vector<int> v;
};

/**
 * Your Solution object will be instantiated and called as such:
 * Solution obj = new Solution(nums);
 * vector<int> param_1 = obj.reset();
 * vector<int> param_2 = obj.shuffle();
 */

```

5.9 Missing Number (M)

Given an array containing n distinct numbers taken from $0, 1, 2, \dots, n$, find the one that is missing from the array.

For example, Given $\text{nums} = [0, 1, 3]$ return 2.

Note: Your algorithm should run in linear runtime complexity. Could you implement it using only constant extra space complexity?

```

# Expected sum - Actual sum
class Solution(object):
    def missingNumber(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        sum1, sum2 = 0, 0
        # sum1 = len(nums) * (len(nums)+1) / 2
        for i in range(len(nums)+1):
            sum1 += i
        for num in nums:
            sum2 += num
        return sum1 - sum2

# Use set
class Solution(object):
    def missingNumber(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        num_set = set(nums)
        for num in range(len(nums)+1):
            if num not in num_set: return num

```

```
class Solution {
public:
    int missingNumber(vector<int> &nums) {
        int n = nums.size(), res = (1 + n) * n / 2;
        for (int i = 0; i < n; ++i) {
            res -= nums[i];
        }
        return res;
    }
};
```

5.10 First Missing Positive (H)

Given an unsorted integer array, find the first missing positive integer.

For example, Given [1,2,0] return 3, and [3,4,-1,1] return 2.

Your algorithm should run in $O(n)$ time and uses constant space.

```
class Solution {
public:
    int firstMissingPositive(vector<int>& nums) {
        int i = 0, n = nums.size();
        while (i < n) {
            if (nums[i] <= n && nums[i] > 0 && nums[i] != nums[nums[i] - 1]) {
                swap(nums[i], nums[nums[i] - 1]);
            } else {
                ++i;
            }
        }
        for (int i = 0; i < n; ++i) {
            if (nums[i] != i + 1) {
                return i + 1;
            }
        }
        return n + 1;
    }
};
```

5.11 Summary Ranges (M)

Given a sorted integer array without duplicates, return the summary of its ranges.

For example, given [0,1,2,4,5,7], return ["0->2", "4->5", "7"].

```
class Solution {
public:
    vector<string> summaryRanges(vector<int>& nums) {
        vector<string> res;
        int i = 0, n = nums.size();
        while (i < n) {
            int j = 1;
            // save the start and end of an increasing sequence
            while (i + j < n && nums[i + j] == nums[i] + j) ++j;
            if (j > 1) { // an increasing sequence exists
                res.push_back(to_string(nums[i]) + "->" + to_string(nums[i + j - 1]));
            } else { // individual element
                res.push_back(to_string(nums[i]));
            }
            i += j;
        }
        return res;
    }
};
```

5.12 Missing Ranges (M)

Given a sorted integer array where the range of elements are [0, 99] inclusive, return its missing ranges.

For example, given [0, 1, 3, 50, 75], return ["2", "4->49", "51->74", "76->99"]

```
class Solution {
public:
    vector<string> findMissingRanges(vector<int>& nums, int lower, int upper) {
        vector<string> res;
        int l = lower, r;
        for (int i = 0; i <= nums.size(); ++i) {
            // find the current r
            if (i < nums.size() && nums[i] <= upper) r = nums[i];
            else r = upper + 1;
            // find the missing value or range
        }
    }
};
```

```

        if (l == r) {
            ++l;
        } else if (r > l) {
            if (r - l == 1) res.push_back(to_string(l)); // l is the missing
            value
            else res.push_back(to_string(l) + "->" + to_string(r - 1)); // l
            to r-1 is the missing range
            l = r + 1; // update l to the new position
        }
    }
    return res;
}
};

```

5.13 Intersection of Two Arrays (E)

Given two arrays, write a function to compute their intersection.

Example: Given nums1 = [1, 2, 2, 1], nums2 = [2, 2], return [2].

Note:

Each element in the result must be unique.

The result can be in any order.

```

class Solution(object):
    def intersection(self, nums1, nums2):
        """
        :type nums1: List[int]
        :type nums2: List[int]
        :rtype: List[int]
        """
        s1 = set(nums1)
        s2 = set(nums2)
        res = []
        for n in s2:
            if n in s1:
                res.append(n)
        return res

```

```

class Solution {
public:
    vector<int> intersection(vector<int>& nums1, vector<int>& nums2) {
        unordered_set<int> s(nums1.begin(), nums1.end());
        vector<int> res;

```

```

    for (auto x : nums2) {
        if (s.find(x) != s.end()) { // Searches x in s, returns 1 if x is
            found, otherwise return 0
            res.push_back(x);
            s.erase(x);
        }
    }
    return res;
}
};

```

5.14 Intersection of Two Arrays II (E)

Given two arrays, write a function to compute their intersection.

Example: Given `nums1 = [1, 2, 2, 1]`, `nums2 = [2, 2]`, return `[2, 2]`.

Note:

Each element in the result should appear as many times as it shows in both arrays.
The result can be in any order.

Follow up:

What if the given array is already sorted? How would you optimize your algorithm?

What if `nums1`'s size is small compared to `nums2`'s size? Which algorithm is better?

What if elements of `nums2` are stored on disk, and the memory is limited such that you cannot load all elements into the memory at once?

```

class Solution(object):
    def intersect(self, nums1, nums2):
        """
        :type nums1: List[int]
        :type nums2: List[int]
        :rtype: List[int]
        """
        nums1.sort()
        nums2.sort()
        n1 = len(nums1)
        n2 = len(nums2)
        p1, p2 = 0, 0
        res = []
        while p1 < n1 and p2 < n2:
            if nums1[p1] < nums2[p2]:
                p1 += 1
            elif nums1[p1] > nums2[p2]:

```

```

        p2 += 1
    else:
        res.append(nums1[p1])
        p1 += 1
        p2 += 1
    return res

```

// Sol1: Hash table

```

class Solution {
public:
    vector<int> intersect(vector<int>& nums1, vector<int>& nums2) {
        unordered_map<int,int> dict;
        vector<int> res;

        for (int i = 0; i < nums1.size(); ++i)
            dict[nums1[i]]++;

        for (int i = 0; i < nums2.size(); ++i){
            if (--dict[nums2[i]] >= 0)
                res.push_back(nums2[i]);
        }

        return res;
    }
};

```

// Sol2: Sorting & Two pointers

```

class Solution {
public:
    vector<int> intersect(vector<int>& nums1, vector<int>& nums2) {
        sort(nums1.begin(), nums1.end());
        sort(nums2.begin(), nums2.end());

        int n1 = nums1.size(), n2 = nums2.size();
        int i1 = 0, i2 = 0;
        vector<int> res;

        while(i1 < n1 && i2 < n2) {
            if (nums1[i1] == nums2[i2]) {
                res.push_back(nums1[i1]);
                ++i1;
                ++i2;
            } else if (nums1[i1] < nums2[i2]) {
                ++i1;
            } else {
                ++i2;
            }
        }
    }
};

```

```

    }

    return res;
}
};

```

5.15 Merge Sorted Array (E)

Given two sorted integer arrays `nums1` and `nums2`, merge `nums2` into `nums1` as one sorted array.

Note: You may assume that `nums1` has enough space (size that is greater or equal to $m + n$) to hold additional elements from `nums2`. The number of elements initialized in `nums1` and `nums2` are `m` and `n` respectively.

```

class Solution(object):
    def merge(self, nums1, m, nums2, n):
        """
        :type nums1: List[int]
        :type m: int
        :type nums2: List[int]
        :type n: int
        :rtype: None Do not return anything, modify nums1 in-place instead.
        """
        i = m - 1
        j = n - 1
        k = m + n - 1
        while i >= 0 and j >= 0:
            if nums1[i] <= nums2[j]:
                nums1[k] = nums2[j]
                j -= 1
            else:
                nums1[k] = nums1[i]
                i -= 1
            k -= 1
        while j >= 0:
            nums1[k] = nums2[j]
            j -= 1
            k -= 1

```

```

class Solution {
public:
    void merge(vector<int>& nums1, int m, vector<int>& nums2, int n) {
        int i = m - 1;

```

```

int j = n - 1;
int k = m + n - 1;

while (i >= 0 && j >= 0) {           // compare from end to start of two
    arrays
    if (nums1[i] < nums2[j]) {         // put the largest element to the end
        of array
        nums1[k--] = nums2[j--];
    } else {
        nums1[k--] = nums1[i--];
    }
}

while (i >= 0)                         // keep writing for the left over
    nums1[k--] = nums1[i--];

while (j >= 0)
    nums1[k--] = nums2[j--];
}
};

```

5.16 Sort Transformed Array (M)

Given a sorted array of integers `nums` and integer values `a`, `b` and `c`. Apply a function of the form $f(x) = ax^2 + bx + c$ to each element `x` in the array. The returned array must be in sorted order.

Expected time complexity: $O(n)$

Example:

`nums = [-4, -2, 2, 4]`, `a = 1`, `b = 3`, `c = 5`, Result: `[3, 9, 15, 33]`

`nums = [-4, -2, 2, 4]`, `a = -1`, `b = 3`, `c = 5` Result: `[-23, -5, 1, 7]`

```

class Solution {
public:
    vector<int> sortTransformedArray(vector<int>& nums, int a, int b, int c) {
        int n = nums.size(), i = 0, j = n - 1, k;
        vector<int> res(n);
        // Decide which side we should write sorted result to res
        if (a >= 0) { // parabola open up
            k = n - 1;
        } else {     // parabola open down
            k = 0;
        }
    }
}

```

```

while (i <= j) {
    if (a >= 0) { // large number first
        if (cal(nums[i],a,b,c) >= cal(nums[j],a,b,c)) {
            res[j--] = cal(nums[i++],a,b,c);
        } else {
            res[j--] = cal(nums[j--],a,b,c);
        }
    } else { // small number first
        if (cal(nums[i],a,b,c) >= cal(nums[j],a,b,c)) {
            res[i++] = cal(nums[j--],a,b,c);
        } else {
            res[i++] = cal(nums[i++],a,b,c);
        }
    }
}
return res;
}
int cal(int x, int a, int b, int c) {
    return a * x * x + b * x + c;
}
};

```

5.17 H-Index (M)

Given an array of citations (each citation is a non-negative integer) of a researcher, write a function to compute the researcher's h-index.

According to the definition of h-index on Wikipedia: "A scientist has index h if h of his/her N papers have at least h citations each, and the other N-h papers have no more than h citations each."

For example, given citations = [3, 0, 6, 1, 5], which means the researcher has 5 papers in total and each of them had received 3, 0, 6, 1, 5 citations respectively. Since the researcher has 3 papers with at least 3 citations each and the remaining two with no more than 3 citations each, his h-index is 3.

Note: If there are several possible values for h, the maximum one is taken as the h-index.

Hint:

An easy approach is to sort the array first.

What are the possible values of h-index?

A faster approach is to use extra space.

```

class Solution(object):

```

```

def hIndex(self, citations):
    """
    :type citations: List[int]
    :rtype: int
    """
    citations.sort()
    n = len(citations)
    for i in range(n):
        if citations[i] >= n-i:
            return n - i
    return 0

```

```

// H-index: N papers have received N citations
// 1. O(NlogN)
class Solution{
public:
    int hIndex(vector<int> &citations) {
        sort(citations.begin(), citations.end());
        int n = citations.size();
        for (int i = 0; i < n; ++i) {
            if (citations[i] >= n-i){
                return n-i;
            }
        }
        return 0;
    }
};

// 2. O(N) time, O(N) space
class Solution {
public:
    int hIndex(vector<int>& citations) {
        int n = citations.size(), h = 0;
        vector<int> count(n+1, 0);
        for (int i = 0; i < n; ++i) {
            if (citations[i] > n) ++count[n];
            else ++count[citations[i]];
        }
        for (int i = n; i >= 0; --i) {
            h += count[i];
            if (h >= i) return i;
        }
        return h;
    }
};

```

5.18 H-Index II (M)

Follow up for H-Index: What if the citations array is sorted in ascending order? Could you optimize your algorithm?

Hint: Expected runtime complexity is in $O(\log n)$ and the input is sorted.

```
# find the min index such that citations[i] >= len(citations) - i, then the
    answer is len(citations)-i
class Solution(object):
    def hIndex(self, citations):
        """
        :type citations: List[int]
        :rtype: int
        """
        n = len(citations)
        left, right = 0, n-1
        while left <= right:
            mid = (left + right) / 2
            if citations[mid] == n - mid:
                return n - mid
            elif citations[mid] > n - mid:
                right = mid - 1
            else:
                left = mid + 1
        return n - left
```

```
class Solution {
public:
    int hIndex(vector<int>& citations) {
        int n = citations.size();
        int start = 0, end = n - 1;
        while (start <= end) {
            int mid = start + (end - start) / 2;
            if (citations[mid] >= n - mid) {
                end = mid - 1;
            } else {
                start = mid + 1;
            }
        }
        return n - start;
    }
};
```

5.19 Majority Element (E)

Given an array of size n , find the majority element. The majority element is the element that appears more than $\text{floor}(n/2)$ times.

You may assume that the array is non-empty and the majority element always exist in the array.

```
class Solution(object):
    def majorityElement(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        hashmap = {}
        n = len(nums)
        for num in nums:
            if num in hashmap:
                hashmap[num] += 1
            else:
                hashmap.update({num: 1})
        for k, v in hashmap.items():
            if v > n / 2:
                return k
```

```
class Solution {
public:
    int majorityElement(vector<int>& nums) {
        int element, counts = 0;

        for (int i = 0; i < nums.size(); ++i) {
            if (counts == 0) {
                element = nums[i];
                ++counts;
            } else {
                if (element == nums[i])
                    ++counts;
                else
                    --counts;
            }
        }

        return element;
    }
};
```

5.20 Majority Element II (M)

Given an integer array of size n , find all elements that appear more than $\text{floor}(n/3)$ times. The algorithm should run in linear time and in $O(1)$ space.

```
class Solution(object):
    def majorityElement(self, nums):
        """
        :type nums: List[int]
        :rtype: List[int]
        """
        hashmap = {}
        res = []
        for num in nums:
            if num in hashmap:
                hashmap[num] += 1
            else:
                hashmap.update({num: 1})
        for k, v in hashmap.items():
            if v > len(nums) / 3:
                res.append(k)
        return res
```

```
class Solution {
public:
    vector<int> majorityElement(vector<int>& nums) {
        int candidate1 = 0, candidate2 = 0, count1 = 0, count2 = 0;
        vector<int> res;

        // 1. get candidates
        for (auto n : nums) {
            if (candidate1 == n) {
                ++count1;
            } else if (candidate2 == n) {
                ++count2;
            } else if (count1 == 0) {
                candidate1 = n;
                ++count1;
            } else if (count2 == 0) {
                candidate2 = n;
                ++count2;
            } else {
                --count1;
                --count2;
            }
        }
    }
}
```

```

// 2. get the count of each candidate
count1 = 0;
count2 = 0;
for (auto n : nums) {
    if (candidate1 == n)
        ++count1;
    else if (candidate2 == n)
        ++count2;
}

// 3. check if each candidate satisfies the majority condition
if (count1 > nums.size() / 3)
    res.push_back(candidate1);
if (count2 > nums.size() / 3)
    res.push_back(candidate2);

return res;
}
};

```

5.21 Contains Duplicate (E)

Given an array of integers, find if the array contains any duplicates. Your function should return true if any value appears at least twice in the array, and it should return false if every element is distinct.

```

class Solution(object):
    def containsDuplicate(self, nums):
        """
        :type nums: List[int]
        :rtype: bool
        """
        # sort and compare adjacent numbers
        nums.sort()
        for i in range(len(nums)-1):
            if nums[i] == nums[i+1]: return True
        return False

        # use set and compare length
        # return len(nums) != len(set(nums))

```

```

class Solution {
public:

```

```

bool containsDuplicate(vector<int>& nums) {
    unordered_set<int> s;
    for (int i = 0; i < nums.size(); ++i) {
        if (s.find(nums[i]) != s.end())
            return true;
        s.insert(nums[i]);
    }
    return false;
}
};

```

5.22 Contains Duplicate II (E)

Given an array of integers and an integer k , find out whether there are two distinct indices i and j in the array such that $\text{nums}[i] = \text{nums}[j]$ and the difference between i and j is at most k .

```

class Solution(object):
    def containsNearbyDuplicate(self, nums, k):
        """
        :type nums: List[int]
        :type k: int
        :rtype: bool
        """
        d = {}
        for i in range(len(nums)):
            if nums[i] in d and i - d[nums[i]] <= k:
                return True
            d.update({nums[i]: i})
        return False

```

```

class Solution {
public:
    bool containsNearbyDuplicate(vector<int>& nums, int k) {
        unordered_set<int> s;

        if (k <= 0)
            return false;
        if (k >= nums.size())
            k = nums.size() - 1;

        for (int i = 0; i < nums.size(); ++i) {
            if (i > k)
                s.erase(nums[i-k-1]);
            if (s.find(nums[i]) != s.end())

```

```

        return true;
        s.insert(nums[i]);
    }

    return false;
}
};

```

5.23 Contains Duplicate III (M)

Given an array of integers, find out whether there are two distinct indices i and j in the array such that the difference between $\text{nums}[i]$ and $\text{nums}[j]$ is at most t and the difference between i and j is at most k .

```

class Solution {
public:
    bool containsNearbyAlmostDuplicate(vector<int>& nums, int k, int t) {
        set<int> s; // set is ordered automatically

        for (int i = 0; i < nums.size(); i++) {
            // keep the set contains nums i j at most k
            if (i > k)
                s(nums[i-k-1]);

            // |x - nums[i]| <= t ==> -t <= x - nums[i] <= t;
            auto pos = s(nums[i] - t); // x-nums[i] >= -t ==> x >= nums[i]-t
            if (pos != s() && *pos - nums[i] <= t) // x - nums[i] <= t
                return true;

            s(nums[i]);
        }

        return false;
    }
};

```

5.24 Find the Duplicate Number (M)

Given an array nums containing $n + 1$ integers where each integer is between 1 and n (inclusive), prove that at least one duplicate number must exist. Assume that there is only one duplicate number, find the duplicate one.

Note: You must not modify the array (assume the array is read only).

You must use only constant, $O(1)$ extra space.

Your runtime complexity should be less than $O(n^2)$.

There is only one duplicate number in the array, but it could be repeated more than once.

```
# Sorting
class Solution(object):
    def findDuplicate(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        nums.sort()
        for i in range(1, len(nums)):
            if nums[i-1] == nums[i]:
                return nums[i]
```

```
# Use set()
class Solution(object):
    def findDuplicate(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        s = set()
        for num in nums:
            if num in s:
                return num
            s.add(num)
```

```
class Solution {
public:
    int findDuplicate(vector<int>& nums) {
        int low = 1, high = nums.size() - 1;
        // Use the mid of 1~n, not the mid of nums[0]~nums[nums.size()-1]
        while (low < high) {
            int mid = low + (high - low) / 2;
            int cnt = 0;
            for (int i = 0; i < nums.size(); ++i) {
                if (nums[i] <= mid) {
                    ++cnt;
                }
            }
            if (cnt <= mid) {
                low = mid + 1;
            } else {

```

```

        high = mid;
    }
}
return low;
}
};

```

5.25 Two Sum (E)

Given an array of integers, return indices of the two numbers such that they add up to a specific target. You may assume that each input would have exactly one solution.

Example:

Given `nums = [2, 7, 11, 15]`, `target = 9`,
 Because `nums[0] + nums[1] = 2 + 7 = 9`, return `[0, 1]`.

Python:

```

class Solution(object):
    def twoSum(self, nums, target):
        """
        :type nums: List[int]
        :type target: int
        :rtype: List[int]
        """

        # O(N^2)
        n = len(nums)
        for i in range(n):
            for j in range(i+1, n):
                if nums[i] + nums[j] == target:
                    return [i, j]

        # One-pass hash table: O(N)
        dict_nums = {}
        for index, num in enumerate(nums):
            another = target - num
            if another in dict_nums.keys():
                if dict_nums[another] != index:
                    return [dict_nums[another], index]
            dict_nums[num] = index

        # Use index()
        for idx, num in enumerate(nums):
            another = target - num
            if another in nums and nums.index(another) != idx:

```



```
return[idx, nums.index(another)]
```

C++:

```
class Solution {
public:
    vector<int> twoSum(vector<int> &nums, int target) {
        vector<int> res;
        unordered_map<int, int> map;

        for (int i = 0; i < nums.size(); ++i)
            map[nums[i]] = i;

        for (int i = 0; i < nums.size(); ++i) {
            int tmp = target - nums[i];
            if (map.find(tmp) != map.end() && i != map[tmp]){
                res.push_back(i);
                res.push_back(map[tmp]);
                break;
            }
        }

        return res;
    }
};
```

5.26 Two Sum II - Input array is sorted (M)

Given an array of integers that is already sorted in ascending order, find two numbers such that they add up to a specific target number.

The function twoSum should return indices of the two numbers such that they add up to the target, where index1 must be less than index2. Please note that your returned answers (both index1 and index2) are not zero-based.

You may assume that each input would have exactly one solution.

Input: numbers=2, 7, 11, 15, target=9

Output: index1=1, index2=2

Python:

```
class Solution(object):
    def twoSum(self, numbers, target):
        """
        :type numbers: List[int]
```

```

:type target: int
:rtype: List[int]
"""
# Two pointers: O(N)
left = 0
right = len(numbers) - 1
if target < numbers[left]: return []
while left < right:
    if numbers[left] + numbers[right] > target:
        right -= 1
    elif numbers[left] + numbers[right] < target:
        left += 1
    else:
        return [left+1, right+1]
return []

```

C++:

```

class Solution {
public:
    vector<int> twoSum(vector<int> &nums, int target) {
        vector<int> res;
        int left = 0, right = nums.size() - 1;

        while (left < right) {
            int tmp = nums[left] + nums[right];
            if (tmp < target) {
                ++left;
            } else if (tmp > target) {
                --right;
            } else {
                res.push_back(left+1);
                res.push_back(right+1);
                return res;
            }
        }
    }
};

```

5.27 Two Sum III (E)

Design and implement a TwoSum class. It should support the following operations: add and find.

add - Add the number to an internal data structure.

find - Find if there exists any pair of numbers which sum is equal to the value.

For example,
add(1); add(3); add(5);
find(4) - > true
find(7) - > false

```
class Solution {
public:
    unordered_map<int, int> map;

    void add(int num) {
        ++map[num];
    }

    bool find(int num) {
        for (auto i : map) {
            int tmp = num - i.first;
            if (map.find(tmp) != map.end()) {
                if (tmp != i.first)           // the pair of numbers has two
                    different numbers
                    return true;
                else if (i.second >= 2)       // the pair of numbers has two same
                    numbers
                    return true;
            }
        }
        return false;
    }
};
```

5.28 Two Sum IV - Input is a BST (E)

Given a Binary Search Tree and a target number, return true if there exist two elements in the BST such that their sum is equal to the given target.

Python:

```
# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

# 1. Recursive: O(N)
class Solution(object):
```

```

def findTarget(self, root, k):
    """
    :type root: TreeNode
    :type k: int
    :rtype: bool
    """
    lst = []
    return self.helper(root, k, lst)
def helper(self, node, k, lst):
    if node is None:
        return False
    target = k - node.val
    if target in lst:
        return True
    lst.append(node.val)
    return self.helper(node.left, k, lst) or self.helper(node.right, k, lst)

# 2. Inorder traversal + Two pointers: O(N)
class Solution(object):
    def findTarget(self, root, k):
        """
        :type root: TreeNode
        :type k: int
        :rtype: bool
        """
        nums = []
        self.inorder(root, nums)
        left, right = 0, len(nums) - 1
        while left < right:
            if nums[left] + nums[right] == k:
                return True
            if nums[left] + nums[right] < k:
                left += 1
            elif nums[left] + nums[right] > k:
                right -= 1
            else:
                return True
        return False
    def inorder(self, node, nums):
        if node is None: return
        self.inorder(node.left, nums)
        nums.append(node.val)
        self.inorder(node.right, nums)

```

5.29 Two Sum (Amazon phone screen 2016.10.04)

Given an array of integers, return two numbers such that they add up to a specific target.

Example:

Given input = [1, 4, 6, 7], target = 10, return [(4, 6)].

```
vector<pair<int, int>> sum(vector<int> input, int target) {
    vector<pair<int, int>> res;
    pair<int, int> p;
    sort(input.begin(), input.end());
    for (int i = 0; i < input.size(); ++i) {
        for (int j = i + 1; j < input.size(); ++j) {
            if (input[i] + input[j] == target) {
                pair.first = input[i];
                pair.second = input[j];
                res.push_back(pair);
            }
        }
    }
    return res;
}
```

```
vector<pair<int, int>> sum(vector<int> input, int target) {
    vector<pair<int, int>> res;
    pair<int, int> p;
    unordered_map<int, int> map;
    for (auto a : input) ++map[a];
    // TODO: need to remove duplicate
    for (auto m : map) {
        int tmp = target - m.first;
        if (map.find(tmp) != map.end()) {
            if (tmp != m.first) {
                pair.first = m.first;
                pair.second = tmp;
                res.push_back(pair);
            }
        }
    }
    return res;
}
```

5.30 3Sum (M)

Given an array S of n integers, are there elements a, b, c in S such that $a + b + c = 0$? Find all unique triplets in the array which gives the sum of zero. The solution set must not contain duplicate triplets.

For example, given array $S = [-1, 0, 1, 2, -1, -4]$,
A solution set is: $\begin{bmatrix} [-1, 0, 1], [-1, -1, 2] \end{bmatrix}$

Python:

```
class Solution(object):
    def threeSum(self, nums):
        """
        :type nums: List[int]
        :rtype: List[List[int]]
        """
        # O(Nlog(N))
        res = []
        n = len(nums)
        nums.sort()
        if not nums or n < 3 or nums[0] > 0 or nums[-1] < 0: return []
        for k in range(n - 2):
            if nums[k] > 0: break
            if k > 0 and nums[k] == nums[k - 1]: continue
            i, j = k + 1, n - 1
            while i < j:
                if nums[k] + nums[i] + nums[j] == 0:
                    res.append([nums[k], nums[i], nums[j]])
                    while (i < j and nums[i] == nums[i + 1]): i += 1
                    while (i < j and nums[j] == nums[j - 1]): j -= 1
                    i += 1
                    j -= 1
                elif nums[k] + nums[i] + nums[j] < 0:
                    i += 1
                else:
                    j -= 1
            return res
```

C++:

```
class Solution {
public:
    vector<vector<int>> threeSum(vector<int>& nums) {
        vector<vector<int>> res;
        if (nums.size() < 3) return res;
        sort(nums.begin(), nums.end());
```

```

for (int i = 0; i < nums.size()-2; ++i) {
    if (i != 0 && nums[i] == nums[i-1]) continue; // skip duplicates

    // like the two sum problem, let j to be left, and k to be right
    int j = i + 1, k = nums.size() - 1;
    while (j < k) {
        if (nums[i] + nums[j] + nums[k] == 0) {
            res.push_back({nums[i], nums[j], nums[k]});
            ++j;
            --k;
            while (j < k && nums[j] == nums[j-1]) ++j; // skip duplicates
            while (j < k && nums[k] == nums[k+1]) --k; // skip duplicates
        } else if (nums[i] + nums[j] + nums[k] < 0) {
            ++j;
            while (j < k && nums[j] == nums[j-1]) ++j; // skip duplicates
        } else {
            --k;
            while (j < k && nums[k] == nums[k+1]) --k; // skip duplicates
        }
    }
}

return res;
}
};

```

5.31 3Sum Closest (M)

Given an array S of n integers, find three integers in S such that the sum is closest to a given number, target. Return the sum of the three integers. You may assume that each input would have exactly one solution.

For example, given array $S = -1\ 2\ 1\ -4$, and target = 1. The sum that is closest to the target is 2. ($-1 + 2 + 1 = 2$).

Python:

```

import sys
class Solution(object):
    def threeSumClosest(self, nums, target):
        """
        :type nums: List[int]
        :type target: int
        :rtype: int
        """
        res = sum(nums[0:3])

```

```

ls = len(nums)
nums.sort()
for k in range(ls - 2):
    l, r = k + 1, ls - 1
    while l < r:
        tmp = nums[k] + nums[l] + nums[r]
        if abs(tmp - target) < abs(res - target):
            res = tmp
        if tmp < target: l += 1
        else: r -= 1
return res

```

C++:

```

class Solution {
public:
    int threeSumClosest(vector<int> &nums, int target) {
        if (nums.size() < 3) return 0;
        int res = 0, min = INT_MAX;
        sort(nums.begin(), nums.end());

        for (int i = 0; i < nums.size() - 2; ++i) {
            int j = i + 1, k = nums.size() - 1;
            while (j < k) {
                int sum = nums[i] + nums[j] + nums[k];
                int diff = abs(sum - target);
                if (diff < min) {           // find the closest sum
                    min = diff;
                    res = sum;
                }
                if (sum < target)           // update j and k
                    ++j;
                else if (sum > target)
                    --k;
                else
                    return res;
            }
        }
        return res;
    }
};

```

5.32 3Sum Smaller (M)

Given an array of n integers $nums$ and a target, find the number of index triplets i, j, k with $0 \leq i < j < k < n$ that satisfy the condition $nums[i] + nums[j] + nums[k] < target$.

For example, given $\text{nums} = [-2, 0, 1, 3]$, and $\text{target} = 2$.

Return 2. Because there are two triplets which sums are less than 2: $[-2, 0, 1]$ $[-2, 0, 3]$

```
class Solution {
public:
    int threeSumSmaller(vector<int> &nums, int target) {
        if (nums.size() < 3) return 0;
        int cnt = 0;
        sort(nums.begin(), nums.end());

        for (int i = 0; i < nums.size() - 2; ++i){
            int j = i + 1; k = nums.size() - 1;
            while (j < k) {
                int sum = nums[i] + nums[j] + nums[k]
                if (sum >= target) {
                    --k;
                } else {
                    cnt += k - j; // if j is fixed, all numbers from j to k (less
                                // than k, not include j) are satisfied
                    ++j;         // update j for the next iteration
                }
            }
        }

        return cnt;
    }
};
```

5.33 4Sum (M)

Given an array S of n integers, are there elements a , b , c , and d in S such that $a + b + c + d = \text{target}$? Find all unique quadruplets in the array which gives the sum of target. The solution set must not contain duplicate quadruplets.

For example, given array $S = [1, 0, -1, 0, -2, 2]$, and $\text{target} = 0$.

A solution set is: $[-1, 0, 0, 1]$, $[-2, -1, 1, 2]$, $[-2, 0, 0, 2]$

```
class Solution {
public:
    vector<vector<int>> fourSum(vector<int>& nums, int target) {
        vector<vector<int>> res;
        if (nums.size() < 4) return res;
```

```

sort(nums.begin(), nums.end());

for (int i = 0; i < nums.size() - 3; ++i) {
    if (i != 0 && nums[i] == nums[i-1]) continue;
    for (int j = i + 1; j < nums.size() - 2; ++j) {
        if (j != i + 1 && nums[j] == nums[j-1]) continue;
        int p = j + 1, q = nums.size() - 1;
        while (p < q) {
            int sum = nums[i] + nums[j] + nums[p] + nums[q];
            if (sum < target) {
                ++p;
                while (p < q && nums[p] == nums[p-1]) ++p;
            } else if (sum > target) {
                --q;
                while (p < q && nums[q] == nums[q+1]) --q;
            } else {
                res.push_back({nums[i], nums[j], nums[p], nums[q]});
                ++p;
                --q;
                while (p < q && nums[p] == nums[p-1]) ++p;
                while (p < q && nums[q] == nums[q+1]) --q;
            }
        }
    }
}
return res;
};

```

5.34 Range Addition (M)

Assume you have an array of length n initialized with all 0's and are given k update operations. Each operation is represented as a triplet: $[\text{startIndex}, \text{endIndex}, \text{inc}]$ which increments each element of subarray $A[\text{startIndex} \dots \text{endIndex}]$ (startIndex and endIndex inclusive) with inc . Return the modified array after all k operations were executed.

Example: Given: $\text{length} = 5$, $\text{updates} = [[1, 3, 2], [2, 4, 3], [0, 2, -2]]$

Output: $[-2, 0, 3, 5, 3]$

Explanation:

Initial state: $[0, 0, 0, 0, 0]$

After applying operation $[1, 3, 2]$: $[0, 2, 2, 2, 0]$

After applying operation [2, 4, 3]: [0, 2, 5, 5, 3]

After applying operation [0, 2, -2]: [-2, 0, 3, 5, 3]

Hint:

Thinking of using advanced data structures? You are thinking it too complicated.

For each update operation, do you really need to update all elements between i and j?

Update only the first and end element is sufficient.

The optimal time complexity is $O(k + n)$ and uses $O(1)$ extra space.

```
class Solution {
public:
    vector<int> getModifiedArray(int length, vector<vector<int>>& updates) {
        vector<int> res(length+1, 0);

        // 1. The update query (l, r, v) requires that arr[i] += v for i in l..r
        //    (both l and r inclusive).
        // 2. Applying the final transformation [3] ensures that the increment of
        //    +v on arr[l] is carried through to all arr[i] for i >= l.
        // 3. The increment of -v on arr[r+1] ensures that the previous +v
        //    increment is cancelled out for each arr[i] for i >= r+1.
        for (int i = 0; i < update.size(); ++i) {
            res[update[i][0]] += update[i][2];
            res[update[i][1] + 1] -= update[i][2];
        }

        // propagate the addition number to all corresponding positions except
        // the last one
        for (int i = 1; i < length; ++i) {
            res[i] += res[i-1];
        }

        res.pop_back(); // remove the last element
        return res;
    }
};
```

5.35 Maximum Subarray (M)

Find the contiguous subarray within an array (containing at least one number) which has the largest sum.

For example, given the array [-2,1,-3,4,-1,2,1,-5,4], the contiguous subarray [4,-1,2,1] has the

largest sum = 6.

```
class Solution(object):
    def maxSubArray(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        res = float('-inf')
        cur_sum = 0
        for num in nums:
            cur_sum = max(cur_sum + num, num)
            res = max(res, cur_sum)
        return res
```

```
class Solution {
public:
    int maxSubArray(vector<int>& nums) {
        if (nums.empty()) return 0;
        int res = INT_MIN, tmp = 0;
        for (int i = 0; i < nums.size(); ++i) {
            tmp = max(nums[i], tmp + nums[i]);
            res = max(res, tmp);
        }
        return res;
    }
};
```

5.36 Maximum Product Subarray (M)

Find the contiguous subarray within an array (containing at least one number) which has the largest product.

For example, given the array [2,3,-2,4], the contiguous subarray [2,3] has the largest product = 6.

```
class Solution(object):
    def maxProduct(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        mx = mn = res = nums[0]
```

```

for i in range(1, len(nums)):
    if nums[i] > 0:
        mx = max(mx * nums[i], nums[i])
        mn = min(mn * nums[i], nums[i])
    else:
        t = mx
        mx = max(mn * nums[i], nums[i])
        mn = min(t * nums[i], nums[i])
    res = max(res, mx)
return res

```

```

class Solution {
public:
    int maxProduct(vector<int>& nums) {
        int mx = 1, mn = 1, res = INT_MIN;
        for (int i = 0; i < nums.size(); ++i) {
            int tmp = mx; // keep the previous max to avoid overwriting of max
                           value
            mx = max(max(nums[i], mx * nums[i]), mn * nums[i]);
            mn = min(min(nums[i], tmp * nums[i]), mn * nums[i]); // use the prev
                           max here
            res = max(mx, res);
        }
        return res;
    }
};

```

5.37 Maximum Size Subarray Sum Equals k (M)

Given an array `nums` and a target value `k`, find the maximum length of a subarray that sums to `k`. If there isn't one, return 0 instead.

Example 1:

Given `nums = [1, -1, 5, -2, 3]`, `k = 3`, return 4. (because the subarray `[1, -1, 5, -2]` sums to 3 and is the longest)

Example 2:

Given `nums = [-2, -1, 2, 1]`, `k = 1`, return 2. (because the subarray `[-1, 2]` sums to 1 and is the longest)

Follow Up: Can you do it in $O(n)$ time?

```

class Solution {
public:

```

```

int maxSubArrayLen(vector<int>& nums, int k) {
    int sum = 0, res = 0;
    unordered_map<int, int> m;
    for (int i = 0; i < nums.size(); ++i) {
        sum += nums[i];
        if (sum == k) res = i + 1;
        // if sum - prev_sum = k, i.e. sum - k = prev_sum,
        // we can remove prev_sum from sum to get the subarray sum equals k
        else if (m.count(sum-k)) res = max(res, i - m[sum-k]);
        if (!m.count(sum)) m[sum] = i;
    }
    return res;
}
};

```

5.38 Minimum Size Subarray Sum (M)

Given an array of n positive integers and a positive integer s , find the minimal length of a subarray of which the sum $\geq s$. If there isn't one, return 0 instead.

For example, given the array $[2,3,1,2,4,3]$ and $s = 7$, the subarray $[4,3]$ has the minimal length under the problem constraint.

```

class Solution(object):
    def minSubArrayLen(self, s, nums):
        """
        :type s: int
        :type nums: List[int]
        :rtype: int
        """
        n = len(nums)
        left = 0
        res = n + 1
        cur_sum = 0
        for i in range(n):
            cur_sum += nums[i]
            while cur_sum >= s:
                res = min(res, i - left + 1)
                cur_sum -= nums[left]
                left += 1
        return 0 if res == n + 1 else res

```

```

class Solution {
public:

```

```

int minSubArrayLen(int s, vector<int>& nums) {
    int left = 0, right = 0, sum = 0, res = INT_MAX, n = nums.size();
    while (right < n) {
        // must have "right < n" to jump out the inner while loop
        while (sum < s && right < n) {
            sum += nums[right++];
        }
        while (sum >= s) {
            res = min(res, right - left);
            sum -= nums[left++];
        }
    }
    if (res == INT_MAX) return 0;
    else return res;
}
};

```

5.39 Subarray Sum Equals K (M)

Given an array of integers and an integer k, you need to find the total number of continuous subarrays whose sum equals to k.

Example 1:

Input: nums = [1,1,1], k = 2

Output: 2

```

# O(N^2)
class Solution(object):
    def subarraySum(self, nums, k):
        """
        :type nums: List[int]
        :type k: int
        :rtype: int
        """
        res = 0
        n = len(nums)
        for i in range(n):
            sum_n = 0
            for j in range(i, n):
                sum_n += nums[j]
                if sum_n == k: res += 1
        return res

# O(N)
class Solution(object):

```

```

def subarraySum(self, nums, k):
    """
    :type nums: List[int]
    :type k: int
    :rtype: int
    """
    sum_n, res = 0, 0
    m = {0:1}
    for i in range(len(nums)):
        sum_n += nums[i]
        if sum_n - k in m:
            res += m[sum_n - k]
        if sum_n in m:
            m[sum_n] += 1
        else:
            m[sum_n] = 1
    return res

```

5.40 Continuous Subarray Sum (M)

Given a list of non-negative numbers and a target integer k , write a function to check if the array has a continuous subarray of size at least 2 that sums up to a multiple of k , that is, sums up to $n*k$ where n is also an integer.

Example 1:

Input: [23, 2, 4, 6, 7], $k=6$

Output: True

Explanation: Because [2, 4] is a continuous subarray of size 2 and sums up to 6.

Example 2:

Input: [23, 2, 6, 4, 7], $k=6$

Output: True

Explanation: Because [23, 2, 6, 4, 7] is an continuous subarray of size 5 and sums up to 42.

```

class Solution(object):
    def checkSubarraySum(self, nums, k):
        """
        :type nums: List[int]
        :type k: int
        :rtype: bool
        """
        n = len(nums)
        for i in range(n):
            sum_n = 0

```



```

        cnt = 0
        for j in range(i, n):
            sum_n += nums[j]
            cnt += 1
            if cnt >= 2:
                if sum_n == k or (k != 0 and sum_n % k == 0):
                    return True
        return False

class Solution(object):
    def checkSubarraySum(self, nums, k):
        """
        :type nums: List[int]
        :type k: int
        :rtype: bool
        """
        cur_sum = 0
        m = {0:-1}
        for i in range(len(nums)):
            cur_sum += nums[i]
            if k != 0:
                cur_sum %= k
            if cur_sum in m:
                if i - m[cur_sum] > 1:
                    return True
            else:
                m[cur_sum] = i
        return False

```

5.41 Product of Array Except Self (M)

Given an array of n integers where $n > 1$, `nums`, return an array `output` such that `output[i]` is equal to the product of all the elements of `nums` except `nums[i]`. Solve it without division and in $O(n)$.

For example, given `[1,2,3,4]`, return `[24,12,8,6]`.

Follow up: Could you solve it with constant space complexity? (Note: The output array does not count as extra space for the purpose of space complexity analysis.)

```

# Space  $O(N)$ 
class Solution(object):
    def productExceptSelf(self, nums):
        """
        :type nums: List[int]

```

```

        :rtype: List[int]
        """
        n = len(nums)
        L, R, res = [0] * n, [0] * n, [0] * n

        # L[i] contains the product of all the elements to the left
        L[0] = 1
        for i in range(1, n):
            L[i] = L[i-1] * nums[i-1]

        # R[i] contains the product of all the elements to the right
        R[n-1] = 1
        for i in range(n-2, -1, -1):
            R[i] = R[i+1] * nums[i+1]

        for i in range(n):
            res[i] = L[i] * R[i]
        return res

# Space O(1)
class Solution(object):
    def productExceptSelf(self, nums):
        """
        :type nums: List[int]
        :rtype: List[int]
        """
        n = len(nums)
        res = [0] * n
        res[0] = 1
        for i in range(1, n):
            res[i] = res[i-1] * nums[i-1]
        R = 1
        for i in range(n-1, -1, -1):
            res[i] *= R
            R *= nums[i]
        return res

```

```

class Solution {
public:
    vector<int> productExceptSelf(vector<int> &nums) {
        int n = nums.size(), tmp = 1;
        vector<int> res(n, 1);

        // production of all elements before i
        for (int i = 1; i < n; ++i) {
            res[i] = res[i-1] * nums[i-1];
        }
    }
}

```

```

    // production of all elements after i
    for (int i = n-1; i >= 0; --i) {
        res[i] *= tmp;    // the tmp element after the last i is set to 1
        tmp *= nums[i];  // update tmp during each iteration
    }

    return res;
}
};

```

5.42 Task Scheduler (M)

Given a char array representing tasks CPU need to do. It contains capital letters A to Z where different letters represent different tasks. Tasks could be done without original order. Each task could be done in one interval. For each interval, CPU could finish one task or just be idle.

However, there is a non-negative cooling interval n that means between two same tasks, there must be at least n intervals that CPU are doing different tasks or just be idle.

You need to return the least number of intervals the CPU will take to finish all the given tasks.

Example:

Input: tasks = ["A","A","A","B","B","B"], $n = 2$

Output: 8

Explanation: A -> B -> idle -> A -> B -> idle -> A -> B.

```

class Solution(object):
    def leastInterval(self, tasks, n):
        """
        :type tasks: List[str]
        :type n: int
        :rtype: int
        """
        task_map = [0] * 26
        for c in tasks:
            task_map[ord(c) - ord('A')] += 1
        task_map.sort()
        res = 0
        while task_map[25] > 0:
            i = 0
            while i <= n:
                if task_map[25] == 0:

```

```

        break
    if i < 26 and task_map[25 - i] > 0:
        task_map[25 - i] -= 1
    res += 1
    i += 1
    task_map.sort()
return res

```

5.43 Merge Intervals (M)

Given a collection of intervals, merge all overlapping intervals.

```

class Solution(object):
    def merge(self, intervals):
        """
        :type intervals: List[List[int]]
        :rtype: List[List[int]]
        """
        # sort according to the first element of the inner list
        intervals.sort(key = lambda x: x[0])
        merged = []
        for interval in intervals:
            # if the list of merged intervals is empty or if the current
            # interval does not overlap with the previous, simply append it.
            if not merged or merged[-1][-1] < interval[0]:
                merged.append(interval)
            else:
                # otherwise, there is an overlapping
                # so we merge the current and previous intervals.
                merged[-1][-1] = max(merged[-1][-1], interval[-1])
        return merged

```

5.44 Insert Intervals (H)

Given a set of non-overlapping intervals, insert a new interval into the intervals (merge if necessary).

You may assume that the intervals were initially sorted according to their start times.

Example 1:

Input: intervals = [[1,3],[6,9]], newInterval = [2,5]

Output: [[1,5],[6,9]]

Example 2: Input: intervals = [[1,2],[3,5],[6,7],[8,10],[12,16]], newInterval = [4,8]
Output: [[1,2],[3,10],[12,16]]
Explanation: Because the new interval [4,8] overlaps with [3,5],[6,7],[8,10].

```
class Solution(object):
    def insert(self, intervals, newInterval):
        """
        :type intervals: List[List[int]]
        :type newInterval: List[int]
        :rtype: List[List[int]]
        """
        res = []
        n = len(intervals)
        pos = 0 # insert position
        for i in range(n):
            # newInterval can be insert after intervals[i]
            if intervals[i][1] < newInterval[0]:
                res.append(intervals[i])
                pos += 1 # update pos
            # newInterval has already been included before intervals[i]
            elif intervals[i][0] > newInterval[1]:
                res.append(intervals[i])
            # merge intervals[i] and newInterval, update newInterval
            else:
                newInterval[0] = min(newInterval[0], intervals[i][0])
                newInterval[1] = max(newInterval[1], intervals[i][1])
        # insert newInterval based on pos
        # note that the overlapping between intervals and the original newInterval
        # has already been merged together into the new newInterval
        res.insert(pos, newInterval)
        return res
```

5.45 Interval List Intersections (M)

Given two lists of closed intervals, each list of intervals is pairwise disjoint and in sorted order.

Return the intersection of these two interval lists.

(Formally, a closed interval $[a, b]$ (with a $j = b$) denotes the set of real numbers x with a $j = x \leq b$. The intersection of two closed intervals is a set of real numbers that is either empty, or can be represented as a closed interval. For example, the intersection of $[1, 3]$ and $[2, 4]$ is $[2, 3]$.)

```
class Solution(object):
    def intervalIntersection(self, A, B):
        """
```

```

:type A: List[List[int]]
:type B: List[List[int]]
:rtype: List[List[int]]
"""
res = []
i = j = 0
# check intersection
while i < len(A) and j < len(B):
    # lowerbound is the largest start point
    # upperbound is the smallest end point
    low = max(A[i][0], B[j][0])
    high = min(A[i][1], B[j][1])
    if low <= high:
        res.append([low, high])
    # check next intersection by removing the smaller endpoint
    if A[i][1] < B[j][1]:
        i += 1
    else:
        j += 1
return res

```

5.46 Meeting Rooms (E)

Given an array of meeting time intervals consisting of start and end times $[[s_1, e_1], [s_2, e_2], \dots]$ ($s_i < e_i$), determine if a person could attend all meetings.

For example, given $[[0, 30], [5, 10], [15, 20]]$, return false.

```

class Solution(object):
    def canAttendMeetings(self, intervals):
        intervals.sort(key = lambda x: x[0])
        for i in range(1, len(intervals)):
            if intervals[i][0] < intervals[i-1][-1]:
                return False
        return True
\begin{lstlisting}

\begin{lstlisting}
/**
 * Definition for an interval.
 * struct Interval {
 *     int start;
 *     int end;
 *     Interval() : start(0), end(0) {}
 *     Interval(int s, int e) : start(s), end(e) {}

```

```

* };
*/
class Solution {
public:
    bool canAttendMeetings(vector<Interval>& intervals) {
        sort(intervals.begin(), intervals.end(), compare);
        for (int i = 1; i < intervals.size(); ++i) {
            // the start time of i should be larger than the end time of i-1 for
            // a valid case
            if (intervals[i].start < intervals[i - 1].end) {
                return false;
            }
        }
        return true;
    }

    // use the start time to compare
    bool compare(Interval& i1, Interval& i2) {
        return i1.start < i2.start;
    }
};

```

5.47 Meeting Rooms II (M)

Given an array of meeting time intervals consisting of start and end times $[[s_1, e_1], [s_2, e_2], \dots]$ ($s_i < e_i$), find the minimum number of conference rooms required.

For example, given $[[0, 30], [5, 10], [15, 20]]$, return 2.

```

class Solution(object):
    def minMeetingRooms(self, intervals):
        starts, ends = [], []
        res, idx = 0, 0
        for interval in intervals:
            starts.append(interval[0])
            ends.append(interval[1])
        starts.sort()
        ends.sort()
        for i in range(len(intervals)):
            if starts[i] < end[idx]:
                res += 1
            else:
                idx += 1
        return res

```

```

// 1. Map
class Solution {
public:
    int minMeetingRooms(vector<Interval>& intervals) {
        map<int, int> m; // map keeps their elements ordered rather than
                        // unordered_map
        for (auto a : intervals) {
            ++m[a.start];
            --m[a.end];
        }
        int rooms = 0, res = 0;
        for (auto it : m) {
            rooms += it.second;
            res = max(res, rooms); // always store the max room number
        }
        return res;
    }
};

// 2. Two vectors
class Solution {
public:
    int minMeetingRooms(vector<Interval>& intervals) {
        vector<int> starts, ends;
        int res = 0, endpos = 0;
        for (auto a : intervals) {
            starts.push_back(a.start);
            ends.push_back(a.end);
        }
        sort(starts.begin(), starts.end());
        sort(ends.begin(), ends.end());
        for (int i = 0; i < intervals.size(); ++i) {
            if (starts[i] < ends[endpos]) ++res; // need a new room
            else ++endpos;
        }
        return res;
    }
};

```

5.48 Logger Rate Limiter (E)

Design a logger system that receive stream of messages along with its timestamps, each message should be printed if and only if it is not printed in the last 10 seconds. Given a message and a timestamp (in seconds granularity), return true if the message should be printed in the given timestamp, otherwise returns false. It is possible that several messages arrive roughly

at the same time.

Example:

```
Logger logger = new Logger();

// logging string "foo" at timestamp 1
logger.shouldPrintMessage(1, "foo"); returns true;

// logging string "bar" at timestamp 2
logger.shouldPrintMessage(2,"bar"); returns true;

// logging string "foo" at timestamp 3
logger.shouldPrintMessage(3,"foo"); returns false;

// logging string "bar" at timestamp 8
logger.shouldPrintMessage(8,"bar"); returns false;

// logging string "foo" at timestamp 10
logger.shouldPrintMessage(10,"foo"); returns false;

// logging string "foo" at timestamp 11
logger.shouldPrintMessage(11,"foo"); returns true;
```

```
class Logger {
public:
    Logger() {}

    bool shouldPrintMessage(int timestamp, string message) {
        if (!m.count(message)) {           // if the current message is not in m
            m[message] = timestamp;         // store it and return true
            return true;
        }
        if (timestamp - m[message] >= 10) { // if the current message should be
            printed
            m[message] = timestamp;         // update the timestamp of the current
            message
            return true;
        }
        return false;
    }

private:
    unordered_map<string, int> m;           // build a hashtable to store the
        message/timestamp pair
};
```

5.49 Design Hit Counter (M)

Design a hit counter which counts the number of hits received in the past 5 minutes. Each function accepts a timestamp parameter (in seconds granularity) and you may assume that calls are being made to the system in chronological order (ie, the timestamp is monotonically increasing). You may assume that the earliest timestamp starts at 1. It is possible that several hits arrive roughly at the same time.

Example:

```
HitCounter counter = new HitCounter();
```

```
// hit at timestamp 1.
counter.hit(1);
```

```
// hit at timestamp 2.
counter.hit(2);
```

```
// hit at timestamp 3.
counter.hit(3);
```

```
// get hits at timestamp 4, should return 3.
counter.getHits(4);
```

```
// hit at timestamp 300.
counter.hit(300);
```

```
// get hits at timestamp 300, should return 4.
counter.getHits(300);
```

```
// get hits at timestamp 301, should return 3.
counter.getHits(301);
```

Follow up: What if the number of hits per second could be very large? Does your design scale?

```
// 1. Use queue
class HitCounter {
public:
    /** Initialize your data structure here. */
    HitCounter() {}

    /** Record a hit.
        @param timestamp - The current timestamp (in seconds granularity). */
    void hit(int timestamp) {
        q.push(timestamp);
    }
};
```

```

    }

    /** Return the number of hits in the past 5 minutes.
     * @param timestamp - The current timestamp (in seconds granularity). */
    int getHits(int timestamp) {
        while (!q.empty() && timestamp - q.front() >= 300) {
            q.pop();
        }
        return q.size();
    }

private:
    queue<int> q;
};

// 2. Use two vectors
class HitCounter {
public:
    /** Initialize your data structure here. */
    HitCounter() {
        times.resize(300);
        hits.resize(300);
    }

    /** Record a hit.
     * @param timestamp - The current timestamp (in seconds granularity). */
    void hit(int timestamp) {
        int idx = timestamp % 300;
        if (times[idx] != timestamp) { // time limit exceeded
            times[idx] = timestamp; // reset timestamp
            hits[idx] = 1;           // reset hit count
        } else {                    // same time stamp
            ++hits[idx];             // increase hit count
        }
    }

    /** Return the number of hits in the past 5 minutes.
     * @param timestamp - The current timestamp (in seconds granularity). */
    int getHits(int timestamp) {
        int res = 0;
        for (int i = 0; i < 300; ++i) {
            if (timestamp - times[i] < 300) {
                res += hits[i];
            }
        }
        return res;
    }
};

```

```
    }  
  
private:  
    vector<int> times, hits;  
};
```

5.50 Flatten 2D Vector (M)

Implement an iterator to flatten a 2d vector.

For example,

Given 2d vector = [[1,2], [3], [4,5,6]]

By calling next repeatedly until hasNext returns false, the order of elements returned by next should be: [1,2,3,4,5,6].

Hint:

How many variables do you need to keep track?

Two variables is all you need. Try with x and y.

Beware of empty rows. It could be the first few rows.

To write correct code, think about the invariant to maintain. What is it?

The invariant is x and y must always point to a valid point in the 2d vector. Should you maintain your invariant ahead of time or right when you need it?

Not sure? Think about how you would implement hasNext(). Which is more complex?

Common logic in two different places should be refactored into a common method.

Follow up: As an added challenge, try to code it using only iterators in C++ or iterators in Java.

```
// 1. Use 1D vector  
class Vector2D {  
public:  
    Vector2D(vector<vector<int>> &vec2d) {  
        for (auto a : vec2d){  
            v.insert(v.end(), a.begin(), a.end());  
        }  
    }  
    int next() {  
        return v[i++];  
    }  
    bool hasNext() {  
        return i < v.size();  
    }  
private:  
    vector<int> v;
```

```

    int i = 0;
};

// 2. Use two variables x and y
class Vector2D {
public:
    Vector2D(vector<vector<int>>& vec2d) {
        v = vec2d;
        x = y = 0;
    }
    int next() {
        return v[x][y++];
    }
    bool hasNext() {
        while (x < v.size() && y == v[x].size()) {
            ++x;
            y = 0;
        }
        return x < v.size();
    }
private:
    vector<vector<int>> v;
    int x, y;
};

// 3. Use iterator
class Vector2D {
public:
    Vector2D(vector<vector<int>>& vec2d) {
        x = vec2d.begin();
        end = vec2d.end();
    }
    int next() {
        return (*x)[y++];
    }
    bool hasNext() {
        while (x != end && y == (*x).size()) {
            ++x;
            y = 0;
        }
        return x != end;
    }
private:
    vector<vector<int>>::iterator x, end;
    int y = 0;
};

```

5.51 Zigzag Iterator (M)

Given two 1d vectors, implement an iterator to return their elements alternately.

For example, given two 1d vectors:

v1 = [1, 2]

v2 = [3, 4, 5, 6]

By calling next repeatedly until hasNext returns false, the order of elements returned by next should be: [1, 3, 2, 4, 5, 6].

Follow up: What if you are given k 1d vectors? How well can your code be extended to such cases?

Clarification for the follow up question - Update (2015-09-18):

The "Zigzag" order is not clearly defined and is ambiguous for k > 2 cases. If "Zigzag" does not look right to you, replace "Zigzag" with "Cyclic". For example, given the following input: [[1,2,3], [4,5,6,7], [8,9]]

It should return [1,4,8,2,5,9,3,6,7].

```
// 1. Use 1D vector
class ZigzagIterator {
public:
    ZigzagIterator(vector<int> &v1, vector<int> &v2) {
        int n1 = v1.size(), n2 = v2.size(), n = max(n1, n2);
        for (int i = 0; i < n; ++i) {
            if (i < n1) v.push_back(v1[i]);
            if (i < n2) v.push_back(v2[i]);
        }
    }
    int next() {
        return v[i++];
    }
    bool hasNext() {
        return i < v.size();
    }
private:
    vector<int> v;
    int i = 0;
};
```

```
// 2. Use two variables i and j
class ZigzagIterator {
public:
    ZigzagIterator(vector<int>& v1, vector<int>& v2) {
        v.push_back(v1);
        v.push_back(v2);
```

```

        i = j = 0;
    }
    int next() {
        return i <= j ? v[0][i++] : v[1][j++];
    }
    bool hasNext() {
        if (i >= v[0].size()) i = INT_MAX;
        if (j >= v[1].size()) j = INT_MAX;
        return i < v[0].size() || j < v[1].size();
    }
private:
    vector<vector<int>>> v;
    int i, j;
};

// 3. Use queue and iterator
class ZigzagIterator {
public:
    ZigzagIterator(vector<int>& v1, vector<int>& v2) {
        if (!v1.empty()) q.push(make_pair(v1.begin(), v1.end()));
        if (!v2.empty()) q.push(make_pair(v2.begin(), v2.end()));
    }
    int next() {
        auto it = q.front().first, end = q.front().second;
        q.pop();
        if (it + 1 != end) q.push(make_pair(it + 1, end));
        return *it;
    }
    bool hasNext() {
        return !q.empty();
    }
private:
    queue<pair<vector<int>::iterator, vector<int>::iterator>> q;
};

```

5.52 Sparse Matrix Multiplication (M)

Given two sparse matrices A and B, return the result of AB. You may assume that A's column number is equal to B's row number.

```

def multiplyMatrix(A, B):
    m, p, n = len(A), len(B), len(B[0])
    res = [[0 for i in range(n)] for j in range(m)]
    for i in range(m):
        for k in range(p):

```

```

        if A[i][k] != 0:
            for j in range(n):
                if B[k][j] != 0: res[i][j] += A[i][k] * B[k][j]
    return res

```

```

class Solution {
public:
    vector<vector<int>> multiply(vector<vector<int>>& A, vector<vector<int>>& B) {
        int m = A.size(), n = B.size(), p = B[0].size();
        vector<vector<int>> res(m, vector<int>(p));

        for (int i = 0; i < m; ++i) {
            for (int j = 0; j < n; ++j) {
                if (A[i][j] != 0) {
                    for (int k = 0; k < p; ++k) {
                        if (B[j][k] != 0) {
                            res[i][k] += A[i][j] * B[j][k];
                        }
                    }
                }
            }
        }

        return res;
    }
};

```

5.53 Set Matrix Zeroes (M)

Given a $m \times n$ matrix, if an element is 0, set its entire row and column to 0. Do it in place.

Follow up:

Did you use extra space?

A straight forward solution using $O(mn)$ space is probably a bad idea.

A simple improvement uses $O(m + n)$ space, but still not the best solution.

Could you devise a constant space solution?

```

# Time - O(MN) Space - O(M+N)
class Solution(object):
    def setZeroes(self, matrix):
        """
        :type matrix: List[List[int]]
        :rtype: None Do not return anything, modify matrix in-place instead.
        """

```



```

m = len(matrix)
n = len(matrix[0])
row, col = set(), set()
for i in range(m):
    for j in range(n):
        if matrix[i][j] == 0:
            row.add(i)
            col.add(j)
for i in range(m):
    for j in range(n):
        if i in row or j in col:
            matrix[i][j] = 0

# Time - O(MN) Space - O(1)
class Solution(object):
    def setZeroes(self, matrix):
        """
        :type matrix: List[List[int]]
        :rtype: None Do not return anything, modify matrix in-place instead.
        """
        m = len(matrix)
        n = len(matrix[0])
        row_flag, col_flag = 0, 0

        for i in range(m):
            if matrix[i][0] == 0: col_flag = 1

        for j in range(n):
            if matrix[0][j] == 0: row_flag = 1

        for i in range(1, m):
            for j in range(1, n):
                if matrix[i][j] == 0:
                    matrix[i][0] = 0
                    matrix[0][j] = 0

        for i in range(1, m):
            for j in range(1, n):
                if matrix[i][0] == 0 or matrix[0][j] == 0:
                    matrix[i][j] = 0

        if row_flag:
            for j in range(n):
                matrix[0][j] = 0

        if col_flag:
            for i in range(m):

```

matrix[i][0] = 0

```
class Solution {
public:
    void setZeroes(vector<vector<int>> &matrix) {
        if (matrix.empty() || matrix[0].empty()) return;
        int m = matrix.size(), n = matrix[0].size();
        bool rowFlag = false, colFlag = false;

        // if the first column has a zero element, update flag
        for (int i = 0; i < m; ++i) {
            if (matrix[i][0] == 0) colFlag = true;
        }
        // if the first row has a zero element, update flag
        for (int j = 0; j < n; ++j) {
            if (matrix[0][j] == 0) rowFlag = true;
        }

        // if an element of matrix expect the first row and column is zero,
        // set corresponding indices in the first row and column to zero
        for (int i = 1; i < m; ++i) {
            for (int j = 1; j < n; ++j) {
                if (matrix[i][j] == 0) {
                    matrix[i][0] = 0;
                    matrix[0][j] = 0;
                }
            }
        }

        // set corresponding element in matrix to zero
        for (int i = 1; i < m; ++i) {
            for (int j = 1; j < n; ++j) {
                if (matrix[i][0] == 0 || matrix[0][j] == 0) {
                    matrix[i][j] = 0;
                }
            }
        }

        // set the first row and column to zero based on the flags
        if (colFlag == true) {
            for (int i = 0; i < m; ++i) matrix[i][0] = 0;
        }
        if (rowFlag == true) {
            for (int j = 0; j < n; ++j) matrix[0][j] = 0;
        }
    }
};
```

5.54 Spiral Matrix (M)

Given a matrix of $m \times n$ elements (m rows, n columns), return all elements of the matrix in spiral order.

For example,

Given the following matrix: $\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$ You should return $[1, 2, 3, 6, 9, 8, 7, 4, 5]$.

```
class Solution(object):
    def spiralOrder(self, matrix):
        """
        :type matrix: List[List[int]]
        :rtype: List[int]
        """
        if not matrix or not matrix[0]: return []
        m = len(matrix)
        n = len(matrix[0])
        res = []
        left, right, up, down = 0, n-1, 0, m-1
        while True:
            for j in range(left, right+1):
                res.append(matrix[up][j])
            up += 1
            if up > down: break

            for i in range(up, down+1):
                res.append(matrix[i][right])
            right -= 1
            if right < left: break

            for j in range(right, left-1, -1):
                res.append(matrix[down][j])
            down -= 1
            if down < up: break

            for i in range(down, up-1, -1):
                res.append(matrix[i][left])
            left += 1
            if left > right: break
        return res
```

```
class Solution {
public:
    vector<int> spiralOrder(vector<vector<int>>& matrix) {
        vector<int> res;
```

```

    if (matrix.empty()) return res;
    int rowBegin = 0, rowEnd = matrix.size()-1;
    int colBegin = 0, colEnd = matrix[0].size()-1;

    // Use four variables to locate search ranges and update values
    // based on the search progress
    while (rowBegin <= rowEnd && colBegin <= colEnd) {
        // Traverse Right
        for (int j = colBegin; j <= colEnd; ++j) {
            res.push_back(matrix[rowBegin][j]);
        }
        ++rowBegin;

        // Traverse Down
        for (int i = rowBegin; i <= rowEnd; ++i) {
            res.push_back(matrix[i][colEnd]);
        }
        --colEnd;

        // Traverse Left
        if (rowBegin <= rowEnd) {
            for (int j = colEnd; j >= colBegin; --j) {
                res.push_back(matrix[rowEnd][j]);
            }
            --rowEnd;
        }

        // Traverse Up
        if (colBegin <= colEnd) {
            for (int i = rowEnd; i >= rowBegin; --i) {
                res.push_back(matrix[i][colBegin]);
            }
            ++colBegin;
        }
    }

    return res;
}
};

```

5.55 Spiral Matrix II (M)

Given an integer n , generate a square matrix filled with elements from 1 to n^2 in spiral order.

For example,

Given $n = 3$, You should return the following matrix: $\begin{bmatrix} 1, & 2, & 3 \\ 8, & 9, & 4 \\ 7, & 6, & 5 \end{bmatrix}$

```

class Solution(object):
    def generateMatrix(self, n):
        """
        :type n: int
        :rtype: List[List[int]]
        """
        res = [[1] * n for i in range(n)]
        val = 1
        up, down, left, right = 0, n-1, 0, n-1
        while True:
            for j in range(left, right+1):
                res[up][j] = val
                val += 1
            up += 1
            if (up > down): break

            for i in range(up, down+1):
                res[i][right] = val
                val += 1
            right -= 1
            if right < left: break

            for j in range(right, left-1, -1):
                res[down][j] = val
                val += 1
            down -= 1
            if down < up: break

            for i in range(down, up-1, -1):
                res[i][left] = val
                val += 1
            left += 1
            if left > right: break
        return res

```

```

class Solution {
public:
    vector<vector<int>> generateMatrix(int n) {
        vector<vector<int>> res(n, vector<int> (n));
        int start = 0, end = n-1, num = 1;
        // Iterate the matrix from outside level to insider level
        // Iterate each row and col from index 0 to n-2
        while (start < end) {
            for (int j = start; j < end; ++j) res[start][j] = num++;
            for (int i = start; i < end; ++i) res[i][end] = num++;

```

```

        for (int j = end; j > start; --j) res[end][j] = num++;
        for (int i = end; i > start; --i) res[i][start] = num++;
        ++start; // update index for the next inside level
        --end;
    }
    // In case that matrix[n/2][n/2] is the last num
    if (start == end) res[start][end] = num;
    return res;
}
};

```

5.56 Spiral Matrix III (M)

On a 2 dimensional grid with R rows and C columns, we start at (r0, c0) facing east.

Here, the north-west corner of the grid is at the first row and column, and the south-east corner of the grid is at the last row and column.

Now, we walk in a clockwise spiral shape to visit every position in this grid.

Whenever we would move outside the boundary of the grid, we continue our walk outside the grid (but may return to the grid boundary later.)

Eventually, we reach all $R * C$ spaces of the grid.

Return a list of coordinates representing the positions of the grid in the order they were visited.

```

class Solution(object):
    def spiralMatrixIII(self, R, C, r0, c0):
        """
        :type R: int
        :type C: int
        :type r0: int
        :type c0: int
        :rtype: List[List[int]]
        """
        self.res = [[r0, c0]]
        step = 1
        while len(self.res) < R * C:
            for i in range(step):
                c0 += 1
                self.add(R, C, r0, c0)
            for i in range(step):

```

```

        r0 += 1
        self.add(R, C, r0, c0)
    step += 1
    for i in range(step):
        c0 -= 1
        self.add(R, C, r0, c0)
    for i in range(step):
        r0 -= 1
        self.add(R, C, r0, c0)
    step += 1
    return self.res
def add(self, R, C, x, y):
    if x >= 0 and x < R and y >= 0 and y < C:
        self.res.append([x, y])

```

5.57 Rotate Image (M)(Amazon phone screen 2016.9.16)

You are given an $n \times n$ 2D matrix representing an image. Rotate the image by 90 degrees (clockwise).

Follow up: Could you do this in-place?

```

# Clockwise 90deg rotation: Vertical flip + Transpose (Diagonal flip)
class Solution(object):
    def rotate(self, matrix):
        """
        :type matrix: List[List[int]]
        :rtype: None Do not return anything, modify matrix in-place instead.
        """
        n = len(matrix)
        matrix.reverse()
        for i in range(n):
            for j in range(i+1, n):
                matrix[i][j], matrix[j][i] = matrix[j][i], matrix[i][j]

# Counter-clockwise 90deg rotation: Horizontal flip + Transpose (Diagonal flip)
class Solution(object):
    def rotate(self, matrix):
        """
        :type matrix: List[List[int]]
        :rtype: None Do not return anything, modify matrix in-place instead.
        """
        n = len(matrix)
        for row in matrix:
            row.reverse()

```

```

        for i in range(n):
            for j in range(i+1, n):
                matrix[i][j], matrix[j][i] = matrix[j][i], matrix[i][j]

```

```

// 1. Direct rotate
class Solution {
public:
    void rotate(vector<vector<int> > &matrix) {
        int n = matrix.size();
        for (int i = 0; i < n / 2; ++i) { // iterate layer by layer
            for (int j = i; j < n - 1 - i; ++j) {
                int tmp = matrix[i][j]; // upper left to tmp
                matrix[i][j] = matrix[n - 1 - j][i]; // bottom left to upper left
                matrix[n - 1 - j][i] = matrix[n - 1 - i][n - 1 - j]; // bottom
                    right to bottom left
                matrix[n - 1 - i][n - 1 - j] = matrix[j][n - 1 - i]; // upper
                    right to bottom right
                matrix[j][n - 1 - i] = tmp; // tmp to upper right
            }
        }
    }
};

// 2. Flip by antidiagonal line, then flip by the middle row
class Solution {
public:
    void rotate(vector<vector<int>>& matrix) {
        int n = matrix.size();
        // swap elements by antidiagonal line
        for (int i = 0; i < n; ++i)
            for (int j = 0; j < n-i; ++j)
                swap(matrix[i][j], matrix[n-1-j][n-1-i]);
        // swap elements by horizontal center line
        for (int i = 0; i < n/2; ++i)
            for (int j = 0; j < n; ++j)
                swap(matrix[i][j], matrix[n-1-i][j]);
    }
};

// 3. Transpose the matrix (i.e. flip by diagonal line), then reverse each row
class Solution {
public:
    void rotate(vector<vector<int> > &matrix) {
        int n = matrix.size();
        for (int i = 0; i < n; ++i) {
            for (int j = i + 1; j < n; ++j) {
                swap(matrix[i][j], matrix[j][i]);

```



```

        }
        reverse(matrix[i].begin(), matrix[i].end());
    }
}
};

```

5.58 Flatten Nested List Iterator (M)

Given a nested list of integers, implement an iterator to flatten it. Each element is either an integer, or a list – whose elements may also be integers or other lists.

Example 1: Given the list `[[1,1],2,[1,1]]`,

By calling `next` repeatedly until `hasNext` returns false, the order of elements returned by `next` should be: `[1,1,2,1,1]`.

Example 2: Given the list `[1,[4,[6]]]`,

By calling `next` repeatedly until `hasNext` returns false, the order of elements returned by `next` should be: `[1,4,6]`.

```

# """
# This is the interface that allows for creating nested lists.
# You should not implement it, or speculate about its implementation
# """
#class NestedInteger(object):
#    def isInteger(self):
#        """
#        @return True if this NestedInteger holds a single integer, rather than a
#        nested list.
#        :rtype bool
#        """
#
#    def getInteger(self):
#        """
#        @return the single integer that this NestedInteger holds, if it holds a
#        single integer
#        Return None if this NestedInteger holds a nested list
#        :rtype int
#        """
#
#    def getList(self):
#        """
#        @return the nested list that this NestedInteger holds, if it holds a
#        nested list
#        Return None if this NestedInteger holds a single integer

```

```

#         :rtype List[NestedInteger]
#         """

class NestedIterator(object):

    # append each list/integer in the nested list to a stack
    def __init__(self, nestedList):
        """
        Initialize your data structure here.
        :type nestedList: List[NestedInteger]
        """
        self.stack = []
        for i in range(len(nestedList) - 1, -1, -1):
            self.stack.append(nestedList[i])

    def next(self):
        """
        :rtype: int
        """
        return self.stack.pop().getInteger()

    def hasNext(self):
        """
        :rtype: bool
        """
        while self.stack:
            t = self.stack[-1]
            if t.isInteger():
                return True
            # need to pop the element if it's a list
            # then append integer/list inside the element to the stack
            self.stack.pop()
            for i in range(len(t.getList()) - 1, -1, -1):
                self.stack.append(t.getList()[i])
        return False

# Your NestedIterator object will be instantiated and called as such:
# i, v = NestedIterator(nestedList), []
# while i.hasNext(): v.append(i.next())

```

```

/**
 * // This is the interface that allows for creating nested lists.
 * // You should not implement it, or speculate about its implementation
 * class NestedInteger {
 *     public:
 *         // Return true if this NestedInteger holds a single integer, rather than a

```

```

    nested list.
*   bool isInteger() const;
*
*   // Return the single integer that this NestedInteger holds, if it holds a
    single integer
*   // The result is undefined if this NestedInteger holds a nested list
*   int getInteger() const;
*
*   // Return the nested list that this NestedInteger holds, if it holds a
    nested list
*   // The result is undefined if this NestedInteger holds a single integer
*   const vector<NestedInteger> &getList() const;
* };
*/

class NestedIterator {
public:
    NestedIterator(vector<NestedInteger> &nestedList) {
        for (int i = nestedList.size() - 1; i >= 0; --i)
            s.push(nestedList[i]);
    }

    int next() {
        NestedInteger n = s.top();
        s.pop();
        return n.getInteger();
    }

    bool hasNext() {
        while(!s.empty()) {
            NestedInteger n = s.top();
            if (n.isInteger()) return true;
            s.pop();    // pop the current element for the following push
                        // push to s if the current element is a list
            for (int i = n.getList().size() - 1; i >= 0; --i)
                s.push(n.getList()[i]);
        }
        return false;
    }

private:
    stack<NestedInteger> s;
};

/**
 * Your NestedIterator object will be instantiated and called as such:
 * NestedIterator i(nestedList);
 */

```

```
* while (i.hasNext()) cout << i.next();
*/
```

5.59 Nested List Weight Sum (E)

Given a nested list of integers, return the sum of all integers in the list weighted by their depth. Each element is either an integer, or a list – whose elements may also be integers or other lists.

Example 1:

Given the list $[[1,1],2,[1,1]]$, return 10. (four 1's at depth 2, one 2 at depth 1)

Example 2:

Given the list $[1,[4,[6]]]$, return 27. (one 1 at depth 1, one 4 at depth 2, and one 6 at depth 3; $1 + 4*2 + 6*3 = 27$)

```
class Solution {
public:
    int depthSum(vector<NestedInteger>& nestedList) {
        int res = 0;
        for (auto l : nestedList)
            res += getSum(l, 1);
        return res;
    }

    int getSum(NestedInteger nl, int level) {
        int res = 0;
        if (nl.isInteger())
            return level * nl.getInteger();
        for (auto l : nl.getList())
            res += getSum(l, level+1);
        return res;
    }
};
```

5.60 Nested List Weight Sum II (M)

Given a nested list of integers, return the sum of all integers in the list weighted by their depth. Each element is either an integer, or a list – whose elements may also be integers or other lists.

Different from the previous question where weight is increasing from root to leaf, now the

weight is defined from bottom up. i.e., the leaf level integers have weight 1, and the root level integers have the largest weight.

Example 1:

Given the list $[[1,1],2,[1,1]]$, return 8. (four 1's at depth 1, one 2 at depth 2)

Example 2:

Given the list $[1,[4,[6]]]$, return 17. (one 1 at depth 3, one 4 at depth 2, and one 6 at depth 1; $1*3 + 4*2 + 6*1 = 17$)

```
class Solution {
public:
    int depthSumInverse(vector<NestedInteger> &nestedList) {
        int unweighted = 0, weighted = 0;

        while (!nestedList.empty()) {
            vector<NestedInteger> nextLevel;
            for (auto l : nestedList) {
                if (l.isInteger()) {
                    unweighted += l.getInteger();    // add all integers of the
                                                    // current level together
                } else {
                    // insert(position, first, last)
                    nextLevel.insert(nextLevel.end(), l.getList().begin(),
                                     l.getList().end());
                }
            }
            weighted += unweighted;    // add all integers in level n to level n+1
                                     // twice
            nestedList = nextLevel;    // update the nested list
        }

        return weighted;
    }
};
```

5.61 Mini Parser (M)

Given a nested list of integers represented as a string, implement a parser to deserialize it. Each element is either an integer, or a list – whose elements may also be integers or other lists.

Note: You may assume that the string is well-formed:

String is non-empty.

String does not contain white spaces.

String contains only digits 0-9, [, -, ,,].

Example 1: Given s = "324", You should return a NestedInteger object which contains a single integer 324.

Example 2: Given s = "[123,[456,[789]]]", Return a NestedInteger object containing a nested list with 2 elements:

1. An integer containing value 123.
2. A nested list containing two elements:
 - i. An integer containing value 456.
 - ii. A nested list with one element:
 - a. An integer containing value 789.

```
/**
 * // This is the interface that allows for creating nested lists.
 * // You should not implement it, or speculate about its implementation
 * class NestedInteger {
 *   public:
 *     // Constructor initializes an empty nested list.
 *     NestedInteger();
 *
 *     // Constructor initializes a single integer.
 *     NestedInteger(int value);
 *
 *     // Return true if this NestedInteger holds a single integer, rather than a
 *     nested list.
 *     bool isInteger() const;
 *
 *     // Return the single integer that this NestedInteger holds, if it holds a
 *     single integer
 *     // The result is undefined if this NestedInteger holds a nested list
 *     int getInteger() const;
 *
 *     // Set this NestedInteger to hold a single integer.
 *     void setInteger(int value);
 *
 *     // Set this NestedInteger to hold a nested list and adds a nested integer
 *     to it.
 *     void add(const NestedInteger &ni);
 *
 *     // Return the nested list that this NestedInteger holds, if it holds a
 *     nested list
 *     // The result is undefined if this NestedInteger holds a single integer
 *     const vector<NestedInteger> &getList() const;
 * };
 */
```

// 1. Recursive solution

```
class Solution {
public:
    NestedInteger deserialize(string s) {
        if (s.empty()) return NestedInteger();
        if (s[0] != '[') return NestedInteger(stoi(s));
        if (s.size() <= 2) return NestedInteger();
        NestedInteger res;
        int start = 1, cnt = 0;
        for (int i = 1; i < s.size(); ++i) {
            if (cnt == 0 && (s[i] == ',' || i == s.size() - 1)) {
                res.add(deserialize(s.substr(start, i - start)));
                start = i + 1;
            } else if (s[i] == '[') ++cnt;
            else if (s[i] == ']') --cnt;
        }
        return res;
    }
};
```

// 2. Iterative solution

```
class Solution {
public:
    NestedInteger deserialize(string s) {
        if (s.empty()) return NestedInteger();
        if (s[0] != '[') return NestedInteger(stoi(s));
        stack<NestedInteger> st;
        int start = 1;
        for (int i = 0; i < s.size(); ++i) {
            if (s[i] == '[') {
                st.push(NestedInteger());
                start = i + 1;
            } else if (s[i] == ',' || s[i] == ']') {
                if (i > start) {
                    st.top().add(NestedInteger(stoi(s.substr(start, i - start))));
                }
                start = i + 1;
                if (s[i] == ']') {
                    if (st.size() > 1) {
                        NestedInteger t = st.top(); st.pop();
                        st.top().add(t);
                    }
                }
            }
        }
        return st.top();
    }
};
```

```

};

// 3. istream solution
class Solution {
public:
    NestedInteger deserialize(string s) {
        istream in(s);
        return deserialize(in);
    }
    NestedInteger deserialize(istream& in) {
        int num;
        if (in >> num) return NestedInteger(num);
        in.clear();
        in.get();
        NestedInteger list;
        while (in.peek() != ']') {
            list.add(deserialize(in));
            if (in.peek() == ',') {
                in.get();
            }
        }
        in.get();
        return list;
    }
};

```

5.62 Brick Wall (M)

There is a brick wall in front of you. The wall is rectangular and has several rows of bricks. The bricks have the same height but different width. You want to draw a vertical line from the top to the bottom and cross the least bricks.

The brick wall is represented by a list of rows. Each row is a list of integers representing the width of each brick in this row from left to right.

If your line go through the edge of a brick, then the brick is not considered as crossed. You need to find out how to draw the line to cross the least bricks and return the number of crossed bricks.

You cannot draw a line just along one of the two vertical edges of the wall, in which case the line will obviously cross no bricks.

```

class Solution(object):
    def leastBricks(self, wall):

```



```

"""
:type wall: List[List[int]]
:rtype: int
"""
mx = 0
idx_freq_map = {}
for w in wall:
    idx = 0
    n = len(w)
    for i in range(n-1):
        idx += w[i]
        if idx in idx_freq_map:
            idx_freq_map[idx] += 1
        else:
            idx_freq_map[idx] = 1
        mx = max(mx, idx_freq_map[idx])
return len(wall) - mx

```

Chapter 6

String

6.1 Add Binary (E)

Given two binary strings, return their sum (also a binary string).

For example, a = "11", b = "1", Return "100".

```
class Solution(object):
    def addBinary(self, a, b):
        """
        :type a: str
        :type b: str
        :rtype: str
        """
        s1, s2 = [], []
        res = ''
        carry = 0
        for i in a:
            s1.append(int(i))
        for i in b:
            s2.append(int(i))
        while s1 or s2:
            val = carry
            if s1:
                val += s1.pop()
            if s2:
                val += s2.pop()
            carry = val / 2
            val %= 2
            res += str(val)
        if carry == 1:
            res += str(carry)
        return res[::-1]
```

```

class Solution {
public:
    string addBinary(string a, string b) {
        string res = "";
        int ai, bi, val, carry = 0;
        int i = a.size() - 1;
        int j = b.size() - 1;

        while (i >= 0 || j >= 0 || carry == 1) {
            if (i >= 0)
                ai = a[i--] - '0';           // convert char to integer
            else
                ai = 0;

            if (j >= 0)
                bi = b[j--] - '0';
            else
                bi = 0;

            val = (ai + bi + carry) % 2;
            carry = (ai + bi + carry) / 2;

            res = char(val + '0') + res;      // convert integer to char by
                                             char(val + '0')

        }

        return res;
    }
};

```

6.2 Add Strings (E)

Given two non-negative integers num1 and num2 represented as string, return the sum of num1 and num2.

Note:

The length of both num1 and num2 is ≤ 5100.

Both num1 and num2 contains only digits 0-9.

Both num1 and num2 does not contain any leading zero.

You must not use any built-in BigInteger library or convert the inputs to integer directly.

```

class Solution(object):
    def addStrings(self, num1, num2):

```

```

"""
:type num1: str
:type num2: str
:rtype: str
"""
res = ''
carry = 0
n1, n2 = len(num1) - 1, len(num2) - 1
while n1 >= 0 or n2 >= 0:
    val = carry
    if n1 >= 0:
        val += ord(num1[n1]) - ord('0')
        n1 -= 1
    if n2 >= 0:
        val += ord(num2[n2]) - ord('0')
        n2 -= 1
    carry = val / 10
    val %= 10
    res = str(val) + res
if carry > 0:
    res = str(carry) + res
return res

```

6.3 Multiply Strings (M)

Given two numbers represented as strings, return multiplication of the numbers as a string.

Note:

The numbers can be arbitrarily large and are non-negative.

Converting the input string to integer is NOT allowed.

You should NOT use internal library such as BigInteger.

```

class Solution(object):
    def multiply(self, num1, num2):
        """
        :type num1: str
        :type num2: str
        :rtype: str
        """
        res = ''
        m, n = len(num1), len(num2)
        # the length of res is smaller or equal to m + n
        vals = [0 for i in range(m + n)]
        for i in range(m - 1, -1, -1):
            for j in range(n - 1, -1, -1):

```

```

        mul = (ord(num1[i]) - ord('0')) * (ord(num2[j]) - ord('0'))
        p1 = i + j # higher bit
        p2 = i + j + 1 #lower bit
        cur_sum = mul + vals[p2] # add existed lower bit
        vals[p1] += cur_sum / 10 # update higher bit
        vals[p2] = cur_sum % 10 # update lower bit
    # skip leading zeros
    for val in vals:
        if res or val != 0: res += str(val)
    # res could be zero
    if not res:
        return '0'
    else:
        return res

```

```

class Solution {
public:
    string multiply(string num1, string num2) {
        string res;
        int n1 = num1.size(), n2 = num2.size();
        int k = n1 + n2 - 2, carry = 0;
        vector<int> v(n1 + n2, 0);
        for (int i = 0; i < n1; ++i) {
            for (int j = 0; j < n2; ++j) {
                v[k - i - j] += (num1[i] - '0') * (num2[j] - '0');
            }
        }
        for (int i = 0; i < n1 + n2; ++i) {
            v[i] += carry;
            carry = v[i] / 10;
            v[i] %= 10;
        }
        int i = n1 + n2 - 1;
        while (v[i] == 0) --i;
        if (i < 0) return "0";
        while (i >= 0) res.push_back(v[i--] + '0');
        return res;
    }
};

```

6.4 Count and Say (E)

The count-and-say sequence is the sequence of integers beginning as follows: 1, 11, 21, 1211, 111221, ...

1 is read off as "one 1" or 11.

11 is read off as "two 1s" or 21.

21 is read off as "one 2, then one 1" or 1211.

Given an integer n, generate the nth sequence. The sequence of integers will be represented as a string.

```
class Solution(object):
    def countAndSay(self, n):
        """
        :type n: int
        :rtype: str
        """
        if n <= 0: return ''
        res = '1'
        while n - 1:
            s = ''
            m = len(res)
            j = 0
            while j < m:
                cnt = 1
                # count the same element
                while j + 1 < m and res[j] == res[j+1]:
                    cnt += 1
                    j += 1
                # temp string is count + element
                s += str(cnt) + res[j]
                j += 1
            res = s
            n -= 1
        return res
```

```
class Solution {
public:
    string countAndSay(int n) {
        if (n == 0) return NULL;

        string res = "1";    // start at 1

        while (n != 1) {
            string cur = "";
            for (int i = 0; i < res.size(); ++i) {
                int cnt = 1;
                while ( (i+1) < res.size() && res[i] == res[i+1] ) { // count
                    res[i]
                    ++cnt;
                    ++i;
                }
            }
            res = cur;
            n--;
        }
        return res;
    }
};
```

```

        }
        cur += to_string(cnt) + res[i];           // count and
            say res[i]
    }
    res = cur;    // update current result
    --n;         // decrease n until n = 1
}

return res;
}
};

```

6.5 Length of Last Word (E)

Given a string *s* consists of upper/lower-case alphabets and empty space characters ' ', return the length of last word in the string. If the last word does not exist, return 0. A word is defined as a character sequence consists of non-space characters only.

```

class Solution {
public:
    int lengthOfLastWord(string s) {
        if (s.empty()) return 0;

        int cnt = 0, n = s.size() - 1;

        while (s[n] == ' ' && n >= 0) {
            --n;
        }

        while (s[n] != ' ' && n >= 0) {
            ++cnt;
            --n;
        }

        return cnt;
    }
};

```

6.6 Longest Common Prefix (E)

Write a function to find the longest common prefix string amongst an array of strings.

```

class Solution {
public:
    string longestCommonPrefix(vector<string> &strs) {
        string prefix = "";           // define the initial prefix
        if (strs.size() == 0) return prefix;

        int i, j;
        // iterate different chars in the first string
        for (i = 0; i < strs[0].size(); ++i) {

            // iterate different strings from the second string
            for (j = 1; j < strs.size() && i < strs[j].size(); ++j) {
                if (strs[j][i] != strs[0][i])    // compare each char between the
                    // first string and the other strings
                    return prefix;              // if no match for the current
                                                // char, return prefix immediately
            }

            if (j == strs.size())                // if the i-th char in the first
                // string matches all others strings
                prefix += strs[0][i];           // update prefix
        }
        return prefix;
    }
};

```

6.7 Implement strStr() (E)

Implement strStr(). Returns the index of the first occurrence of needle in haystack, or -1 if needle is not part of haystack.

```

class Solution(object):
    def strStr(self, haystack, needle):
        """
        :type haystack: str
        :type needle: str
        :rtype: int
        """
        m, n = len(haystack), len(needle)
        for i in range(m - n + 1):
            if haystack[i:i+n] == needle:
                return i
        return -1

```

```

class Solution {
public:
    int strStr(string haystack, string needle) {
        if (needle.empty()) return 0;

        for (int i = 0; ; ++i) {
            for (int j = 0; ; ++j) {
                if (needle[j] == '\0')           // if the current j reaches the end
                                                    of needle, i is the correct index
                    return i;
                if (haystack[i + j] == '\0') // if i+j reaches the end of
                                                    haystack, there is no chance to find the needle
                    return -1;
                if (haystack[i + j] != needle[j]) // break for each no-match
                    break;
            }
        }
    };
};

```

6.8 Is Subsequence (M)

Given a string *s* and a string *t*, check if *s* is subsequence of *t*. You may assume that there is only lower case English letters in both *s* and *t*. *t* is potentially a very long (length = 500,000) string, and *s* is a short string (≤ 100).

A subsequence of a string is a new string which is formed from the original string by deleting some (can be none) of the characters without disturbing the relative positions of the remaining characters. (ie, "ace" is a subsequence of "abcde" while "aec" is not).

Example 1: *s* = "abc", *t* = "ahbgdc" Return true.

Example 2: *s* = "axc", *t* = "ahbgdc" Return false.

Follow up: If there are lots of incoming *S*, say *S*₁, *S*₂, ... , *S*_k where $k \leq 10^4$, and you want to check one by one to see if *T* has its subsequence. In this scenario, how would you change your code?

```

class Solution {
public:
    bool isSubsequence(string s, string t) {
        int i = 0, j = 0;
        while (i < s.size() && j < t.size()) {
            if (s[i] == t[j]) ++i;
            ++j;
        }
        return i == s.size();
    }
};

```

```

        ++j;
    }
    if (i == s.size()) return true;
    else return false;
}
};

```

6.9 Ransom Note (E)

Given an arbitrary ransom note string and another string containing letters from all the magazines, write a function that will return true if the ransom note can be constructed from the magazines; otherwise, it will return false. Each letter in the magazine string can only be used once in your ransom note.

Note: You may assume that both strings contain only lowercase letters.

```

canConstruct("a", "b") -> false
canConstruct("aa", "ab") -> false
canConstruct("aa", "aab") -> true

```

```

class Solution {
public:
    bool canConstruct(string ransomNote, string magazine) {
        unordered_map<char, int> m;
        for (auto c : magazine) ++m[c];
        for (auto c : ransomNote) {
            if (--m[c] < 0) return false;
        }
        return true;
    }
};

```

6.10 Find the Difference (M)

Given two strings s and t which consist of only lowercase letters. String t is generated by random shuffling string s and then add one more letter at a random position. Find the letter that was added in t.

Example:

Input: s = "abcd", t = "abcde"

Output: e

Explanation: 'e' is the letter that was added.

```
class Solution {
public:
    char findTheDifference(string s, string t) {
        unordered_map<char, int> m;
        for (auto c : s) ++m[c];
        for (auto c : t) {
            if (--m[c] < 0) return c;
        }
        return 0;
    }
};
```

6.11 First Unique Character in a String (E)

Given a string, find the first non-repeating character in it and return its index. If it doesn't exist, return -1.

Examples:

s = "leetcode" return 0.

s = "loveleetcode", return 2.

Note: You may assume the string contain only lowercase letters.

```
class Solution(object):
    def firstUniqChar(self, s):
        """
        :type s: str
        :rtype: int
        """
        # Initialize the dictionary with keys from s and values as 0
        d = dict.fromkeys(s, 0)
        for c in s:
            d[c] += 1
        for c in s:
            if d[c] == 1:
                return s.index(c)
        return -1
```

// 1. Brute-force with scanning s twice

```
class Solution {
public:
```

```

int firstUniqChar(string s) {
    if (s.empty()) return -1;
    unordered_map<char, int> m;
    for (auto c : s) ++m[c];
    for (int i = 0; i < s.size(); ++i) {
        if (m[s[i]] == 1) return i;
    }
    return -1;
}

};

// 2. Brute-force with scanning s only once
class Solution {
public:
    int firstUniqChar(string s) {
        if (s.empty()) return -1;
        unordered_map<char, pair<int, int>> m;
        int idx = s.size();
        for (int i = 0; i < s.size(); ++i) {
            m[s[i]].first++; // save the count of chars
            m[s[i]].second = i; // save the index of chars
        }
        for (auto a : m) {
            if (a.second.first == 1) {
                idx = min(idx, a.second.second); // find the smallest index
            }
        }
        return idx == s.size() ? -1 : idx;
    }
};

```

6.12 Permutation in String (M)

Given two strings *s1* and *s2*, write a function to return true if *s2* contains the permutation of *s1*. In other words, one of the first string's permutations is the substring of the second string.

```

class Solution(object):
    def checkInclusion(self, s1, s2):
        """
        :type s1: str
        :type s2: str
        :rtype: bool
        """
        m1, m2 = [0] * 26, [0] * 26
        n1, n2 = len(s1), len(s2)

```

```

if n1 > n2: return False

# count the frequency of each char for s1 and the first n1 chars of s2
# if the two counts are the same, then s2 contains the permutation of s1
for i in range(n1):
    m1[ord(s1[i]) - ord('a')] += 1
    m2[ord(s2[i]) - ord('a')] += 1
if m1 == m2: return True

# apply the sliding window to check if the counts between
# the length n1 substring of s2 and s1 are the same
for i in range(n1, n2):
    m2[ord(s2[i]) - ord('a')] += 1
    m2[ord(s2[i - n1]) - ord('a')] -= 1
    if m1 == m2: return True

return False

```

6.13 ZigZag Conversion (E)

Write the code that will take a string and make this conversion given a number of rows:
string convert(string text, int nRows).
convert(“PAYPALISHIRING”, 3) should return “PAHNAPLSIIGYIR”.

```

class Solution {
public:
    string convert(string s, int numRows) {
        if (numRows <= 1) return s;

        vector<string> tmp(numRows);
        string res;
        int row = 0, flag = 1;

        for (int i = 0; i < s.size(); ++i) {
            tmp[row].push_back(s[i]);

            // perform zigzag
            if (row == 0)                // increase row number
                flag = 1;
            else if (row == numRows - 1) // decrease row number
                flag = -1;
            row += flag;
        }

        for (int i = 0; i < numRows; ++i)

```

```

        res.append(tmp[i]);

    return res;
}
};

```

6.14 Group Shifted Strings (E)

Given a string, we can “shift” each of its letter to its successive letter, for example: “*abc*” – > “*bcd*”. We can keep “shifting” which forms the sequence: “*abc*” – > “*bcd*” – > ... – > “*xyz*”

Given a list of strings which contains only lowercase alphabets, group all strings that belong to the same shifting sequence.

For example, given: [“*abc*”, “*bcd*”, “*acef*”, “*xyz*”, “*az*”, “*ba*”, “*a*”, “*z*”],

Return: [[“*abc*”, “*bcd*”, “*xyz*”], [“*az*”, “*ba*”], [“*acef*”], [“*a*”, “*z*”]]

Note: For the return value, each inner list’s elements must follow the lexicographic order.

```

class Solution {
public:
    vector<vector<string>> groupStrings(vector<string>& strings) {
        vector<vector<string> > res;
        unordered_map<string, multiset<string>> m;
        for (auto a : strings) {
            string t = "";
            for (char c : a) {
                t += to_string((c + 26 - a[0]) % 26) + ",";
            }
            m[t].insert(a);
        }
        for (auto it = m.begin(); it != m.end(); ++it) {
            res.push_back(vector<string>(it->second.begin(), it->second.end()));
        }
        return res;
    }
};

```

6.15 Compare Version Numbers (E)

Compare two version numbers version1 and version2. If version1 > version2 return 1, if version1 < version2 return -1, otherwise return 0.

You may assume that the version strings are non-empty and contain only digits and the . character. The . character does not represent a decimal point and is used to separate number sequences. For instance, 2.5 is not "two and a half" or "half way to version three", it is the fifth second-level revision of the second first-level revision.

Here is an example of version numbers ordering: $0.1 < 1.1 < 1.2 < 13.37$

```
class Solution(object):
    def compareVersion(self, version1, version2):
        """
        :type version1: str
        :type version2: str
        :rtype: int
        """
        v1_list = version1.split('.')
        v2_list = version2.split('.')
        max_len = max(len(v1_list), len(v2_list))
        for i in range(max_len):
            v1_int = int(v1_list[i]) if i < len(v1_list) else 0
            v2_int = int(v2_list[i]) if i < len(v2_list) else 0
            if v1_int < v2_int:
                return -1
            elif v1_int > v2_int:
                return 1
        return 0
```

```
class Solution {
public:
    int compareVersion(string version1, string version2) {
        int n1 = version1.size(), n2 = version2.size();
        int i, j, num1, num2;
        i = j = num1 = num2 = 0;

        //first compare the left part before ".", then compare the right part
        after "."
        while (i < n1 || j < n2) {
            while (i < n1 && version1[i] != '.')
                num1 = num1 * 10 + (version1[i++] - '0'); // string to int

            while (j < n2 && version2[j] != '.')
                num2 = num2 * 10 + (version2[j++] - '0');

            if (num1 > num2)
                return 1;
            else if (num1 < num2)
                return -1;
        }
```

```

        num1 = num2 = 0;
        ++i;
        ++j;
    }

    return 0;
}
};

```

6.16 Additive Number (M)

Additive number is a string whose digits can form additive sequence. A valid additive sequence should contain at least three numbers. Except for the first two numbers, each subsequent number in the sequence must be the sum of the preceding two.

For example:

"112358" is an additive number because the digits can form an additive sequence: 1, 1, 2, 3, 5, 8.

$1 + 1 = 2$, $1 + 2 = 3$, $2 + 3 = 5$, $3 + 5 = 8$

"199100199" is also an additive number, the additive sequence is: 1, 99, 100, 199.

$1 + 99 = 100$, $99 + 100 = 199$

Note: Numbers in the additive sequence cannot have leading zeros, so sequence 1, 2, 03 or 1, 02, 3 is invalid.

Given a string containing only digits '0'-'9', write a function to determine if it's an additive number.

Follow up: How would you handle overflow for very large input integers?

```

// Non-recursion
class Solution {
public:
    bool isAdditiveNumber(string num) {
        for (int i = 1; i < num.size(); ++i) {
            for (int j = i + 1; j < num.size(); ++j) {
                string s1 = num.substr(0, i);
                string s2 = num.substr(i, j - i);
                long long d1 = atoll(s1.c_str()), d2 = atoll(s2.c_str());
                if ((s1.size() > 1 && s1[0] == '0') || (s2.size() > 1 && s2[0] ==
                    '0')) continue;
            }
        }
    }
};

```



```

        long long next = d1 + d2;
        string nexts = to_string(next);
        string now = s1 + s2 + nexts;
        while (now.size() < num.size()) {
            d1 = d2;
            d2 = next;
            next = d1 + d2;
            nexts = to_string(next);
            now += nexts;
        }
        if (now == num) return true;
    }
    return false;
}
};

```

6.17 Evaluate Division (M)

Equations are given in the format $A / B = k$, where A and B are variables represented as strings, and k is a real number (floating point number). Given some queries, return the answers. If the answer does not exist, return -1.0.

Example:

Given $a / b = 2.0$, $b / c = 3.0$.

queries are: $a / c = ?$, $b / a = ?$, $a / e = ?$, $a / a = ?$, $x / x = ?$.

return $[6.0, 0.5, -1.0, 1.0, -1.0]$.

According to the example above:

equations = $[["a", "b"], ["b", "c"]]$,

values = $[2.0, 3.0]$,

queries = $[["a", "c"], ["b", "a"], ["a", "e"], ["a", "a"], ["x", "x"]]$.

The input is always valid. You may assume that evaluating the queries will result in no division by zero and there is no contradiction.

```

class Solution {
public:
    vector<double> calcEquation(vector<pair<string, string>> equations,
        vector<double>& values, vector<pair<string, string>> queries) {
        vector<double> res(queries.size(), -1);
        set<string> s;
        for (auto a : equations) {
            s.insert(a.first);

```

```

        s.insert(a.second);
    }
    for (int i = 0; i < queries.size(); ++i) {
        vector<string> query{queries[i].first, queries[i].second};
        if (s.count(query[0]) && s.count(query[1])) {
            vector<int> v;
            res[i] = helper(equations, values, query, v);
        }
    }
    return res;
}

double helper(vector<pair<string, string>> equations, vector<double>& values,
vector<string> query, vector<int>& v) {
    for (int i = 0; i < equations.size(); ++i) {
        if (equations[i].first == query[0] && equations[i].second ==
            query[1]) return values[i];
        if (equations[i].first == query[1] && equations[i].second ==
            query[0]) return 1.0 / values[i];
    }
    for (int i = 0; i < equations.size(); ++i) {
        if (find(v.begin(), v.end(), i) == v.end() && equations[i].first ==
            query[0]) {
            v.push_back(i);
            double t = values[i] * helper(equations, values,
                {equations[i].second, query[1]}, v);
            if (t > 0) return t;
            else v.pop_back();
        }
        if (find(v.begin(), v.end(), i) == v.end() && equations[i].second ==
            query[0]) {
            v.push_back(i);
            double t = helper(equations, values, {equations[i].first,
                query[1]}, v) / values[i];
            if (t > 0) return t;
            else v.pop_back();
        }
    }
    return -1.0;
}
};

```

```

class Solution {
public:
    vector<double> calcEquation(vector<pair<string, string>> equations,
        vector<double>& values, vector<pair<string, string>> queries) {
        vector<double> res;
    }
};

```

```

unordered_map<string, unordered_map<string, double>> g;
for (int i = 0; i < equations.size(); ++i) {
    g[equations[i].first].emplace(equations[i].second, values[i]);
    g[equations[i].first].emplace(equations[i].first, 1.0);
    g[equations[i].second].emplace(equations[i].first, 1.0 / values[i]);
    g[equations[i].second].emplace(equations[i].second, 1.0);
}
for (auto query : queries) {
    if (!g.count(query.first) || !g.count(query.second))
        res.push_back(-1.0);
    else {
        queue<pair<string, double>> q;
        unordered_set<string> used{query.first};
        bool find = false;
        q.push({query.first, 1.0});
        while (!q.empty() && !find) {
            queue<pair<string, double>> next;
            while (!q.empty() && !find) {
                pair<string, double> t = q.front(); q.pop();
                if (t.first == query.second) {
                    find = true;
                    res.push_back(t.second);
                    break;
                }
                for (auto a : g[t.first]) {
                    if (!used.count(a.first)) {
                        a.second *= t.second;
                        next.push(a);
                        used.insert(a.first);
                    }
                }
            }
            q = next;
        }
        if (!find) res.push_back(-1.0);
    }
}
return res;
};

```

6.18 Restore IP Addresses (M)

Given a string containing only digits, restore it by returning all possible valid IP address combinations.

For example: Given "25525511135", return ["255.255.11.135", "255.255.111.35"]. (Order does not matter)

```
class Solution {
public:
    vector<string> restoreIpAddresses(string s) {
        vector<string> res;
        restore(s, 4, "", res);
        return res;
    }
    void restore(string s, int k, string out, vector<string> &res) {
        if (k == 0) {
            if (s.empty()) res.push_back(out);
        }
        else {
            for (int i = 1; i <= 3; ++i) {
                if (s.size() >= i && isValid(s.substr(0, i))) {
                    if (k == 1) restore(s.substr(i), k - 1, out + s.substr(0, i),
                        res);
                    else restore(s.substr(i), k - 1, out + s.substr(0, i) + ".",
                        res);
                }
            }
        }
    }
    bool isValid(string s) {
        if (s.empty() || s.size() > 3 || (s.size() > 1 && s[0] == '0')) return
            false;
        int res = atoi(s.c_str());
        return res <= 255 && res >= 0;
    }
};
```

6.19 Simplify Path (M)

Given an absolute path for a file (Unix-style), simplify it.

For example,

path = "/home/", -> "/home"

path = "/a/./b/../../c/", -> "/c"

Corner Cases:

Did you consider the case where path = "/./"?

In this case, you should return "/".

Another corner case is the path might contain multiple slashes '/' together, such as "/home-//foo/".

In this case, you should ignore redundant slashes and return "/home/foo".

```
class Solution(object):
    def simplifyPath(self, path):
        """
        :type path: str
        :rtype: str
        """
        path = path.split("/")
        st = []
        for i in path:
            if i == '.' or not i: continue
            elif i == '..':
                if st: st.pop()
            else: continue
            else: st.append(i)
        return "/" + "/".join(st)
```

```
class Solution {
public:
    string simplifyPath(string path) {
        vector<string> v;
        int i = 0;
        while (i < path.size()) {
            while (path[i] == '/' && i < path.size()) ++i;
            if (i == path.size()) break;
            int start = i;
            while (path[i] != '/' && i < path.size()) ++i;
            int end = i - 1;
            string s = path.substr(start, end - start + 1);
            if (s == "..") {
                if (!v.empty()) v.pop_back();
            } else if (s != ".") {
                v.push_back(s);
            }
        }
        if (v.empty()) return "/";
        string res;
        for (int i = 0; i < v.size(); ++i) {
            res += '/' + v[i];
        }
        return res;
    }
};
```

```

class Solution {
public:
    string simplifyPath(string path) {
        string res, t;
        stringstream ss(path);
        vector<string> v;
        while (getline(ss, t, '/')) {
            if (t == "" || t == ".") continue;
            if (t == ".." && !v.empty()) v.pop_back();
            else if (t != "..") v.push_back(t);
        }
        for (string s : v) res += "/" + s;
        return res.empty() ? "/" : res;
    }
};

```

6.20 Longest Absolute File Path (M)

Suppose we abstract our file system by a string in the following manner:

The string "dir/n/tsubdir1/n/tsubdir2/n/t/tfile.ext" represents:

```

dir
  subdir1
    subdir2
      file.ext

```

The directory dir contains an empty sub-directory subdir1 and a sub-directory subdir2 containing a file file.ext.

The string "dir/n/tsubdir1/n/t/tfile1.ext/n/t/tsubsubdir1/n/tsubdir2/n/t/tsubsubdir2/n/t/t/tfile2.ext" represents:

```

dir
  subdir1
    file1.ext
  subsubdir1
    subdir2
      subsubdir2
        file2.ext

```

The directory dir contains two sub-directories subdir1 and subdir2. subdir1 contains a file file1.ext and an empty second-level sub-directory subsubdir1. subdir2 contains a second-level sub-directory subsubdir2 containing a file file2.ext.

We are interested in finding the longest (number of characters) absolute path to a file within our file system. For example, in the second example above, the longest absolute path is

"dir/subdir2/subsubdir2/file2.ext", and its length is 32 (not including the double quotes).

Given a string representing the file system in the above format, return the length of the longest absolute path to file in the abstracted file system. If there is no file in the system, return 0.

Note:

The name of a file contains at least a . and an extension.

The name of a directory or sub-directory will not contain a ..

Time complexity required: $O(n)$ where n is the size of the input string.

Notice that a/aa/aaa/file1.txt is not the longest file path, if there is another path
aaaaaaaaaaaaaaaaaaaa/sth.png.

```
class Solution {
public:
    int lengthLongestPath(string input) {
        int res = 0, n = input.size(), level = 0;
        unordered_map<int, int> m {{0, 0}};
        for (int i = 0; i < n; ++i) {
            int start = i;
            // find a directory or a file
            while (i < n && input[i] != '\n' && input[i] != '\t') ++i;
            if (i >= n || input[i] == '\n') {
                string t = input.substr(start, i - start); // get the file name
                if (t.find('.') != string::npos) { // update res if we find a file
                    res = max(res, m[level] + (int)t.size());
                } else { // update level if we find a directory
                    ++level;
                    m[level] = m[level - 1] + (int)t.size() + 1;
                }
                level = 0;
            } else {
                ++level;
            }
        }
        return res;
    }
};
```

```
class Solution {
public:
    int lengthLongestPath(string input) {
        int res = 0;
        istringstream ss(input);
        unordered_map<int, int> m {{0, 0}};
        string line;
```

```

while (getline(ss, line)) {
    auto pos = line.find_last_of('\t');
    string t = (pos != string::npos) ? line.substr(pos + 1) : line;
    int level = line.size() - t.size();
    if (line.find('.') != string::npos) {
        res = max(res, m[level] + (int)t.size());
    } else {
        m[level + 1] = m[level] + (int)t.size() + 1;
    }
}
return res;
}
};

```

6.21 Valid Parentheses (E)

Given a string containing just the characters '(', ')', '{', '}', '[' and ']', determine if the input string is valid. The brackets must close in the correct order, “()” and “(){}” are all valid but “[)” and “([)]” are not.

```

class Solution(object):
    def isValid(self, s):
        """
        :type s: str
        :rtype: bool
        """
        stack = []
        for bracket in s:
            if bracket == '(' or bracket == '[' or bracket == '{':
                stack.append(bracket)
            else:
                if not stack: return False
                if bracket == ')' and stack[-1] != '(': return False
                if bracket == ']' and stack[-1] != '[': return False
                if bracket == '}' and stack[-1] != '{': return False
                stack.pop()
        return not stack

```

```

class Solution {
public:
    bool isValid(string s) {
        stack<char> tmp;

        for (int i = 0; i < s.size(); ++i) {

```



```

        if (s[i] == '(' || s[i] == '[' || s[i] == '{') {
            tmp.push(s[i]);
        } else if ( (!tmp.empty() && tmp.top() == '(' && s[i] == ')') ||
                    (!tmp.empty() && tmp.top() == '[' && s[i] == ']') ||
                    (!tmp.empty() && tmp.top() == '{' && s[i] == '}') ){
            tmp.pop();
        } else {
            return false;
        }
    }

    return tmp.empty();
}
};

```

6.22 Generate Parentheses (M)

Given n pairs of parentheses, write a function to generate all combinations of well-formed parentheses.

```

class Solution(object):
    def generateParenthesis(self, n):
        """
        :type n: int
        :rtype: List[str]
        """
        out, res = '', []
        self.gen(n, n, '', res)
        return res

    def gen(self, left, right, out, res):
        if left > right: return
        if left == 0 and right == 0:
            res.append(out)
        else:
            if left > 0:
                self.gen(left-1, right, out+'(', res)
            if right > 0:
                self.gen(left, right-1, out+')', res)

```

```

class Solution {
public:
    vector<string> generateParenthesis(int n) {
        vector<string> res;
        generate(res, "", n, 0);
    }
};

```

```

        return res;
    }
    void generate(vector<string> &res, string str, int left, int right) {
        if (left == 0 && right == 0) {
            res.push_back(str);
            return;
        }
        if (right > 0) generate(res, str+")", left, right-1);
        if (left > 0) generate(res, str+"(", left-1, right+1);
    }
};

```

6.23 Different Ways to Add Parentheses (M)

Given a string of numbers and operators, return all possible results from computing all the different possible ways to group numbers and operators. The valid operators are +, - and *.

Example: Input: "2-1-1".

$((2-1)-1) = 0$

$(2-(1-1)) = 2$

Output: [0, 2]

```

class Solution {
public:
    vector<int> diffWaysToCompute(string input) {
        vector<int> res;
        int n = input.size();

        for (int i = 0; i < n; ++i) {
            char c = input[i];
            if (c == '+' || c == '-' || c == '*') {
                vector<int> result1 = diffWaysToCompute(input.substr(0,i));
                vector<int> result2 = diffWaysToCompute(input.substr(i+1));
                for (int j = 0; j < result1.size(); ++j) {
                    for (int k = 0; k < result2.size(); ++k) {
                        switch (c) {
                            case '+':
                                res.push_back(result1[j] + result2[k]);
                                break;
                            case '-':
                                res.push_back(result1[j] - result2[k]);
                                break;
                            case '*':
                                res.push_back(result1[j] * result2[k]);
                                break;
                        }
                    }
                }
            }
        }
        return res;
    }
};

```

```

    }
    }
    }
    }

    if (res.empty())
        res.push_back(stoi(input));

    return res;
}
};

```

6.24 Longest Valid Parentheses (H)

Given a string containing just the characters '(' and ')', find the length of the longest valid (well-formed) parentheses substring.

For "()", the longest valid parentheses substring is "()", which has length = 2.

Another example is ")()())", where the longest valid parentheses substring is "()()", which has length = 4.

```

class Solution {
public:
    int longestValidParentheses(string s) {
        int maxlen = 0, last = -1;
        stack<int> tmp;

        for (int i = 0; i < s.size(); ++i) {
            if (s[i] == '(') {
                tmp.push(i);           // push the index of '(' to stack
            } else {
                if (tmp.empty()) {     // if no match for the current ')'
                    last = i;          // update last index of '('
                } else {              // if find a match for the current ')'
                    tmp.pop();          // pop the index of '('
                    if (tmp.empty()) {
                        maxlen = max(maxlen, i - last);
                    } else {
                        maxlen = max(maxlen, i - tmp.top());
                    }
                }
            }
        }
    }
}

```

```

        return maxlen;
    }
};

```

6.25 Remove Invalid Parentheses (H)

Remove the minimum number of invalid parentheses in order to make the input string valid. Return all possible results.

Note: The input string may contain letters other than the parentheses (and).

```

class Solution(object):
    def removeInvalidParentheses(self, s):
        """
        :type s: str
        :rtype: List[str]
        """
        res = []
        idx = 0
        cnt1, cnt2 = 0, 0
        for c in s:
            if c == '(':
                cnt1 += 1
            elif c == ')':
                if cnt1 == 0: cnt2 += 1 # more ')' than '('
                else: cnt1 -= 1 # for each valid pair just reduce cnt1
        self.bfs(s, idx, cnt1, cnt2, res)
        return res

    def bfs(self, s, idx, cnt1, cnt2, res):
        # if the string is valid when the excess number of left or right
        # parentheses is zero, save that string to res
        if cnt1 == 0 and cnt2 == 0:
            if self.isValid(s): res.append(s)
            return
        for i in range(idx, len(s)):
            # skip duplicated parentheses since the result is the same
            if i != idx and s[i] == s[i-1]: continue
            # for each excess parentheses, check the string without the it
            # recursively
            if cnt1 > 0 and s[i] == '(':
                self.bfs(s[:i] + s[i+1:], i, cnt1 - 1, cnt2, res)
            if cnt2 > 0 and s[i] == ')':
                self.bfs(s[:i] + s[i+1:], i, cnt1, cnt2 - 1, res)

```

```

def isValid(self, s):
    cnt = 0
    for c in s:
        if c == '(':
            cnt += 1
        elif c == ')':
            cnt -= 1
            if cnt < 0: return False
    return cnt == 0

```

```

class Solution {
public:
    vector<string> removeInvalidParentheses(string s) {
        unordered_set<string> result;
        int left_removed = 0;
        int right_removed = 0;
        for(auto c : s) {
            if(c == '(') {
                ++left_removed;
            }
            if(c == ')') {
                if(left_removed != 0) {
                    --left_removed;
                }
                else {
                    ++right_removed;
                }
            }
        }
        helper(s, 0, left_removed, right_removed, 0, "", result);
        return vector<string>(result.begin(), result.end());
    }
private:
    void helper(string s, int index, int left_removed, int right_removed, int
        pair, string path, unordered_set<string>& result) {
        if(index == s.size()) {
            if(left_removed == 0 && right_removed == 0 && pair == 0) {
                result.insert(path);
            }
            return;
        }
        if(s[index] != '(' && s[index] != ')') {
            helper(s, index + 1, left_removed, right_removed, pair, path +
                s[index], result);
        }
        else {

```

```

        if(s[index] == '(') {
            if(left_removed > 0) {
                helper(s, index + 1, left_removed - 1, right_removed, pair,
                    path, result);
            }
            helper(s, index + 1, left_removed, right_removed, pair + 1, path +
                s[index], result);
        }
        if(s[index] == ')') {
            if(right_removed > 0) {
                helper(s, index + 1, left_removed, right_removed - 1, pair,
                    path, result);
            }
            if(pair > 0) {
                helper(s, index + 1, left_removed, right_removed, pair - 1,
                    path + s[index], result);
            }
        }
    }
}
};

```

6.26 Flip Game (E)

You are playing the following Flip Game with your friend: Given a string that contains only these two characters: + and -, you and your friend take turns to flip two consecutive “++” into “- -”. The game ends when a person can no longer make a move and therefore the other person will be the winner. Write a function to compute all possible states of the string after one valid move.

For example, given s = “++++”, after one move, it may become one of the following states: [“- -++”, “+- -+”, “++- -”] If there is no valid move, return an empty list [].

```

class Solution {
public:
    vector<string> generatePossibleNextMoves(string s) {
        vector<string> res;
        for (int i = 1; i < s.size(); ++i) {
            if (s[i] == '+' && s[i-1] == '+') {
                res.push_back(s.substr(0, i-1) + "--" + s.substr(i+1)); //
                    substr(pos, len);
            }
        }
        return res;
    }
}

```

```
};
```

6.27 Flip Game II (M)

You are playing the following Flip Game with your friend: Given a string that contains only these two characters: + and -, you and your friend take turns to flip two consecutive "++" into "--". The game ends when a person can no longer make a move and therefore the other person will be the winner. Write a function to determine if the starting player can guarantee a win.

For example, given s = "++++", return true. The starting player can guarantee a win by flipping the middle "++" to become "+-+".

```
class Solution {
public:
    bool canWin(string s) {
        for (int i = 1; i < s.size(); ++i) {
            if (s[i] == '+' && s[i - 1] == '+' && !canWin(s.substr(0, i - 1) +
                "--" + s.substr(i + 1))) {
                return true;
            }
        }
        return false;
    }
};
```

6.28 Excel Sheet Column Number (E)

Given a column title as appear in an Excel sheet, return its corresponding column number.

For example:

A -> 1

B -> 2

C -> 3

...

Z -> 26

AA -> 27

AB -> 28

```
class Solution(object):
    def titleToNumber(self, s):
```

```

    """
    :type s: str
    :rtype: int
    """
    res = 0
    for i in range(0, len(s)):
        res = res * 26 + (ord(s[i]) - ord('A') + 1)
    return res

```

```

class Solution {
public:
    int titleToNumber(string s) {
        int result = 0;

        for (int i = 0; i < s.size(); ++i)
            result = result * 26 + (s[i] - 'A' + 1);

        return result;
    }
};

```

6.29 Excel Sheet Column Title (E)

Given a positive integer, return its corresponding column title as appear in an Excel sheet.

For example:

```

1 -> A
2 -> B
3 -> C
...
26 -> Z
27 -> AA
28 -> AB

```

```

class Solution(object):
    def convertToTitle(self, n):
        """
        :type n: int
        :rtype: str
        """
        res = ''
        while n:
            res += chr((n - 1) % 26 + ord('A'))
            n = (n - 1) // 26

```

```

        return res[::-1]

```

```

class Solution {
public:
    string convertToTitle(int n) {
        if (n <= 0)
            return NULL;

        string result;
        char tmp;

        while (n != 0) {
            n -= 1;
            tmp = n % 26 + 'A';
            result = tmp + result;
            n /= 26;
        }

        return result;
    }
};

```

6.30 Roman to Integer (E)

Given a roman numeral, convert it to an integer.

Input is guaranteed to be within the range from 1 to 3999.

Python:

```

class Solution(object):
    def romanToInt(self, s):
        """
        :type s: str
        :rtype: int
        """
        d = {'I':1, 'V':5, 'X':10, 'L':50, 'C':100, 'D':500, 'M':1000}
        res = 0
        for i in range(len(s)):
            val = d[s[i]]
            if (i + 1 == len(s)) or (d[s[i+1]] <= d[s[i]]):
                res += val
            else:
                res -= val
        return res

```

C++:

```
class Solution {
public:
    int romanToInt(string s) {
        int n = s.size();
        if (n == 0)
            return 0;

        unordered_map<char, int> roman = { { 'I' , 1 },
                                           { 'V' , 5 },
                                           { 'X' , 10 },
                                           { 'L' , 50 },
                                           { 'C' , 100 },
                                           { 'D' , 500 },
                                           { 'M' , 1000 } };

        int num = 0;
        for (int i = 0; i < n-1; ++i) {
            if (roman[s[i]] < roman[s[i+1]])
                num -= roman[s[i]];
            else
                num += roman[s[i]];
        }

        num += roman[s[n-1]];

        return num;
    }
};
```

6.31 Integer to Roman (M)

Given an integer, convert it to a roman numeral.

Input is guaranteed to be within the range from 1 to 3999.

Python:

```
class Solution(object):
    def intToRoman(self, num):
        """
        :type num: int
        :rtype: str
        """
        val = [1000, 900, 500, 400, 100, 90, 50, 40, 10, 9, 5, 4, 1]
```

```

roman = ["M", "CM", "D", "CD", "C", "XC", "L", "XL", "X", "IX", "V",
         "IV", "I"]
res = ''
for i in range(len(val)):
    while num >= val[i]:
        num -= val[i]
        res += roman[i]
return res

```

C++:

```

class Solution {
public:
    string intToRoman(int num) {
        int value[] = {1000, 900, 500, 400, 100, 90, 50, 40, 10, 9, 5, 4, 1};
        string symbol[] = {"M", "CM", "D", "CD", "C", "XC", "L", "XL", "X", "IX",
                           "V", "IV", "I"};
        string result;
        int digit, idx = 0;

        while (num != 0) {
            digit = num / value[idx];
            num %= value[idx];
            while (digit != 0) {
                result += symbol[idx];
                --digit;
            }
            ++idx;
        }

        return result;
    }
};

```

6.32 Integer to English Words (H)

Convert a non-negative integer to its english words representation. Given input is guaranteed to be less than $(2 \text{ to the power of } 31) - 1$.

```

class Solution(object):
    def numberToWords(self, num):
        """
        :type num: int
        :rtype: str
        """

```

```

if num == 0: return 'Zero'
self.word1 = ['Zero', "One", "Two", "Three", "Four", "Five", "Six",
              "Seven", \
              "Eight", "Nine", "Ten", "Eleven", "Twelve", "Thirteen", \
              "Fourteen", "Fifteen", "Sixteen", "Seventeen", "Eighteen", \
              "Nineteen"]
self.word2 = ['Zero', "Ten", "Twenty", "Thirty", "Forty", "Fifty",
              "Sixty", \
              "Seventy", "Eighty", "Ninety"]
return self.int2str(num)[1:]
def int2str(self, n):
    if n >= 10**9:
        return self.int2str(n / (10**9)) + ' Billion' + self.int2str(n %
            (10**9))
    elif n >= 10**6:
        return self.int2str(n / (10**6)) + ' Million' + self.int2str(n %
            (10**6))
    elif n >= 10**3:
        return self.int2str(n / (10**3)) + ' Thousand' + self.int2str(n %
            (10**3))
    elif n >= 10**2:
        return self.int2str(n / (10**2)) + ' Hundred' + self.int2str(n %
            (10**2))
    elif n >= 20:
        return ' ' + self.word2[n / 10] + self.int2str(n % 10)
    elif n >= 1:
        return ' ' + self.word1[n]
    else:
        return ''

```

6.33 String to Integer (atoi) (E)

Implement atoi to convert a string to an integer.

```

class Solution(object):
    def myAtoi(self, str):
        """
        :type str: str
        :rtype: int
        """
        int_max = pow(2, 31) - 1
        int_min = -pow(2, 31)
        sign = 1
        res, pos = 0, 0
        n = len(str)

```

```

# skip all whitespaces
while pos < n and str[pos] == ' ':
    pos += 1

# get the sign
if pos < n and str[pos] == '-':
    sign = -1
    pos += 1
elif pos < n and str[pos] == '+':
    pos += 1

# get the numeral from the string
while pos < n and \
    ord(str[pos]) >= ord('0') and \
    ord(str[pos]) <= ord('9'):
    num = ord(str[pos]) - ord('0')
    # handle overflow
    if res > int_max / 10 or (res == int_max / 10 and num >= 8):
        if sign == 1:
            return int_max
        else:
            return int_min
    res = res * 10 + num
    pos += 1

return sign * res

```

```

class Solution {
public:
    int myAtoi(string str) {
        int sign = 1, base = 0, i = 0;

        while (str[i] == ' ')           // ignor whitespace
            ++i;

        if (str[i] == '-') {           // get the sign
            sign = -1;
            ++i;
        } else if (str[i] == '+'){
            sign = 1;
            ++i;
        }

        while (str[i] >= '0' && str[i] <= '9') {
            // catch the max int or min int case
            if (base > INT_MAX / 10 || (base == INT_MAX / 10 && str[i] - '0' >

```

```

        7)) {
        if (sign == 1)
            return INT_MAX;
        else
            return INT_MIN;
    }

    base = 10 * base + (str[i++] - '0');
}

return base * sign;
}
};

```

6.34 Reverse String (E)

Write a function that takes a string as input and returns the string reversed.

Example: Given `s = "hello"`, return `"olleh"`.

```

class Solution(object):
    def reverseString(self, s):
        """
        :type s: List[str]
        :rtype: None Do not return anything, modify s in-place instead.
        """
        if not s: return
        left = 0
        right = len(s) - 1
        while left < right:
            t = s[left]
            s[left] = s[right]
            s[right] = t
            left += 1
            right -= 1

```

```

class Solution {
public:
    string reverseString(string s) {
        int start = 0, end = s.length()-1;
        char tmp;
        while (start < end) {
            tmp = s[start];
            s[start++] = s[end];

```

```

        s[end--] = tmp;
    }
    return s;
}
};

```

6.35 Reverse String II (E)

Given a string and an integer k, you need to reverse the first k characters for every 2k characters counting from the start of the string. If there are less than k characters left, reverse all of them. If there are less than 2k but greater than or equal to k characters, then reverse the first k characters and left the other as original.

```

class Solution(object):
    def reverseStr(self, s, k):
        a = list(s)
        for i in xrange(0, len(a), 2*k):
            a[i:i+k] = reversed(a[i:i+k])
        return "".join(a)

```

6.36 Reverse Vowels of a String (E)

Write a function that takes a string as input and reverse only the vowels of a string.

Example 1: Given s = "hello", return "holle".

Example 2: Given s = "leetcode", return "leotcede".

```

class Solution {
public:
    bool isVowel(char c) {
        return c == 'a' || c == 'e' || c == 'i' || c == 'o' || c == 'u' || c ==
            'A' || c == 'E' || c == 'I' || c == 'O' || c == 'U';
    }

    string reverseVowels(string s) {
        int i = 0, j = s.length() - 1;

        while (i < j) {
            while (!isVowel(s[i]))
                ++i;
            while (!isVowel(s[j]))
                --j;

```

```

        if (i < j) {
            swap(s[i], s[j]);
            ++i;
            --j;
        }
    }

    return s;
}
};

```

6.37 Reverse Words in a String (M)

Given an input string, reverse the string word by word.

For example, Given s = "the sky is blue", return "blue is sky the".

For C programmers: Try to solve it in-place in $O(1)$ space.

Clarification:

What constitutes a word?

A sequence of non-space characters constitutes a word.

Could the input string contain leading or trailing spaces?

Yes. However, your reversed string should not contain leading or trailing spaces.

How about multiple spaces between two words?

Reduce them to a single space in the reversed string.

```

class Solution(object):
    def reverseWords(self, s):
        """
        :type s: str
        :rtype: str
        """
        res = ''
        words = s.split(' ')
        for i in range(len(words)-1, -1, -1):
            res += words[i] + ' '
        return ' '.join(res.split())

```

```

class Solution {
public:
    void reverseWords(string &s) {
        int i = 0, j = 0, k = 0, wordCount = 0;
        while (true) {

```



```

        while (i < s.size() && s[i] == ' ') ++i;
        if (i == s.size()) break; // break if space is the last char
        if (wordCount) s[j++] = ' ';
        k = j;
        while (i < s.size() && s[i] != ' ') {
            s[j] = s[i];
            ++j;
            ++i;
        }
        reverseWord(s, k, j - 1); // reverse the word
        ++wordCount; // increase counter
    }
    s.resize(j); // resize the new string based on the index of j
    reverseWord(s, 0, j - 1); // reverse the whole string
}
void reverseWord(string &s, int i, int j) {
    while (i < j) {
        char t = s[i];
        s[i++] = s[j];
        s[j--] = t;
    }
}
};

```

6.38 Reverse Words in a String II (M)

Given an input string, reverse the string word by word.

Example:

Input: ["t","h","e"," ","s","k","y"," ","i","s"," ","b","l","u","e"]
 Output: ["b","l","u","e"," ","i","s"," ","s","k","y"," ","t","h","e"]

A word is defined as a sequence of non-space characters. The input string does not contain leading or trailing spaces and the words are always separated by a single space.

For example, Given s = "the sky is blue", return "blue is sky the".

Could you do it in-place without allocating extra space?

```

class Solution(object):
    def reverseWords(self, s):
        """
        :type s: str

```

```

:rtype: str
"""
left = 0
n = len(s)
self.reverse(s, 0, n - 1)
for i in range(n):
    if i == n or s[i] == ' ':
        self.reverse(s, left, i - 1)
        left = i + 1
def reverse(s, left, right):
    while left < right:
        t = s[left]
        s[left] = s[right]
        s[right] = t
        left += 1
        right -= 1

```

```

class Solution {
public:
    void reverseWords(string &s) {
        int pos = 0;
        for (int i = 0; i <= s.size(); ++i) {
            if (i == s.size() || s[i] == ' ') {
                reverse(s, pos, i - 1);
                pos = i + 1;
            }
        }
        reverse(s, 0, s.size() - 1);
    }
    void reverse(string &s, int left, int right) {
        while (left < right) {
            char t = s[left];
            s[left++] = s[right];
            s[right--] = t;
        }
    }
};

```

6.39 Reverse Words in a String III (E)

Given a string, you need to reverse the order of characters in each word within a sentence while still preserving whitespace and initial word order.

Example:

Input: "Let's take LeetCode contest"

Output: "s'teL ekat edoCteeL tsetnoc"

Note: In the string, each word is separated by single space and there will not be any extra space in the string.

```
class Solution(object):
    def reverseWords(self, s):
        """
        :type s: str
        :rtype: str
        """
        words = s.split(' ')
        res = []
        for w in words:
            res.append(w[::-1])
        return ' '.join(res)
```

6.40 Valid Anagram (E)

Given two strings s and t, write a function to determine if t is an anagram of s.

For example,

s = "anagram", t = "nagaram", return true.

s = "rat", t = "car", return false.

Note:

You may assume the string contains only lowercase alphabets.

Follow up:

What if the inputs contain unicode characters? How would you adapt your solution to such case?

```
class Solution(object):
    def isAnagram(self, s, t):
        """
        :type s: str
        :type t: str
        :rtype: bool
        """
        if len(s) != len(t): return False
        m = {}
        for char in s:
            if char in m:
```

```

        m[char] += 1
    else:
        m[char] = 1
    for char in t:
        if char in m and m[char] != 0:
            m[char] -= 1
        else:
            return False
    return True

class Solution(object):
    def isAnagram(self, s, t):
        """
        :type s: str
        :type t: str
        :rtype: bool
        """
        if len(s) != len(t): return False
        m = [0 for i in range(26)]
        for i in range(len(s)):
            m[ord(s[i]) - ord('a')] += 1
            m[ord(t[i]) - ord('a')] -= 1
        for v in m:
            if v != 0: return False
        return True

```

```

// unordered_map<Key,T>::iterator it;
// (*it).first;           // the key value (of type Key)
// (*it).second;          // the mapped value (of type T)
// (*it);                 // the "element value" (of type pair<const Key,T>)

// Sol1: Hash table
class Solution {
public:
    bool isAnagram(string s, string t) {
        if(s.length() != t.length())
            return false;

        unordered_map<char,int> counts;
        for (int i = 0; i < s.length(); ++i) {
            ++counts[s[i]];
            --counts[t[i]];
        }
        for (auto count : counts) {
            if (count.second)
                return false;
        }
    }
}

```

```

        return true;
    }
};

// Sol2: Optimization by the fix-size array
class Solution {
public:
    bool isAnagram(string s, string t) {
        if(s.length() != t.length())
            return false;

        int counts[26] = {0};
        for (int i = 0; i < s.length(); ++i) {
            ++counts[s[i] - 'a'];
            --counts[t[i] - 'a'];
        }
        for (int i = 0; i < 26; ++i) {
            if (counts[i])
                return false;
        }
        return true;
    }
};

```

6.41 Group Anagrams (M)

Given an array of strings, group anagrams together.

For example, given: ["eat", "tea", "tan", "ate", "nat", "bat"],
 Return: [["ate", "eat","tea"], ["nat","tan"], ["bat"]].

Note: All inputs will be in lower-case.

```

class Solution(object):
    def groupAnagrams(self, strs):
        """
        :type strs: List[str]
        :rtype: List[List[str]]
        """
        m, res = {}, []
        # key: val -> sorted string: list of strings
        for s in strs:
            key = ''.join(sorted(s))
            if key in m:
                m[key].append(s)

```

```

        else:
            m[key] = [s]
    for key in m:
        res.append(m[key])
    return res

```

```

class Solution {
public:
    vector<vector<string>> groupAnagrams(vector<string>& strs) {
        unordered_map<string, vector<string>> group;

        for (string s : strs) {
            string key = s;
            sort(key.begin(), key.end());
            group[key].push_back(s);
        }

        vector<vector<string>> anagrams;
        for (auto g : group)
            anagrams.push_back(g.second);

        return anagrams;
    }
};

```

6.42 Valid Palindrome (E)

Given a string, determine if it is a palindrome, considering only alphanumeric characters and ignoring cases.

For example,

“A man, a plan, a canal: Panama” is a palindrome.

“race a car” is not a palindrome.

Python:

```

class Solution(object):
    def isPalindrome(self, s):
        """
        :type s: str
        :rtype: bool
        """
        if not s: return True
        n = len(s)
        left, right = 0, n - 1

```

```

while left < right:
    if not s[left].isalnum():
        left += 1
    elif not s[right].isalnum():
        right -= 1
    elif s[left].lower() == s[right].lower():
        left += 1
        right -= 1
    else:
        return False
return True

```

C++:

```

class Solution {
public:
    bool isPalindrome(string s) {

        int start = 0, end = s.size()-1;

        while (start < end) {
            if (isalnum(s[start]) == false)    // isalnum: checks whether c is
                ++start;                       an alphanumeric character
            else if (isalnum(s[end]) == false)
                --end;
            else if (tolower(s[start++]) != tolower(s[end--])) // tolower:
                return false;    Converts parameter c to its lowercase equivalent if c is an
                                uppercase letter and has a lowercase equivalent
        }

        return true;
    }
};

```

6.43 Valid Palindrome II (E)

Given a non-empty string *s*, you may delete at most one character. Judge whether you can make it a palindrome.

Examples:

Input: "aba", Output: True

Input: "abca", Output: True

Python:

```

# O(N^2)
class Solution(object):
    def validPalindrome(self, s):
        """
        :type s: str
        :rtype: bool
        """
        n = len(s)
        for i in range(n):
            t = s[:i] + s[i+1:n]
            if t == t[::-1]: return True
        return s == s[::-1]

# O(N)
class Solution(object):
    def validPalindrome(self, s):
        """
        :type s: str
        :rtype: bool
        """
        n = len(s)
        left, right = 0, n - 1
        while left < right:
            if s[left] != s[right]:
                return self.isValid(s, left+1, right) or self.isValid(s, left,
                    right-1)
            left += 1
            right -= 1
        return True
    def isValid(self, s, left, right):
        while left < right:
            if s[left] != s[right]: return False
            left += 1
            right -= 1
        return True

```

6.44 Palindromic Substrings (M)

Given a string, your task is to count how many palindromic substrings in this string.

The substrings with different start indexes or end indexes are counted as different substrings even they consist of same characters.

Example1:

Input: "abc", Output: 3

Explanation: Three palindromic strings: "a", "b", "c".

Input: "aaa", Output: 6

Explanation: Six palindromic strings: "a", "a", "a", "aa", "aa", "aaa".

Python:

```
# O(N^2)
class Solution(object):
    def countSubstrings(self, s):
        """
        :type s: str
        :rtype: int
        """
        if not s: return 0
        n = len(s)
        res = 0
        for i in range(n):
            res = self.findPal(s, n, i, i, res)
            res = self.findPal(s, n, i, i+1, res)
        return res
    def findPal(self, s, n, i, j, res):
        while i >= 0 and j < n and s[i] == s[j]:
            res += 1
            i -= 1
            j += 1
        return res

# # DP with bugs: O(N^2)
# class Solution(object):
#     def countSubstrings(self, s):
#         """
#         :type s: str
#         :rtype: int
#         """
#         n = len(s)
#         res = 0
#         dp = [[0] * n] * n
#         for i in range(n-1, -1, -1):
#             for j in range(i, n, 1):
#                 if s[i] == s[j] and (j - i <= 2 or dp[i+1][j-1] == 1):
#                     dp[i][j] = 1
#                     res += 1
#         return res
```

6.45 Longest Palindromic Substring (M)

Given a string S, find the longest palindromic substring in S. You may assume that the maximum length of S is 1000, and there exists one unique longest palindromic substring.

Python:

```
# O(N^2)
class Solution(object):
    def longestPalindrome(self, s):
        """
        :type s: str
        :rtype: str
        """
        n = len(s)
        start, max_lps_len = 0, 1
        if n < 2: return s
        # check both cases when the substring length is either odd or even
        for i in range(n-1):
            start, max_lps_len = self.findLPS(s, n, i, i, start, max_lps_len)
            start, max_lps_len = self.findLPS(s, n, i, i + 1, start, max_lps_len)
        return s[start: start + max_lps_len]

    def findLPS(self, s, s_len, left, right, start, max_lps_len):
        while left >= 0 and right < s_len and s[left] == s[right]:
            left -= 1
            right += 1
        # the actual left and right here are outside of the lsp substring
        if max_lps_len < right - left - 1:
            start = left + 1
            max_lps_len = right - left - 1
        return start, max_lps_len

# DP: O(N^2) for both time and space complexity
import numpy as np
class Solution(object):
    def longestPalindrome(self, s):
        """
        :type s: str
        :rtype: str
        """
        n = len(s)
        dp = np.zeros(shape=(n,n))
        if n >= 1:
            start, max_len = 0, 1
        else:
            return ''
        for i in range(n):
```

```

        dp[i][i] = 1
    for j in range(i):
        if i - j < 2:
            if s[i] == s[j]: dp[j][i] = 1
        else:
            if s[i] == s[j] and dp[j+1][i-1] == 1: dp[j][i] = 1
            if (dp[j][i] == 1) and (max_len < i - j + 1):
                max_len = i - j + 1
                start = j
    return s[start: start + max_len]

```

C++:

```

// Time complexity O(n*n)
class Solution {
public:
    string longestPalindrome(string s) {
        int startIdx = 0, left = 0, right = 0, len = 0;
        for (int i = 0; i < s.size() - 1; ++i) {
            if (s[i] == s[i + 1]) {
                left = i;
                right = i + 1;
                searchPalindrome(s, left, right, startIdx, len);
            }
            left = right = i;
            searchPalindrome(s, left, right, startIdx, len);
        }
        if (len == 0) len = s.size();
        return s.substr(startIdx, len);
    }
    void searchPalindrome(string s, int left, int right, int &startIdx, int &len)
    {
        int step = 1;
        while ((left - step) >= 0 && (right + step) < s.size()) {
            if (s[left - step] != s[right + step]) break;
            ++step;
        }
        int wide = right - left + 2 * step - 1;
        if (len < wide) {
            len = wide;
            startIdx = left - step + 1;
        }
    }
};

// DP
class Solution {
public:

```

```

string longestPalindrome(string s) {
    int dp[s.size()][s.size()] = {0}, left = 0, right = 0, len = 0;
    for (int i = 0; i < s.size(); ++i) {
        for (int j = 0; j < i; ++j) {
            dp[j][i] = (s[i] == s[j] && (i - j < 2 || dp[j + 1][i - 1]));
            if (dp[j][i] && len < i - j + 1) {
                len = i - j + 1;
                left = j;
                right = i;
            }
        }
        dp[i][i] = 1;
    }
    return s.substr(left, right - left + 1);
}

// Manacher's Algorithm
class Solution {
public:
    string longestPalindrome(string s) {
        string t = "$#";
        for (int i = 0; i < s.size(); ++i) {
            t += s[i];
            t += '#';
        }
        int p[t.size()] = {0}, id = 0, mx = 0, resId = 0, resMx = 0;
        for (int i = 0; i < t.size(); ++i) {
            p[i] = mx > i ? min(p[2 * id - i], mx - i) : 1;
            while (t[i + p[i]] == t[i - p[i]]) ++p[i];
            if (mx < i + p[i]) {
                mx = i + p[i];
                id = i;
            }
            if (resMx < p[i]) {
                resMx = p[i];
                resId = i;
            }
        }
        return s.substr((resId - resMx) / 2, resMx - 1);
    }
};

```

6.46 Longest Palindromic Subsequence (M)

Given a string s , find the longest palindromic subsequence's length in s . You may assume that the maximum length of s is 1000.

Example:

Input: 'bbbab', Output: 4

Python:

```
import numpy as np
class Solution(object):
    def longestPalindromeSubseq(self, s):
        """
        :type s: str
        :rtype: int
        """
        n = len(s)
        dp = np.zeros(shape=(n, n))
        for i in range(n-1, -1, -1):
            dp[i][i] = 1
            for j in range(i+1, n, 1):
                if s[i] == s[j]:
                    dp[i][j] = dp[i+1][j-1] + 2
                else:
                    dp[i][j] = max(dp[i+1][j], dp[i][j-1])
        return int(dp[0][n-1])
```

6.47 Palindrome Permutation (E)

Given a string, determine if a permutation of the string could form a palindrome.

For example, "code" -> False, "aab" -> True, "carerac" -> True.

```
// 1. Hashtable
class Solution {
public:
    bool canPermutePalindrome(string s) {
        unordered_map<char, int> m;
        int cnt = 0;
        for (auto a : s) ++m[a];
        for (auto it : m) {
            if (it.second % 2 == 1)
                ++cnt;
        }
    }
};
```

```

        return cnt == 0 || ((cnt == 1) && (s.size() % 2 == 1));
    }
};

// 2. Set
class Solution {
public:
    bool canPermutePalindrome(string s) {
        set<char> t;
        for (auto a : s) {
            if (t.find(a) == t.end()) t.insert(a);
            else t.erase(a);
        }
        return t.empty() || t.size() == 1;
    }
};

// 3. Bitset
class Solution {
public:
    bool canPermutePalindrome(string s) {
        bitset<256> b;
        for (auto a : s) {
            b.flip(a);
        }
        return b.count() < 2;
    }
};

```

6.48 Palindrome Permutation II (M)

Given a string *s*, return all the palindromic permutations (without duplicates) of it. Return an empty list if no palindromic permutation could be form.

For example:

Given *s* = "aabb", return ["abba", "baab"].

Given *s* = "abc", return [].

```

class Solution {
public:
    vector<string> generatePalindromes(string s) {
        vector<string> res;
        unordered_map<char, int> m;
        string t = "", mid = "";
        for (auto a : s) ++m[a];
    }
};

```

```

    for (auto it : m) {
        if (it.second % 2 == 1)
            mid += it.first;
        t += string(it.second / 2, it.first); // store the first half of
        string
        if (mid.size() > 1) // if the string is palindrome,
            mid size can only be 1
            return res;
    }
    permute(t, 0, mid, res);
    return res;
}

void permute(string &t, int start, string mid, vector<string> &res) {
    // palindrome permutation = permutation of the first half string
    //                               + the only char if exists
    //                               + reverse of the permutation of the first half
    string
    if (start >= t.size()) {
        res.push_back(t + mid + string(t.rbegin(), t.rend()));
    }
    // permutation
    for (int i = start; i < t.size(); ++i) {
        if (i != start && t[i] == t[start]) continue;
        swap(t[i], t[start]);
        permute(t, start + 1, mid, res);
        swap(t[i], t[start]);
    }
}
};

```

6.49 Palindrome Partitioning (M)

Given a string *s*, partition *s* such that every substring of the partition is a palindrome. Return all possible palindrome partitioning of *s*.

For example, given *s* = "aab", Return [["aa","b"], ["a","a","b"]]

```

class Solution {
public:
    vector<vector<string>> partition(string s) {
        vector<vector<string>> res;
        vector<string> out;
        partitionDFS(s, 0, out, res);
        return res;
    }
};

```

```

    }
    void partitionDFS(string s, int pos, vector<string> &out,
        vector<vector<string>> &res) {
        if (pos == s.size()) {
            res.push_back(out);
            return;
        }
        for (int i = pos; i < s.size(); ++i) {
            if (isPalindrome(s, pos, i)) {
                // substr(pos, len): substr starts at pos and spans len chars
                out.push_back(s.substr(pos, i - pos + 1));
                partitionDFS(s, i + 1, out, res);
                out.pop_back();
            }
        }
    }
    bool isPalindrome(string s, int start, int end) {
        while (start < end) {
            if (s[start] != s[end]) return false;
            ++start;
            --end;
        }
        return true;
    }
};

```

6.50 Palindrome Partitioning II (H)

Given a string *s*, partition *s* such that every substring of the partition is a palindrome. Return the minimum cuts needed for a palindrome partitioning of *s*.

For example, given *s* = "aab", Return 1 since the palindrome partitioning ["aa","b"] could be produced using 1 cut.

```

class Solution {
public:
    int minCut(string s) {
        int len = s.size();
        bool P[len][len];
        int dp[len + 1];
        for (int i = 0; i <= len; ++i) {
            dp[i] = len - i - 1;
        }
        for (int i = 0; i < len; ++i) {
            for (int j = 0; j < len; ++j) {

```



```

        P[i][j] = false;
    }
}
for (int i = len - 1; i >= 0; --i) {
    for (int j = i; j < len; ++j) {
        if (s[i] == s[j] && (j - i <= 1 || P[i + 1][j - 1])) {
            P[i][j] = true;
            dp[i] = min(dp[i], dp[j + 1] + 1);
        }
    }
}
return dp[0];
}
};

```

6.51 Longest Substring Without Repeating Characters (M)

Given a string, find the length of the longest substring without repeating characters.

Examples:

Given "abcabcbb", the answer is "abc", which the length is 3.

Given "bbbbbb", the answer is "b", with the length of 1.

Given "pwwkew", the answer is "wke", with the length of 3. Note that the answer must be a substring, "pwke" is a subsequence and not a substring.

Python:

```

class Solution(object):
    def lengthOfLongestSubstring(self, s):
        """
        :type s: str
        :rtype: int
        """
        res = 0
        left = -1
        n = len(s)
        str_hash = {}
        for i in range(n):
            if s[i] in str_hash.keys() and str_hash[s[i]] > left:
                left = str_hash[s[i]]
            str_hash[s[i]] = i
            res = max(res, i - left)
        return res

```

C++:

```
class Solution {
public:
    int lengthOfLongestSubstring(string s) {
        // left is the start position of each substring
        int m[256] = {0}, res = 0, left = 0;
        for (int i = 0; i < s.size(); ++i) {
            if (m[s[i]] == 0 || m[s[i]] < left) {
                res = max(res, i - left + 1);
            } else {
                left = m[s[i]]; // update left if repeat chars is found
            }
            m[s[i]] = i + 1;
        }
        return res;
    }
};

class Solution {
public:
    int lengthOfLongestSubstring(string s) {
        vector<int> m(256, -1);
        int res = 0, left = -1;
        for (int i = 0; i < s.size(); ++i) {
            left = max(left, m[s[i]]);
            m[s[i]] = i;
            res = max(res, i - left);
        }
        return res;
    }
};

class Solution {
public:
    int lengthOfLongestSubstring(string s) {
        set<char> t;
        int res = 0, left = 0, right = 0;
        while (right < s.size()) {
            if (t.find(s[right]) == t.end()) {
                t.insert(s[right++]);
                res = max(res, (int)t.size());
            } else {
                t.erase(s[left++]);
            }
        }
        return res;
    }
};
```

```
};
```

6.52 Longest Substring with At Least K Repeating Characters (M)

Find the length of the longest substring T of a given string (consists of lowercase letters only) such that every character in T appears no less than k times.

Example 1:

Input: s = "aaabb", k = 3 Output: 3

The longest substring is "aaa", as 'a' is repeated 3 times.

Example 2:

Input: s = "ababbc", k = 2 Output: 5

The longest substring is "ababb", as 'a' is repeated 2 times and 'b' is repeated 3 times.

```
class Solution {
public:
    int longestSubstring(string s, int k) {
        int n = s.size(), max_idx = 0, res = 0;
        int m[128] = {0};
        bool ok = true;
        for (char c : s) ++m[c];
        for (int i = 0; i < n; ++i) {
            if (m[s[i]] < k) {
                res = max(res, longestSubstring(s.substr(max_idx, i - max_idx),
                    k));
                ok = false;
                max_idx = i + 1;
            }
        }
        return ok ? n : max(res, longestSubstring(s.substr(max_idx, n - max_idx),
            k));
    }
};
```

```
class Solution {
public:
    int longestSubstring(string s, int k) {
        int res = 0, i = 0, n = s.size();
        while (i + k < n) {
            int m[26] = {0}, mask = 0, max_idx = i;
            for (int j = i; j < n; ++j) {
                int t = s[j] - 'a';
                ++m[t];
            }
        }
    }
};
```

```

        if (m[t] < k) mask |= (1 << t);
        else mask &= ~(1 << t));
        if (mask == 0) {
            res = max(res, j - i + 1);
            max_idx = j;
        }
    }
    i = max_idx + 1;
}
return res;
}
};

```

6.53 Longest Substring with At Most Two Distinct Characters (H)

Given a string S, find the length of the longest substring T that contains at most two distinct characters.

For example, Given S = “eceba”, T is “ece” which its length is 3.

```

class Solution {
public:
    int lengthOfLongestSubstringTwoDistinct(string s) {
        int res = 0, left = 0;
        unordered_map<char, int> m;
        for (int i = 0; i < s.size(); ++i) {
            ++m[s[i]];
            while (m.size() > 2) {
                if (--m[s[left]] == 0) m.erase(s[left]);
                ++left;
            }
            res = max(res, i - left + 1);
        }
        return res;
    }
};

```

```

class Solution {
public:
    int lengthOfLongestSubstringTwoDistinct(string s) {
        int res = 0, left = 0;
        unordered_map<char, int> m;
        for (int i = 0; i < s.size(); ++i) {
            m[s[i]] = i;

```

```

        while (m.size() > 2) {
            if (m[s[left]] == left) m.erase(s[left]);
            ++left;
        }
        res = max(res, i - left + 1);
    }
    return res;
}
};

```

6.54 Longest Substring with At Most K Distinct Characters (H)

Given a string, find the length of the longest substring T that contains at most k distinct characters.

For example, Given s = “eceba” and k = 2, T is “ece” which its length is 3.

```

class Solution {
public:
    int lengthOfLongestSubstringKDistinct(string s, int k) {
        int res = 0, left = 0;
        unordered_map<char, int> m;
        for (int i = 0; i < s.size(); ++i) {
            ++m[s[i]];
            while (m.size() > k) {
                if (--m[s[left]] == 0) m.erase(s[left]);
                ++left;
            }
            res = max(res, i - left + 1);
        }
        return res;
    }
};

```

```

class Solution {
public:
    int lengthOfLongestSubstringKDistinct(string s, int k) {
        int res = 0, left = 0;
        unordered_map<char, int> m;
        for (int i = 0; i < s.size(); ++i) {
            m[s[i]] = i;
            while (m.size() > k) {
                if (m[s[left]] == left) m.erase(s[left]);
            }
            res = max(res, i - left + 1);
            ++left;
        }
        return res;
    }
};

```

```

        ++left;
    }
    res = max(res, i - left + 1);
}
return res;
}
};

```

6.55 Minimum Window Substring (H)

Given a string S and a string T, find the minimum window in S which will contain all the characters in T in complexity $O(n)$.

Example:

Input: S = "ADOBECODEBANC", T = "ABC"

Output: "BANC"

Note:

If there is no such window in S that covers all characters in T, return the empty string "". If there is such window, you are guaranteed that there will always be only one unique minimum window in S.

```

class Solution(object):
    def minWindow(self, s, t):
        """
        :type s: str
        :type t: str
        :rtype: str
        """
        res = ''
        letter_cnt = {}
        left, cnt = 0, 0
        min_len = float('inf')
        for c in t:
            if c in letter_cnt: letter_cnt[c] += 1
            else: letter_cnt[c] = 1
        for i in range(len(s)):
            # find the substring that contains all chars in t
            if s[i] in letter_cnt:
                letter_cnt[s[i]] -= 1
                if letter_cnt[s[i]] >= 0: cnt += 1
            # if cnt matches the length of t, then we find the substring
            while cnt == len(t):
                # update the substring min_len and res

```

```

        # the current sliding window is from left to i
        if min_len > i - left + 1:
            min_len = i - left + 1
            res = s[left : i + 1]
        # check if s[left] is the char that is in t
        # if it is, add the hash value back and reduce cnt
        if s[left] in letter_cnt:
            letter_cnt[s[left]] += 1
            if letter_cnt[s[left]] > 0: cnt -= 1
        # move left window
        left += 1
    return res

```

6.56 Isomorphic Strings (E)

Given two strings *s* and *t*, determine if they are isomorphic.

Two strings are isomorphic if the characters in *s* can be replaced to get *t*. All occurrences of a character must be replaced with another character while preserving the order of characters. No two characters may map to the same character but a character may map to itself.

For example,

Given “egg”, “add”, return true.

Given “foo”, “bar”, return false.

Given “paper”, “title”, return true.

```

class Solution {
public:
    bool isIsomorphic(string s, string t) {
        if (s.size() != t.size()) return false;

        int m1[128] = {0};
        int m2[128] = {0};
        for (int i = 0; i < s.size(); ++i) {
            if (m1[s[i]] != m2[t[i]])
                return false;
            m1[s[i]] = i+1;
            m2[t[i]] = i+1;
        }
        return true;
    }
};

// intuitive solution

```

```

class Solution {
public:
    bool isIsomorphic(string s, string t) {
        if (s.size() == 0) return true;

        unordered_map<char, char> map1;
        unordered_map<char, char> map2;
        map1.insert(make_pair(s[0], t[0]));
        map2.insert(make_pair(t[0], s[0]));

        for (int i = 1; i < s.size(); i++){
            if (map1.find(s[i]) != map1.end()){
                if (t[i] != map1.at(s[i])) {
                    return false;
                }
            }

            if (map2.find(t[i]) != map2.end()){
                if (s[i] != map2.at(t[i])) {
                    return false;
                }
            }

            else {
                map1.insert(make_pair(s[i], t[i]));
                map2.insert(make_pair(t[i], s[i]));
            }
        }
        return true;
    }
};

```

6.57 Word Pattern (E)

Given a pattern and a string str, find if str follows the same pattern. Here follow means a full match, such that there is a bijection between a letter in pattern and a non-empty word in str.

Examples:

pattern = "abba", str = "dog cat cat dog" should return true.

pattern = "abba", str = "dog cat cat fish" should return false.

pattern = "aaaa", str = "dog cat cat dog" should return false.

pattern = "abba", str = "dog dog dog dog" should return false.

```

class Solution {

```



```

public:
    bool wordPattern(string pattern, string str) {
        unordered_map<char, int> p;
        unordered_map<string, int> w;
        istringstream in(str);           // read each word from str to in
        int i = 0;

        for (string word; in >> word; ++i) {
            if (p.find(pattern[i]) != p.end() || w.find(word) != w.end()) {
                if (p[pattern[i]] != w[word]) return false;
            } else {
                p[pattern[i]] = w[word] = i + 1;
            }
        }
        return i == pattern.size();
    }
};

```

6.58 Word Pattern II (H)

Given a pattern and a string str, find if str follows the same pattern. Here follow means a full match, such that there is a bijection between a letter in pattern and a non-empty substring in str.

Examples:

pattern = "abab", str = "redblueredblue" should return true.

pattern = "aaaa", str = "asdasdasdasd" should return true.

pattern = "aabb", str = "xyzabcxyabc" should return false.

Notes: You may assume both pattern and str contains only lowercase letters.

```

class Solution {
public:
    bool wordPatternMatch(string pattern, string str) {
        unordered_map<char, string> m;
        set<string> s;
        return helper(pattern, 0, str, 0, m, s);
    }
    bool helper(string pattern, int p, string str, int r, unordered_map<char,
        string> &m, set<string> &s) {
        if (p == pattern.size() && r == str.size()) return true;
        if (p == pattern.size() || r == str.size()) return false;
        char c = pattern[p];
        for (int i = r; i < str.size(); ++i) {

```

```

        string t = str.substr(r, i - r + 1);
        if (m.count(c) && m[c] == t) {
            if (helper(pattern, p + 1, str, i + 1, m, s)) return true;
        } else if (!m.count(c)) {
            if (s.count(t)) continue;
            m[c] = t;
            s.insert(t);
            if (helper(pattern, p + 1, str, i + 1, m, s)) return true;
            m.erase(c);
            s.erase(t);
        }
    }
    return false;
}
};

```

6.59 Word Break (M)

Given a string *s* and a dictionary of words *dict*, determine if *s* can be segmented into a space-separated sequence of one or more dictionary words.

For example, given *s* = "leetcode", *dict* = ["leet", "code"]. Return true because "leetcode" can be segmented as "leet code".

```

class Solution(object):
    def wordBreak(self, s, wordDict):
        """
        :type s: str
        :type wordDict: List[str]
        :rtype: bool
        """
        dp = [False for i in range(len(s)+1)]
        dp[0] = True
        for i in range(len(dp)):
            for j in range(i):
                # if s[0:j] can be segmented and s[j:i] is in wordDict,
                # then s[0:i] can be segmented
                if dp[j] and s[j:i] in wordDict:
                    dp[i] = True
                    break
        return dp[-1]

```

```

class Solution {
public:

```

```

bool wordBreak(string s, unordered_set<string> &wordDict) {
    int len = s.size();
    vector<bool> res(len + 1, false);
    res[0] = true;
    for (int i = 0; i < len + 1; ++i) {
        for (int j = 0; j < i; ++j) {
            if (res[j] && wordDict.find(s.substr(j, i-j)) != wordDict.end()) {
                res[i] = true;
                break;
            }
        }
    }
    return res[len];
}
};

```

6.60 Word Break II (H)

Given a string *s* and a dictionary of words *dict*, add spaces in *s* to construct a sentence where each word is a valid dictionary word. Return all such possible sentences.

For example, given *s* = "catsanddog", *dict* = ["cat", "cats", "and", "sand", "dog"]. A solution is ["cats and dog", "cat sand dog"].

```

class Solution {
public:
    vector<string> wordBreak(string s, unordered_set<string>& wordDict) {
        vector<string> res;
        string out;
        vector<bool> possible(s.size() + 1, true);
        wordBreakDFS(s, wordDict, 0, possible, out, res);
        return res;
    }
    void wordBreakDFS(string &s, unordered_set<string> &wordDict, int start,
        vector<bool> &possible, string &out, vector<string> &res) {
        if (start == s.size()) {
            res.push_back(out.substr(0, out.size() - 1));
            return;
        }
        for (int i = start; i < s.size(); ++i) {
            string word = s.substr(start, i - start + 1);
            if (wordDict.find(word) != wordDict.end() && possible[i + 1]) {
                out.append(word).append(" ");
                int oldSize = res.size();
                wordBreakDFS(s, wordDict, i + 1, possible, out, res);
                if (res.size() == oldSize) possible[i + 1] = false;
            }
        }
    }
};

```

```

        out.resize(out.size() - word.size() - 1);
    }
}
};

```

6.61 Shortest Word Distance (E)

Given a list of words and two words word1 and word2, return the shortest distance between these two words in the list.

For example,

Assume that words = ["practice", "makes", "perfect", "coding", "makes"].

Given word1 = "coding", word2 = "practice", return 3.

Given word1 = "makes", word2 = "coding", return 1.

Note: You may assume that word1 does not equal to word2, and word1 and word2 are both in the list.

```

class Solution {
public:
    int shortestDistance(vector<string>& words, string word1, string word2) {
        int p1 = -1, p2 = -1, res = INT_MAX;
        for (int i = 0; i < words.size(); ++i) {
            if (words[i] == word1) p1 = i;
            if (words[i] == word2) p2 = i;
            if (p1 != -1 && p2 != -1)
                res = min(res, abs(p1 - p2));
        }
        return res;
    }
};

```

```

class Solution {
public:
    int shortestDistance(vector<string>& words, string word1, string word2) {
        int idx = -1, res = INT_MAX;
        for (int i = 0; i < words.size(); ++i) {
            if (words[i] == word1 || words[i] == word2) {
                if (idx != -1 && words[idx] != words[i]) {
                    res = min(res, i - idx);
                }
                idx = i;
            }
        }
    }
};

```

```

    }
    return res;
}
};

```

6.62 Shortest Word Distance II (M)

This is a follow up of Shortest Word Distance. The only difference is now you are given the list of words and your method will be called repeatedly many times with different parameters. How would you optimize it? Design a class which receives a list of words in the constructor, and implements a method that takes two words word1 and word2 and return the shortest distance between these two words in the list.

For example,

Assume that words = ["practice", "makes", "perfect", "coding", "makes"].

Given word1 = "coding", word2 = "practice", return 3.

Given word1 = "makes", word2 = "coding", return 1.

Note: You may assume that word1 does not equal to word2, and word1 and word2 are both in the list.

```

// 1. O(MN) solution
class WordDistance {
public:
    WordDistance(vector<string> &words) {
        for (int i = 0; i < words.size(); ++i) {
            m[words[i]].push_back(i);
        }
    }

    int shortestDistance(string word1, string word2) {
        int res = INT_MAX;
        for (int i = 0; i < m[word1].size(); ++i) {
            for (int j = 0; j < m[word2].size(); ++j) {
                res = min(res, abs(m[word1][i] - m[word2][j]));
            }
        }
        return res;
    }

private:
    unordered_map<string, vector<int>> m;
};

```

```

// 2. O(M+N) solution
class WordDistance {
public:
    WordDistance(vector<string> &words) {
        for (int i = 0; i < words.size(); ++i) {
            m[words[i]].push_back(i);
        }
    }

    int shortestDistance(string word1, string word2) {
        int i = 0, j = 0, res = INT_MAX;
        while (i < m[word1].size() && j < m[word2].size()) {
            res = min(res, abs(m[word1][i] - m[word2][j]));
            m[word1][i] < m[word2][j] ? ++i : ++j;
        }
        return res;
    }

private:
    unordered_map<string, vector<int>> m;
};

```

6.63 Shortest Word Distance III (M)

This is a follow up of Shortest Word Distance. The only difference is now word1 could be the same as word2. Given a list of words and two words word1 and word2, return the shortest distance between these two words in the list. In this time, word1 and word2 may be the same and they represent two individual words in the list.

For example,

Assume that words = ["practice", "makes", "perfect", "coding", "makes"].

Given word1 = "makes", word2 = "coding", return 1.

Given word1 = "makes", word2 = "makes", return 3.

Note: You may assume word1 and word2 are both in the list.

```

class Solution {
public:
    int shortestWordDistance(vector<string>& words, string word1, string word2) {
        int idx = -1, res = INT_MAX;
        for (int i = 0; i < words.size(); ++i) {
            if (words[i] == word1 || words[i] == word2) {
                if (idx != -1 && (word1 == word2 || words[i] != words[idx])) {
                    res = min(res, i - idx);
                }
                idx = i;
            }
        }
        return res;
    }
};

```

```

    }
}
return res;
}
};

```

6.64 Strobogrammatic Number (E)

A strobogrammatic number is a number that looks the same when rotated 180 degrees (looked at upside down). Write a function to determine if a number is strobogrammatic. The number is represented as a string.

For example, the numbers "69", "88", and "818" are all strobogrammatic.

```

class Solution{
public:
    bool isStrobogrammatic(string num) {
        int l = 0, r = num.size() - 1;
        while (l <= r) {
            if (num[l] == num[r]) {
                if (num[l] != '1' || num[l] != '8' || num[l] != '0') {
                    return false;
                }
            } else {
                if ( (num[l] != '6' || num[r] != '9') && (num[l] != '9' || num[r] != '6') ) {
                    return false;
                }
            }
            ++l;
            --r;
        }
        return true;
    }
};

```

6.65 Strobogrammatic Number II (M)

A strobogrammatic number is a number that looks the same when rotated 180 degrees (looked at upside down). Find all strobogrammatic numbers that are of length = n.

For example, Given n = 2, return ["11","69","88","96"].

Hint: Try to use recursion and notice that it should recurse with $n - 2$ instead of $n - 1$.

```
class Solution {
public:
    vector<string> findStrobogrammatic(int n) {
        return find(n, n);
    }

    vector<string> find(int m, int n) {
        if (m == 0) return {" "};
        if (m == 1) return {"0", "1", "8"};
        vector<string> t = find(m - 2, n), res;

        for (auto a : t) {
            // add 0 to both side of a if level m is not level n
            if (m != n) res.push_back("0" + a + "0");

            res.push_back("1" + a + "1");
            res.push_back("6" + a + "9");
            res.push_back("8" + a + "8");
            res.push_back("9" + a + "6");
        }

        return res;
    }
};
```

6.66 Strobogrammatic Number III (M)

A strobogrammatic number is a number that looks the same when rotated 180 degrees (looked at upside down). Write a function to count the total strobogrammatic numbers that exist in the range of $low \leq num \leq high$.

For example,

Given $low = "50"$, $high = "100"$, return 3. Because 69, 88, and 96 are three strobogrammatic numbers.

Note: Because the range might be a large number, the low and high numbers are represented as string.

```
class Solution {
public:
    int strobogrammaticInRange(string low, string high) {
        int res = 0;
```



```

        find(low, high, "", res);
        find(low, high, "0", res);
        find(low, high, "1", res);
        find(low, high, "8", res);
        return res;
    }
    void find(string low, string high, string w, int &res) {
        if (w.size() >= low.size() && w.size() <= high.size()) {
            if ((w.size() == low.size() && w.compare(low) < 0) || (w.size() ==
                high.size() && w.compare(high) > 0)) {
                return;
            }
            if (!(w.size() > 1 && w[0] == '0')) ++res;
        }
        if (w.size() + 2 > high.size()) return;
        find(low, high, "0" + w + "0", res);
        find(low, high, "1" + w + "1", res);
        find(low, high, "6" + w + "9", res);
        find(low, high, "8" + w + "8", res);
        find(low, high, "9" + w + "6", res);
    }
};

```

6.67 Unique Word Abbreviation (E)

An abbreviation of a word follows the form $\langle \textit{firstletter} \rangle \langle \textit{number} \rangle \langle \textit{lastletter} \rangle$. Below are some examples of word abbreviations:

- a) it -- > it (no abbreviation)
- b) d—o—g -- > d1g
- c) i—nternationalizatio—n -- > i18n
- d) l—ocalizatio—n -- > l10n

Assume you have a dictionary and given a word, find whether its abbreviation is unique in the dictionary. A word's abbreviation is unique if no other word from the dictionary has the same abbreviation.

Example:

```

Given dictionary = [ "deer", "door", "cake", "card" ]
isUnique("dear") - > false
isUnique("cart") - > true

```

```
isUnique("cane") -> false
isUnique("make") -> true
```

```
class ValidWordAbbr {
public:
    ValidWordAbbr(vector<string> &dictionary) {
        for (auto a : dictionary) {
            // get the word abbreviation in dictionary
            string k = a.front() + to_string(a.size() - 2) + a.back();
            m[k].insert(a);
        }
    }

    // If this word (also this word's abbreviation) is not in the dictionary
    // OR this word and only it's abbreviation in the dictionary,
    // we call a word's abbreviation unique.
    bool isUnique(string word) {
        // get the word abbreviation
        string k = word.front() + to_string(word.size() - 2) + word.back();
        return m[k].count(word) == m[k].size();
    }

private:
    unordered_map<string, set<string>> m; // mapping the word abbr and the words
};
```

6.68 Generalized Abbreviation (M)

Write a function to generate the generalized abbreviations of a word.

Example: Given word = "word", return the following list (order does not matter):
["word", "1ord", "w1rd", "wo1d", "wor1", "2rd", "w2d", "wo2", "1o1d", "1or1", "w1r1",
"1o2", "2r1", "3d", "w3", "4"]

```
// 1. Iterative solution
class Solution {
public:
    vector<string> generateAbbreviations(string word) {
        vector<string> res;
        // Use binary bit to code word
        for (int i = 0; i < pow(2, word.size()); ++i) {
            string out = "";
            int cnt = 0, t = i;
            for (int j = 0; j < word.size(); ++j) {
```

```

        if (t & 1 == 1) { // If bit is 1, count it as a number
            ++cnt;
            if (j == word.size() - 1) {
                out += to_string(cnt);
            }
        } else { // If bit is 0, count it as a char
            if (cnt != 0) { // If there is a number counted, output it
                out += to_string(cnt);
                cnt = 0;
            }
            out += word[j]; // Otherwise output char
        }
        t >>= 1; // Move to next bit
    }
    res.push_back(out);
}
return res;
}
};

// 2. Recursive solution
class Solution {
public:
    vector<string> generateAbbreviations(string word) {
        vector<string> res{word};
        helper(word, 0, res);
        return res;
    }
    void helper(string word, int pos, vector<string> &res) {
        for (int i = pos; i < word.size(); ++i) {
            for (int j = 1; i + j <= word.size(); ++j) {
                string t = word.substr(0, i);
                t += to_string(j) + word.substr(i + j);
                res.push_back(t);
                helper(t, i + 1 + to_string(j).size(), res);
            }
        }
    }
};

```

6.69 One Edit Distance (M)

Given two strings S and T, determine if they are both one edit distance apart.

based on the definition of one edit distance

```

def isOneEditDistance(s, t):
    m, n = len(s), len(t)
    diff = abs(m - n)
    if diff >= 2:
        return False
    elif diff == 1:
        for i in range( min(m,n) ):
            if s[i] != t[i]:
                if m > n: return s[i+1:] == t[i:]
                elif m < n: return s[i:] == t[i+1:]
        else:
            cnt = 0
            for i in range(n):
                if s[i] != t[i]:
                    cnt += 1
            return cnt == 1

# compare each char in s and t
def isOneEditDistance(s, t):
    m, n = len(s), len(t)
    for i in range( min(m,n) ):
        if s[i] != t[i]:
            if m == n: return s[i+1:] == t[i+1:]
            elif m > n: return s[i+1:] == t[i:]
            else: return s[i:] == t[i+1:]
    # if all s[i] and t[i] are the same in above loop,
    # then the abs diff between s and t must be 1 when their edit distance is one
    return abs(m-n) == 1

```

```

class Solution {
public:
    bool isOneEditDistance(string s, string t) {
        for (int i = 0; i < min(s.size(), t.size()); ++i) {
            // if the only difference is between s[i] and t[i]
            // then the left substring in both s and t should be exactly the same
            if (s[i] != t[i]) {
                if (s.size() == t.size()) return s.substr(i + 1) == t.substr(i + 1);
                else if (s.size() < t.size()) return s.substr(i) == t.substr(i + 1);
                else return s.substr(i + 1) == t.substr(i);
            }
        }
        // if no difference is found,
        // s and t are valid if they have at least one difference in size
        return abs(s.size() - t.size()) == 1;
    }
}

```

```
};
```

6.70 Edit Distance (H)

Given two words word1 and word2, find the minimum number of steps required to convert word1 to word2. (each operation is counted as 1 step.)

You have the following 3 operations permitted on a word:

- a) Insert a character
- b) Delete a character
- c) Replace a character

```
/** 1. dp[i][0] = i;
 * 2. dp[0][j] = j;
 * 3. dp[i][j] = dp[i - 1][j - 1], if word1[i - 1] = word2[j - 1];
 * 4. dp[i][j] = min(dp[i - 1][j - 1] + 1, dp[i - 1][j] + 1, dp[i][j - 1] + 1),
 *    otherwise.
 *
 * Replace word1[i - 1] by word2[j - 1] (dp[i][j] = dp[i - 1][j - 1] + 1 (for
 * replacement));
 * Delete word1[i - 1] and word1[0..i - 2] = word2[0..j - 1] (dp[i][j] = dp[i -
 * 1][j] + 1 (for deletion));
 * Insert word2[j - 1] to word1[0..i - 1] and word1[0..i - 1] + word2[j - 1] =
 * word2[0..j - 1] (dp[i][j] = dp[i][j - 1] + 1 (for insertion)).
 *
 * For deletion, we are actually converting word1[0..i - 2] to word2[0..j - 1],
 * which costs dp[i - 1][j], and then deleting the word1[i - 1], which costs 1.
 * The case is similar for insertion.
 */
class Solution {
public:
    int minDistance(string word1, string word2) {
        int n1 = word1.size(), n2 = word2.size();
        int dp[n1 + 1][n2 + 1];
        for (int i = 0; i <= n1; ++i) dp[i][0] = i;
        for (int i = 0; i <= n2; ++i) dp[0][i] = i;
        for (int i = 1; i <= n1; ++i) {
            for (int j = 1; j <= n2; ++j) {
                if (word1[i - 1] == word2[j - 1]) {
                    dp[i][j] = dp[i - 1][j - 1];
                } else {
                    dp[i][j] = min(dp[i - 1][j - 1], min(dp[i - 1][j], dp[i][j -
                    1])) + 1;
                }
            }
        }
    }
}
```

```

    }
    return dp[n1][n2];
}
};

```

6.71 String Compression (E)

Given an array of characters, compress it in-place.

The length after compression must always be smaller than or equal to the original array.

Every element of the array should be a character (not int) of length 1.

After you are done modifying the input array in-place, return the new length of the array.

```

class Solution(object):
    def compress(self, chars):
        """
        :type chars: List[str]
        :rtype: int
        """
        cur = 0
        n = len(chars)
        i, j = 0, 0
        while i < n:
            while j < n and chars[i] == chars[j]:
                j += 1
            chars[cur] = chars[i]
            cur += 1
            # j-i is the length of each compressed char
            if j - i == 1:
                i = j
                continue
            for c in str(j-i):
                chars[cur] = c
                cur += 1
            i = j
        return cur

```

6.72 Encode and Decode Strings (M)

Design an algorithm to encode a list of strings to a string. The encoded string is then sent over the network and is decoded back to the original list of strings. Implement the encode and decode methods.

Note:

The string may contain any possible characters out of 256 valid ascii characters. Your algo-

rithm should be generalized enough to work on any possible characters.

Do not use class member/global/static variables to store states. Your encode and decode algorithms should be stateless.

Do not rely on any library method such as eval or serialize methods. You should implement your own encode/decode algorithm.

```
class Codec {
public:
    // Encodes a list of strings to a single string.
    // e.g. "a", "ab", "abc" -> 1/a2/ab3/abc
    string encode(vector<string>& strs) {
        string res = "";
        for (auto a : strs) {
            res.append(to_string(a.size())).append("/").append(a);
        }
        return res;
    }
    // Decodes a single string to a list of strings.
    vector<string> decode(string s) {
        vector<string> res;
        int i = 0;
        while (i < s.size()) {
            auto found = s.find("/", i);
            int len = atoi(s.substr(i, found).c_str());
            res.push_back(s.substr(found + 1, len));
            i = found + len + 1;
        }
        return res;
    }
};
```

6.73 Decode String (M)

Given an encoded string, return it's decoded string. The encoding rule is: $k[\text{encoded-string}]$, where the encoded-string inside the square brackets is being repeated exactly k times. Note that k is guaranteed to be a positive integer.

You may assume that the input string is always valid; No extra white spaces, square brackets are well-formed, etc. Furthermore, you may assume that the original data does not contain any digits and that digits are only for those repeat numbers, k . For example, there won't be input like $3a$ or $2[4]$.

Examples:

$s = "3[a]2[bc]"$, return $"aaabcbc"$.

s = "3[a2[c]]", return "accaccacc".
s = "2[abc]3[cd]ef", return "abcabccdcddcdef".

```
class Solution {
public:
    string decodeString(string s) {
        int i = 0;
        return decode(s, i);
    }
    string decode(string s, int &i) {
        string res = "";
        int n = s.size();
        // check each substring until meet ']' or the end of s
        while (i < n && s[i] != ']') {
            if (s[i] < '0' || s[i] > '9') { // if s[i] is char, store it to res
                res += s[i++];
            } else {
                int cnt = 0;
                // get the value of k
                while (i < n && s[i] >= '0' && s[i] <= '9') {
                    cnt = cnt * 10 + s[i++] - '0';
                }
                ++i; // skip the next [
                string t = decode(s, i); // get the substring
                ++i; // skip the next ]
                while (cnt-- > 0) res += t; // write the substring by k times
            }
        }
        return res;
    }
};
```

6.74 Read N Characters Given Read4 (E)

The API: `int read4(char *buf)` reads 4 characters at a time from a file. The return value is the actual number of characters read. For example, it returns 3 if there is only 3 characters left in the file. By using the `read4` API, implement the function `int read(char *buf, int n)` that reads `n` characters from the file.

Note: The `read` function will only be called once for each test case.

```
int read4(char *buf);
```

```
class Solution {
```



```

public:
    int read(char *buf, int n) {
        int res = 0;
        for (int i = 0; i <= n / 4; ++i) {
            int cur = read4(buf + res);
            if (cur == 0) break;
            res += cur;
        }
        return min(res, n);
    }
};

```

6.75 Read N Characters Given Read4 II (H)

The API: `int read4(char *buf)` reads 4 characters at a time from a file. The return value is the actual number of characters read. For example, it returns 3 if there is only 3 characters left in the file. By using the `read4` API, implement the function `int read(char *buf, int n)` that reads `n` characters from the file.

Note: The `read` function may be called multiple times.

```

class Solution {
public:
    int read(char *buf, int n) {
        for (int i = 0; i < n; ++i) {
            if (readPos == writePos) {
                writePos = read4(buff);
                readPos = 0;
                if (writePos == 0) return i;
            }
            buf[i] = buff[readPos++];
        }
        return n;
    }
private:
    int readPos = 0, writePos = 0;
    char buff[4];
};

```

6.76 Remove Comments (M)

Given a C++ program, remove comments from it. The program source is an array where `source[i]` is the *i*-th line of the source code. This represents the result of splitting the original

source code string by the newline character.

In C++, there are two types of comments, line comments, and block comments.

The string `//` denotes a line comment, which represents that it and rest of the characters to the right of it in the same line should be ignored.

The string `/*` denotes a block comment, which represents that all characters until the next (non-overlapping) occurrence of `*/` should be ignored. (Here, occurrences happen in reading order: line by line from left to right.) To be clear, the string `/*` does not yet end the block comment, as the ending would be overlapping the beginning.

The first effective comment takes precedence over others: if the string `//` occurs in a block comment, it is ignored. Similarly, if the string `/*` occurs in a line or block comment, it is also ignored.

If a certain line of code is empty after removing comments, you must not output that line: each string in the answer list will be non-empty.

There will be no control characters, single quote, or double quote characters. For example, `source = "string s = \"/* Not a comment. */\";"` will not be a test case. (Also, nothing else such as defines or macros will interfere with the comments.)

It is guaranteed that every open block comment will eventually be closed, so `/*` outside of a line or block comment always starts a new comment.

Finally, implicit newline characters can be deleted by block comments. Please see the examples below for details.

After removing the comments from the source code, return the source code in the same format.

```
class Solution(object):
    def removeComments(self, source):
        """
        :type source: List[str]
        :rtype: List[str]
        """
        in_block = False
        res = []
        for line in source:
            i = 0
            if not in_block:
                newline = []
                while i < len(line):
```

```

        if line[i:i+2] == '/*' and not in_block:
            in_block = True
            i += 1
        elif line[i:i+2] == '*/' and in_block:
            in_block = False
            i += 1
        elif line[i:i+2] == '//' and not in_block:
            break
        elif not in_block:
            newline.append(line[i])
            i += 1
    if newline and not in_block:
        res.append("".join(newline))
return res

```

6.77 Maximum Swap (M)

Given a non-negative integer, you could swap two digits at most once to get the maximum valued number. Return the maximum valued number you could get.

Example 1:

Input: 2736

Output: 7236

Explanation: Swap the number 2 and the number 7.

Example 2:

Input: 9973

Output: 9973

Explanation: No swap.

```

# O(N): every digit is considered at most once
class Solution(object):
    def maximumSwap(self, num):
        """
        :type num: int
        :rtype: int
        """
        str_num = str(num)
        n = len(str_num)
        dict_num_idx = {}
        for i in range(n):
            dict_num_idx[ord(str_num[i]) - ord('0')] = i
        # when scanning the number from left to right,
        # if there is a larger digit in the future,

```

```

# we will swap it with the largest such digit;
# if there are multiple such digits,
# we will swap it with the one that occurs the latest.
for i in range(n):
    for j in range(9, ord(str_num[i]) - ord('0'), -1):
        if j in dict_num_idx and dict_num_idx[j] > i:
            str_num = self.swap(str_num, i, dict_num_idx[j])
            return int(str_num)
    return num
# a string has to be converted to a list for swapping
def swap(self, string, i, j):
    l = list(string)
    l[i], l[j] = l[j], l[i]
    return ''.join(l)

```

6.78 Verifying an Alien Dictionary (E)

In an alien language, surprisingly they also use english lowercase letters, but possibly in a different order. The order of the alphabet is some permutation of lowercase letters.

Given a sequence of words written in the alien language, and the order of the alphabet, return true if and only if the given words are sorted lexicographically in this alien language.

Example 1:

Input: words = ["hello","leetcode"], order = "hlabcd efghijklmnopqrstuvwxy z" Output: true

Explanation: As 'h' comes before 'l' in this language, then the sequence is sorted.

Example 2:

Input: words = ["word","world","row"], order = "worldabce fghijklmnopqstuvwxy z" Output:

false Explanation: As 'd' comes after 'l' in this language, then words[0] > words[1], hence the sequence is unsorted.

Example 3:

Input: words = ["apple","app"], order = "abcdefghijklmnopqrstuvwxyz" Output: false Ex-

planation: The first three characters "app" match, and the second string is shorter (in size.) According to lexicographical rules "apple" > "app", because 'l' > 'None', where 'None' is defined as the blank character which is less than any other character (More info).

Note: 1 ≤ words.length ≤ 100 1 ≤ words[i].length ≤ 20 order.length == 26 All characters in words[i] and order are english lowercase letters.

```

class Solution(object):
    def isAlienSorted(self, words, order):
        """
        :type words: List[str]
        :type order: str
        :rtype: bool
        """
        order_index = {c: i for i, c in enumerate(order)}

```

```

for i in xrange(len(words) - 1):
    word1 = words[i]
    word2 = words[i+1]

    # Find the first difference between word1[k] and word2[k]
    for k in xrange(min(len(word1), len(word2))):
        if word1[k] != word2[k]:
            # If they compare badly, it's not sorted
            if order_index[word1[k]] > order_index[word2[k]]:
                return False
            break
        else:
            # If we didn't find any difference between word1[k] and
            word2[k],
            # the words are like ("app", "apple")
            if len(word1) > len(word2):
                return False

    return True

```

Chapter 7

Tree

7.1 Binary Tree Construction

7.1.1 Construct Binary Tree from Preorder and Inorder Traversal (M)

Given preorder and inorder traversal of a tree, construct the binary tree.

Note: You may assume that duplicates do not exist in the tree.

```
# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def buildTree(self, preorder, inorder):
        """
        :type preorder: List[int]
        :type inorder: List[int]
        :rtype: TreeNode
        """
        p_left, i_left = 0, 0
        p_right, i_right = len(preorder) - 1, len(inorder) - 1
        return self.construct(preorder, p_left, p_right, \
                               inorder, i_left, i_right)
    def construct(self, preorder, p_left, p_right, inorder, i_left, i_right):
        if p_left > p_right or i_left > i_right:
            return None
        # find the root node
        for i in range(i_left, i_right+1):
```

```

        if preorder[p_left] == inorder[i]: break
    node = TreeNode(preorder[p_left])
    # i-i_left is the distance between the root node index i
    # and the left index in inorder traversal list
    node.left = self.construct(preorder, p_left+1, p_left+(i-i_left), \
                               inorder, i_left, i-1)
    node.right = self.construct(preorder, p_left+(i-i_left)+1, p_right, \
                                inorder, i+1, i_right)

    return node

```

```

class Solution {
public:
    TreeNode* buildTree(vector<int>& preorder, vector<int>& inorder) {
        return buildTree(inorder, preorder, 0, inorder.size()-1, 0,
                          preorder.size()-1);
    }
    TreeNode* buildTree(vector<int>& inorder, vector<int>& preorder, int
                        in_start, int in_end, int pre_start, int pre_end) {
        if (in_start > in_end) return NULL;
        int index;
        TreeNode *root = new TreeNode(preorder[pre_start]);
        for (int i = in_start; i <= in_end; ++i) {
            if (inorder[i] == root->val) {
                index = i;
                break;
            }
        }
        root->left = buildTree(inorder, preorder, in_start, index-1, pre_start+1,
                               pre_start+index-in_start);
        root->right = buildTree(inorder, preorder, index+1, in_end,
                                pre_end-in_end+index+1, pre_end);
        return root;
    }
};

```

7.1.2 Construct Binary Tree from Inorder and Postorder Traversal (M)

Given inorder and postorder traversal of a tree, construct the binary tree.

Note: You may assume that duplicates do not exist in the tree.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):

```

```

#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def buildTree(self, inorder, postorder):
        """
        :type inorder: List[int]
        :type postorder: List[int]
        :rtype: TreeNode
        """
        p_left, i_left = 0, 0
        p_right, i_right = len(postorder) - 1, len(inorder) - 1
        return self.construct(postorder, p_left, p_right, \
                               inorder, i_left, i_right)
    def construct(self, postorder, p_left, p_right, inorder, i_left, i_right):
        if p_left > p_right or i_left > i_right:
            return None
        # find the root node
        for i in range(i_left, i_right+1):
            if postorder[p_right] == inorder[i]: break
        node = TreeNode(postorder[p_right])
        # i-i_left is the distance between the root node index i
        # and the left index in inorder traversal list
        node.left = self.construct(postorder, p_left, p_left+(i-i_left)-1, \
                                   inorder, i_left, i-1)
        node.right = self.construct(postorder, p_left+(i-i_left), p_right-1, \
                                    inorder, i+1, i_right)
        return node

```

```

class Solution {
public:
    TreeNode* buildTree(vector<int>& inorder, vector<int>& postorder) {
        return buildTree(inorder, postorder, 0, inorder.size()-1, 0,
                           postorder.size()-1);
    }
    TreeNode* buildTree(vector<int>& inorder, vector<int>& postorder, int
        in_start, int in_end, int post_start, int post_end){
        if (in_start > in_end) return NULL;
        int index;
        TreeNode *root = new TreeNode(postorder[post_end]);
        for (int i = in_start; i <= in_end; ++i) {
            if (inorder[i] == root->val) {
                index = i;
                break;
            }
        }
    }
}

```



```

        root->left = buildTree(inorder, postorder, in_start, index-1, post_start,
                               post_start+index-in_start-1);
        root->right = buildTree(inorder, postorder, index+1, in_end,
                                post_end-in_end+index, post_end-1);
        return root;
    }
};

```

7.1.3 Construct Binary Tree from Preorder and Postorder Traversal (M)

Return any binary tree that matches the given preorder and postorder traversals.

Values in the traversals pre and post are distinct positive integers.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def constructFromPrePost(self, pre, post):
        if not pre: return None
        root = TreeNode(pre[0])
        if len(pre) == 1: return root

        L = post.index(pre[1]) + 1
        root.left = self.constructFromPrePost(pre[1:L+1], post[:L])
        root.right = self.constructFromPrePost(pre[L+1:], post[L:-1])
        return root

```

7.1.4 Construct Binary Search Tree from Preorder Traversal (M)

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def bstFromPreorder(self, preorder):

```

```

"""
:type preorder: List[int]
:rtype: TreeNode
"""

start, end = 0, len(preorder)-1
return self.construct(preorder, start, end)
def construct(self, preorder, start, end):
    if not preorder or start > end: return None
    node = TreeNode(preorder[start])
    if start == end: return node
    for i in range(start, end+1):
        # if the right subtree exists, the right root index is i
        if preorder[i] > preorder[start]:
            node.left = self.construct(preorder, start+1, i-1)
            node.right = self.construct(preorder, i, end)
            return node
    # no right subtree
    node.left = self.construct(preorder, start+1, end)
    return node

```

7.1.5 Serialize and Deserialize Binary Tree (H)

Serialization is the process of converting a data structure or object into a sequence of bits so that it can be stored in a file or memory buffer, or transmitted across a network connection link to be reconstructed later in the same or another computer environment.

Design an algorithm to serialize and deserialize a binary tree. There is no restriction on how your serialization/deserialization algorithm should work. You just need to ensure that a binary tree can be serialized to a string and this string can be deserialized to the original tree structure.

Note: Do not use class member/global/static variables to store states. Your serialize and deserialize algorithms should be stateless.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

import json
class Codec:

    def serialize(self, root):

```

```

        """Encodes a tree to a single string.

        :type root: TreeNode
        :rtype: str
        """
        arr = self.preorder(root, [])
        return json.dumps(arr)

def deserialize(self, data):
    """Decodes your encoded data to tree.

    :type data: str
    :rtype: TreeNode
    """
    tree = json.loads(data)
    if not tree: return None
    return self.construct(tree)

def preorder(self, root, arr):
    if not root:
        arr.append(None)
        return
    arr.append(root.val)
    self.preorder(root.left, arr)
    self.preorder(root.right, arr)
    return arr

def construct(self, tree_list):
    val = tree_list.pop(0)
    if val is None: return
    else:
        root = TreeNode(val)
        root.left = self.construct(tree_list)
        root.right = self.construct(tree_list)
        return root

# Your Codec object will be instantiated and called as such:
# codec = Codec()
# codec.deserialize(codec.serialize(root))

```

```

/**
 * Definition for a binary tree node.
 * struct TreeNode {
 *     int val;
 *     TreeNode *left;
 *     TreeNode *right;
 *     TreeNode(int x) : val(x), left(NULL), right(NULL) {}

```

```

* };
*/
// 1. Recursion
class Codec {
public:
    // Encodes a tree to a single string.
    string serialize(TreeNode* root) {
        ostringstream out;
        serialize(root, out);
        return out.str();
    }
    // Decodes your encoded data to tree.
    TreeNode* deserialize(string data) {
        istringstream in(data);
        return deserialize(in);
    }
private:
    void serialize(TreeNode *root, ostringstream &out) {
        if (root) {
            out << root->val << ' ';
            serialize(root->left, out);
            serialize(root->right, out);
        } else {
            out << "# ";
        }
    }
    TreeNode* deserialize(istringstream &in) {
        string val;
        in >> val;
        if (val == "#") return nullptr;
        TreeNode *root = new TreeNode(stoi(val));
        root->left = deserialize(in);
        root->right = deserialize(in);
        return root;
    }
};

```

```

// 2. Non-recursion
class Codec {
public:
    // Encodes a tree to a single string.
    string serialize(TreeNode* root) {
        ostringstream out;
        queue<TreeNode*> q;
        if (root) q.push(root);
        while (!q.empty()) {
            TreeNode *t = q.front(); q.pop();

```

```

        if (t) {
            out << t->val << ' ';
            q.push(t->left);
            q.push(t->right);
        } else {
            out << "# ";
        }
    }
    return out.str();
}

// Decodes your encoded data to tree.
TreeNode* deserialize(string data) {
    if (data.empty()) return nullptr;
    istringstream in(data);
    queue


---



```

7.1.6 Serialize and Deserialize BST (M)

Serialization is the process of converting a data structure or object into a sequence of bits so that it can be stored in a file or memory buffer, or transmitted across a network connection

link to be reconstructed later in the same or another computer environment.

Design an algorithm to serialize and deserialize a binary search tree. There is no restriction on how your serialization/deserialization algorithm should work. You just need to ensure that a binary search tree can be serialized to a string and this string can be deserialized to the original tree structure.

The encoded string should be as compact as possible.

Note: Do not use class member/global/static variables to store states. Your serialize and deserialize algorithms should be stateless.

Solution is the same as "Serialize and Deserialize Binary Tree".

7.1.7 Serialize and Deserialize N-ary Tree (H)

Serialization is the process of converting a data structure or object into a sequence of bits so that it can be stored in a file or memory buffer, or transmitted across a network connection link to be reconstructed later in the same or another computer environment.

Design an algorithm to serialize and deserialize an N-ary tree. An N-ary tree is a rooted tree in which each node has no more than N children. There is no restriction on how your serialization/deserialization algorithm should work. You just need to ensure that an N-ary tree can be serialized to a string and this string can be deserialized to the original tree structure.

Solution is similar to "Serialize and Deserialize Binary Tree" by using for loop to apply recursion to each child node.

7.1.8 Verify Preorder Serialization of a Binary Tree (M)

One way to serialize a binary tree is to use pre-order traversal. When we encounter a non-null node, we record the node's value. If it is a null node, we record using a sentinel value such as #, where # represents a null node.

Given a string of comma separated values, verify whether it is a correct preorder traversal serialization of a binary tree. Find an algorithm without reconstructing the tree. Each comma separated value in the string must be either an integer or a character '#' representing null pointer. You may assume that the input format is always valid, for example it could never contain two consecutive commas such as "1,,3".

Example 1: "9,3,4,N,N,1,N,N,2,N,6,N,N" Return true

Example 2: "1,N" Return false

Example 3: "9,N,N,1" Return false

```
class Solution {
public:
    bool isValidSerialization(string preorder) {
        istringstream iss(preorder);
        string tmp;
        vector<string> vec;
        int nullcnt = 0, nodecnt = 0;
        // save the string stream as a vector
        while (getline(iss, tmp, ',')) vec.push_back(tmp);
        for (int i = 0; i < vec.size(); i++){
            if (vec[i] != "#") nodecnt++; // add node count
            else nullcnt++; // add # count
            // a valid serialization must be:
            // 1. nullcnt = nodecnt + 1 in the whole string
            // 2. nullcnt could not be larger than nodecnt when i != vec.size()-1
            if ((nullcnt == nodecnt + 1) && (i != vec.size() - 1)) return false;
        }
        return nullcnt == nodecnt + 1;
    }
};
```

7.2 Binary Tree Traversal

7.2.1 Binary Tree Preorder Traversal (M)

Given a binary tree, return the preorder traversal of its nodes' values.

For example: Given binary tree [1,null,2,3], return [1,2,3].

```
# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

# recursion
class Solution(object):
    def preorderTraversal(self, root):
        """
        :type root: TreeNode
        :rtype: List[int]
```

```

        """
        res = []
        self.preorder(root, res)
        return res
    def preorder(self, root, res):
        if not root: return
        res.append(root.val)
        if root.left: self.preorder(root.left, res)
        if root.right: self.preorder(root.right, res)

# iteration with stack
class Solution(object):
    def preorderTraversal(self, root):
        """
        :type root: TreeNode
        :rtype: List[int]
        """
        res, s = [], []
        p = root
        while s or p:
            if p:
                s.append(p)
                res.append(s[-1].val)
                p = p.left
            else:
                p = s[-1].right
                s.pop()
        return res

```

```

/**
 * Definition for a binary tree node.
 * struct TreeNode {
 *     int val;
 *     TreeNode *left;
 *     TreeNode *right;
 *     TreeNode(int x) : val(x), left(NULL), right(NULL) {}
 * };
 */
// 1. Recursion solution
class Solution {
public:
    vector<int> preorderTraversal(TreeNode *root) {
        vector<int> res;
        preorder(root, res);
        return res;
    }
    void preorder(TreeNode *root, vector<int> &res) {

```



```

        if (!root) return;
        res.push_back(root->val);
        if (root->left) preorder(root->left, res);
        if (root->right) preorder(root->right, res);
    }
};

// 2. Non-recursion
class Solution {
public:
    vector<int> preorderTraversal(TreeNode *root) {
        vector<int> res;
        stack<TreeNode*> s;
        if (!root) return res;
        s.push(root);
        while (!s.empty()) {
            TreeNode *p = s.top();
            s.pop();
            res.push_back(p->val);
            if (p->right) s.push(p->right);
            if (p->left) s.push(p->left);
        }
        return res;
    }
};

```

7.2.2 Binary Tree Inorder Traversal (M)

Given a binary tree, return the inorder traversal of its nodes' values.

For example: Given binary tree [1,null,2,3], return [1,3,2].

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

# recursion
class Solution(object):
    def inorderTraversal(self, root):
        """
        :type root: TreeNode
        :rtype: List[int]
        """

```

```

        res = []
        self.inorder(root, res)
        return res
    def inorder(self, root, res):
        if not root: return
        if root.left: self.inorder(root.left, res)
        res.append(root.val)
        if root.right: self.inorder(root.right, res)

# iteration with stack
class Solution(object):
    def inorderTraversal(self, root):
        """
        :type root: TreeNode
        :rtype: List[int]
        """
        s, res = [], []
        p = root
        while s or p:
            if p:
                s.append(p)
                p = p.left
            else:
                res.append(s[-1].val)
                p = s[-1].right
                s.pop()
        return res

```

// 1. Recursion solution

```

class Solution {
public:
    vector<int> inorderTraversal(TreeNode *root) {
        vector<int> res;
        inorder(root, res);
        return res;
    }
    void inorder(TreeNode *root, vector<int> &res) {
        if (!root) return;
        if (root->left) inorder(root->left, res);
        res.push_back(root->val);
        if (root->right) inorder(root->right, res);
    }
};

```

// 2. Non-recursion

```

class Solution {
public:

```

```

vector<int> inorderTraversal(TreeNode *root){
    vector<int> res;
    stack<TreeNode*> s;
    TreeNode *p = root;
    while (p || !s.empty()) {
        if (p) {
            s.push(p);
            p = p->left;
        } else {
            p = s.top();
            s.pop();
            res.push_back(p->val);
            p = p->right;
        }
    }
    return res;
}
};

```

7.2.3 Binary Tree Postorder Traversal (H)

Given a binary tree, return the postorder traversal of its nodes' values.

For example: Given binary tree [1,null,2,3], return [3,2,1].

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

# recursion
class Solution(object):
    def postorderTraversal(self, root):
        """
        :type root: TreeNode
        :rtype: List[int]
        """
        res = []
        self.postorder(root, res)
        return res
    def postorder(self, root, res):
        if not root: return
        if root.left: self.postorder(root.left, res)
        if root.right: self.postorder(root.right, res)

```

```

        res.append(root.val)

# iteration with stack
class Solution(object):
    def postorderTraversal(self, root):
        """
        :type root: TreeNode
        :rtype: List[int]
        """
        s, res = [], []
        p = root
        while s or p:
            if p:
                s.append(p)
                res.insert(0, s[-1].val)
                p = p.right
            else:
                p = s[-1].left
                s.pop()
        return res

```

```

// 1. Recursion solution
class Solution {
public:
    vector<int> postorderTraversal(TreeNode *root) {
        vector<int> res;
        postorder(root, res);
        return res;
    }
    void postorder(TreeNode *root, vector<int> &res) {
        if (!root) return;
        if (root->left) postorder(root->left, res);
        if (root->right) postorder(root->right, res);
        res.push_back(root->val);
    }
};

```

```

// 2. Non-recursion
class Solution {
public:
    vector<int> postorderTraversal(TreeNode *root) {
        vector<int> res;
        if (!root) return res;
        stack<TreeNode*> s;
        s.push(root);
        TreeNode *p = root;
        while (!s.empty()) {

```

```

        TreeNode *top = s.top();
        // If the current node top in stack doesn't have any child in tree,
        // or its left or right child has been visited,
        // push back the current element to res
        if ((!top->left && !top->right) || top->left == p || top->right == p)
        {
            res.push_back(top->val);
            s.pop();
            p = top;
        } else { // Otherwise, push its right and left child to stack
            if(top->right) s.push(top->right);
            if(top->left) s.push(top->left);
        }
    }
    return res;
}
};

```

7.2.4 Binary Tree Level Order Traversal (E)

Given a binary tree, return the level order traversal of its nodes' values. (ie, from left to right, level by level).

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

# recursion
class Solution(object):
    def levelOrder(self, root):
        """
        :type root: TreeNode
        :rtype: List[List[int]]
        """
        res = []
        self.level(root, 0, res)
        return res
    def level(self, node, idx, res):
        if not node: return
        if len(res) == idx:
            res.append(list([]))
        res[idx].append(node.val)
        if node.left:

```

```

        self.level(node.left, idx+1, res)
    if node.right:
        self.level(node.right, idx+1, res)

# iteration with queue
class Solution(object):
    def levelOrder(self, root):
        """
        :type root: TreeNode
        :rtype: List[List[int]]
        """
        if not root: return []
        q, res = [], []
        q.insert(0, root)
        while q:
            out = []
            n = len(q)
            for i in range(n):
                out.append(q[-1].val)
                if q[-1].left: q.insert(0, q[-1].left)
                if q[-1].right: q.insert(0, q[-1].right)
            q.pop()
            res.append(list(out))
        return res

```

```

class Solution {
public:
    vector<vector<int>> levelOrder(TreeNode* root) {
        vector<vector<int>> result;
        BFS(root, result, 0);
        return result;
    }

    void BFS(TreeNode *root, vector<vector<int>> &res, int depth) {
        if (root == NULL)
            return;

        if (res.size() == depth) // The level does not exist in output
            res.push_back(vector<int>()); // Create a new level

        res[depth].push_back(root->val); // Add the current value to its level

        BFS(root->left, res, depth+1); // Go to the next level
        BFS(root->right, res, depth+1);
    }
};

```

7.2.5 Binary Tree Level Order Traversal II (E)

Given a binary tree, return the bottom-up level order traversal of its nodes' values. (ie, from left to right, level by level from leaf to root).

```
# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def levelOrderBottom(self, root):
        """
        :type root: TreeNode
        :rtype: List[List[int]]
        """
        if not root: return []
        q, res = [], []
        q.insert(0, root)
        while q:
            out = []
            n = len(q)
            for i in range(n):
                out.append(q[-1].val)
                if q[-1].left: q.insert(0, q[-1].left)
                if q[-1].right: q.insert(0, q[-1].right)
            q.pop()
            res.insert(0, list(out))
        return res
```

```
class Solution {
public:
    vector<vector<int>> levelOrderBottom(TreeNode* root) {
        vector<vector<int>> result;
        BFS(root, result, 0);
        reverse(result.begin(), result.end());    // reverse to get the
            bottom-up level order result
        return result;
    }

    void BFS(TreeNode *root, vector<vector<int>> &res, int depth) {
        if (root == NULL)
            return;
    }
```

```

        if (res.size() == depth)           // The level does not exist in output
            res.push_back(vector<int>()); // Create a new level

        res[depth].push_back(root->val); // Add the current value to its level
        BFS(root->left, res, depth+1);   // Go to the next level
        BFS(root->right, res, depth+1);

    }
};

```

7.2.6 Binary Tree Zigzag Level Order Traversal (M)

Given a binary tree, return the zigzag level order traversal of its nodes' values. (ie, from left to right, then right to left for the next level and alternate between).

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def zigzagLevelOrder(self, root):
        """
        :type root: TreeNode
        :rtype: List[List[int]]
        """
        if not root: return []
        q, res = [], []
        q.append(root)
        level = 1
        while q:
            out = []
            n = len(q)
            for i in range(n):
                out.append(q[-1].val)
                if q[-1].left: q.insert(0, q[-1].left)
                if q[-1].right: q.insert(0, q[-1].right)
            q.pop()
            if level % 2 == 1:
                res.append(list(out))
            else:
                res.append(list(reversed(out)))
            level += 1
        return res

```

```

class Solution {
public:
    vector<vector<int>> zigzagLevelOrder(TreeNode* root) {
        vector<vector<int>> res;
        BFS(root, res, 0);
        return res;
    }

    void BFS(TreeNode *root, vector<vector<int>> &res, int depth) {
        if (root == NULL) return;

        if (res.size() == depth)
            res.push_back(vector<int>());

        if (depth % 2 == 0) {
            res[depth].push_back(root->val);
        } else {
            res[depth].insert(res[depth].begin(), root->val); // insert the
                                                                // current root->val to the beginning of vector
        }

        BFS(root->left, res, depth+1);
        BFS(root->right, res, depth+1);
    }
};

```

7.2.7 Binary Tree Vertical Order Traversal (M)

Given a binary tree, return the vertical order traversal of its nodes' values. (ie, from top to bottom, column by column). If two nodes are in the same row and column, the order should be from left to right.

```

def verticalOrder(root):
    order, m, res = 0, {}, []
    getVerticalOrder(root, order, m)
    for key, val in enumerate(sorted(m)):
        for i in m[val]:
            res.append(i)
    return res

def getVerticalOrder(node, order, m):
    if not node: return None
    if order in m:
        m[order].append(node.val)
    else:
        m[order] = [node.val]

```

```

    getVerticalOrder(node.left, order - 1, m)
    getVerticalOrder(node.right, order + 1, m)

```

```

// 1. Assign index to each tree node, assign 0 to root
// 2. For left node -1, for right node +1
// 3. Mapping index and tree val and save as map with order
// 4. Traversal by level order with queue
// 5. Push back result from map
class Solution {
public:
    vector<vector<int>> verticalOrder(TreeNode* root) {
        vector<vector<int>> res;
        if (!root) return res;
        map<int, vector<int>> m;
        queue<pair<int, TreeNode*>> q;
        q.push({0, root});
        while (!q.empty()) {
            auto a = q.front(); q.pop();
            m[a.first].push_back(a.second->val);
            if (a.second->left) q.push({a.first - 1, a.second->left});
            if (a.second->right) q.push({a.first + 1, a.second->right});
        }
        for (auto a : m) {
            res.push_back(a.second);
        }
        return res;
    }
};

```

7.2.8 Binary Tree Right Side View (M)

Given a binary tree, imagine yourself standing on the right side of it, return the values of the nodes you can see ordered from top to bottom.

For example: Given the following binary tree, [1, 2, 3, #, 5, #, 4], You should return [1, 3, 4].

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def rightSideView(self, root):

```

```

"""
:type root: TreeNode
:rtype: List[int]
"""
if not root: return []
q, res = [], []
q.append(root)
while q:
    res.append(q[-1].val)
    n = len(q)
    for i in range(n):
        if q[-1].right: q.insert(0, q[-1].right)
        if q[-1].left: q.insert(0, q[-1].left)
    q.pop()
return res

```

```

class Solution {
public:
    vector<int> rightSideView(TreeNode* root) {
        vector<int> res;
        rightSideView(root, res, 1);
        return res;
    }

    void rightSideView(TreeNode *p, vector<int> &res, int level) {
        if (p == NULL) return;
        // push back p->val only if it is the right most node in the current level
        if (res.size() < level) res.push_back(p->val);
        rightSideView(p->right, res, level+1);
        rightSideView(p->left, res, level+1);
    }
};

```

7.2.9 Populating Next Right Pointers in Each Node (M)

Given a binary tree

```

struct TreeLinkNode
TreeLinkNode *left;
TreeLinkNode *right;
TreeLinkNode *next;

```

Populate each next pointer to point to its next right node. If there is no next right node, the next pointer should be set to NULL. Initially, all next pointers are set to NULL.

Note:

You may only use constant extra space.

You may assume that it is a perfect binary tree (ie, all leaves are at the same level, and every parent has two children).

```
"""
# Definition for a Node.
class Node(object):
    def __init__(self, val, left, right, next):
        self.val = val
        self.left = left
        self.right = right
        self.next = next
"""
# recursion
class Solution(object):
    def connect(self, root):
        """
        :type root: Node
        :rtype: Node
        """
        if not root: return None
        if root.left:
            root.left.next = root.right
        if root.right:
            if root.next:
                root.right.next = root.next.left
            else:
                root.right.next = None
        self.connect(root.left)
        self.connect(root.right)
        return root
```

```
# iteration with queue
class Solution(object):
    def connect(self, root):
        """
        :type root: Node
        :rtype: Node
        """
        if not root: return None
        q = []
        q.append(root)
        while q:
            n = len(q)
            for i in range(n):
                if i < n - 1:
```

```

        q[-1].next = q[-2]
    else:
        q[-1].next = None
    if q[-1].left: q.insert(0, q[-1].left)
    if q[-1].right: q.insert(0, q[-1].right)
    q.pop()
    return root

# iteration with two pointer, constant space
class Solution(object):
    def connect(self, root):
        """
        :type root: Node
        :rtype: Node
        """
        if not root: return None
        start, cur = root, None
        while start.left:
            cur = start
            while cur:
                cur.left.next = cur.right
                if cur.next:
                    cur.right.next = cur.next.left
                cur = cur.next
            start = start.left
        return root

```

```

/**
 * Definition for binary tree with next pointer.
 * struct TreeLinkNode {
 *   int val;
 *   TreeLinkNode *left, *right, *next;
 *   TreeLinkNode(int x) : val(x), left(NULL), right(NULL), next(NULL) {}
 * };
 */
// 1. Recursion, more than constant space
class Solution {
public:
    void connect(TreeLinkNode *root) {
        if (!root) return;
        if (root->left) root->left->next = root->right;
        if (root->right) root->right->next = root->next? root->next->left : NULL;
        connect(root->left);
        connect(root->right);
    }
};

```

```

// 2. Non-recursion, more than constant space
class Solution {
public:
    void connect(TreeLinkNode *root) {
        if (!root) return;
        queue<TreeLinkNode*> q;
        q.push(root);
        q.push(NULL);
        while (true) {
            TreeLinkNode *cur = q.front();
            q.pop();
            if (cur) {
                cur->next = q.front();
                if (cur->left) q.push(cur->left);
                if (cur->right) q.push(cur->right);
            } else {
                if (q.size() == 0 || q.front() == NULL) return;
                q.push(NULL);
            }
        }
    }
};

// 3. Non-recursion, constant space
class Solution {
public:
    void connect(TreeLinkNode *root) {
        if (!root) return;
        while (root->left) {
            TreeLinkNode *p = root;
            while(p) { //level order traversal from left to right
                p->left->next = p->right;
                if (p->next) p->right->next = p->next->left;
                p = p->next;
            }
            root = root->left;
        }
    }
};

```

7.2.10 Populating Next Right Pointers in Each Node II (H)

Follow up for problem "Populating Next Right Pointers in Each Node". What if the given tree could be any binary tree? Would your previous solution still work?

Note: You may only use constant extra space.

```

"""
# Definition for a Node.
class Node(object):
    def __init__(self, val, left, right, next):
        self.val = val
        self.left = left
        self.right = right
        self.next = next
"""

```

```

# recursion
class Solution(object):
    def connect(self, root):
        """
        :type root: Node
        :rtype: Node
        """
        if not root: return None
        p = root.next
        while p:
            if p.left:
                p = p.left
                break
            if p.right:
                p = p.right
                break
            p = p.next
        if root.right:
            root.right.next = p
        if root.left:
            if root.right:
                root.left.next = root.right
            else:
                root.left.next = p
        self.connect(root.right)
        self.connect(root.left)
        return root

```

```

# iteration with queue
class Solution(object):
    def connect(self, root):
        """
        :type root: Node
        :rtype: Node
        """
        if not root: return None
        q = []

```

```

q.append(root)
while q:
    n = len(q)
    for i in range(n):
        if i < n - 1:
            q[-1].next = q[-2]
        else:
            q[-1].next = None
        if q[-1].left: q.insert(0, q[-1].left)
        if q[-1].right: q.insert(0, q[-1].right)
    q.pop()
return root

```

// 1. Recursion, more than constant space

```

class Solution {
public:
    void connect(TreeLinkNode *root) {
        if (!root) return;
        TreeLinkNode *p = root->next;
        while (p) {
            if (p->left) {
                p = p->left;
                break;
            }
            if (p->right) {
                p = p->right;
                break;
            }
            p = p->next;
        }
        if (root->right) root->right->next = p;
        if (root->left) root->left->next = root->right ? root->right : p;
        connect(root->right);
        connect(root->left);
    }
};

```

// 2. Non-recursion, more than constant space

```

class Solution {
public:
    void connect(TreeLinkNode *root) {
        if (!root) return;
        queue<TreeLinkNode*> q;
        q.push(root);
        q.push(NULL);
        while (true) {
            TreeLinkNode *cur = q.front();

```



```

        q.pop();
        if (cur) {
            cur->next = q.front();
            if (cur->left) q.push(cur->left);
            if (cur->right) q.push(cur->right);
        } else {
            if (q.size() == 0 || q.front() == NULL) return;
            q.push(NULL);
        }
    }
}
};

```

// 3. Non-recursion, constant space

```

class Solution {
public:
    void connect(TreeLinkNode *root) {
        if (!root) return;
        TreeLinkNode *leftMost = root;
        while (leftMost) {
            TreeLinkNode *p = leftMost;
            while (p && !p->left && !p->right) p = p->next;
            if (!p) return;
            leftMost = p->left ? p->left : p->right;
            TreeLinkNode *cur = leftMost;
            while (p) {
                if (cur == p->left) {
                    if (p->right) {
                        cur->next = p->right;
                        cur = cur->next;
                    }
                    p = p->next;
                }
                else if (cur == p->right) {
                    p = p->next;
                }
                else {
                    if (!p->left && !p->right) {
                        p = p->next;
                        continue;
                    }
                    cur->next = p->left ? p->left : p->right;
                    cur = cur->next;
                }
            }
        }
    }
};

```

7.3 Binary Tree Recursion

7.3.1 Same Tree (E)

Given two binary trees, write a function to check if they are equal or not.

Two binary trees are considered equal if they are structurally identical and the nodes have the same value.

```
# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def isSameTree(self, p, q):
        """
        :type p: TreeNode
        :type q: TreeNode
        :rtype: bool
        """
        if not p and not q: return True
        if not p or not q: return False
        if p.val != q.val: return False
        return self.isSameTree(p.left, q.left) and \
               self.isSameTree(p.right, q.right)
```

```
/**
 * Definition for a binary tree node.
 * struct TreeNode {
 *     int val;
 *     TreeNode *left;
 *     TreeNode *right;
 *     TreeNode(int x) : val(x), left(NULL), right(NULL) {}
 * };
 */
class Solution {
public:
    bool isSameTree(TreeNode* p, TreeNode* q) {
        if (p == NULL && q == NULL) return true;
        if (p == NULL || q == NULL) return false;
        return p->val == q->val &&
               isSameTree(p->left, q->left) &&
               isSameTree(p->right, q->right);
    }
};
```

```
    }  
};
```

7.3.2 Symmetric Tree (E)

Given a binary tree, check whether it is a mirror of itself (ie, symmetric around its center).

```
# Definition for a binary tree node.  
# class TreeNode(object):  
#     def __init__(self, x):  
#         self.val = x  
#         self.left = None  
#         self.right = None  
  
class Solution(object):  
    def isSymmetric(self, root):  
        """  
        :type root: TreeNode  
        :rtype: bool  
        """  
        if not root: return True  
        return self.compare(root.left, root.right)  
    def compare(self, left, right):  
        if not left and not right: return True  
        if not left or not right or left.val != right.val: return False  
        return self.compare(left.left, right.right) and \  
            self.compare(left.right, right.left)
```

```
class Solution {  
public:  
    bool isSymmetric(TreeNode* root) {  
        if (!root) return true;  
        return compare(root->left, root->right);  
    }  
  
    bool compare(TreeNode *p, TreeNode *q) {  
        if (!p && !q) return true;  
        if (!p || !q) return false;  
        if (p->val != q->val) return false;  
        return compare(p->left, q->right) && compare(p->right, q->left);  
    }  
};
```

7.3.3 Invert Binary Tree (E)

Invert a binary tree 4-2-7-1-3-6-9 to 4-7-2-9-6-3-1.

```
# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def invertTree(self, root):
        """
        :type root: TreeNode
        :rtype: TreeNode
        """
        if not root: return None
        t = root.left
        root.left = self.invertTree(root.right)
        root.right = self.invertTree(t)
        return root
```

```
class Solution {
public:
    TreeNode* invertTree(TreeNode* root) {
        if (root == NULL)
            return NULL;

        TreeNode *tmp = root->left;
        root->left = invertTree(root->right);
        root->right = invertTree(tmp);
        return root;
    }
};
```

7.3.4 Binary Tree Upside Down (M)

Given a binary tree where all the right nodes are either leaf nodes with a sibling (a left node that shares the same parent node) or empty, flip it upside down and turn it into a tree where the original right nodes turned into left leaf nodes. Return the new root.

For example: Given a binary tree 1,2,3,4,5, return the root of the binary tree [4,5,2,##,3,1].

```

class Solution {
public:
    TreeNode *upsideDownBinaryTree(TreeNode *root) {
        if (!root || !root->left) return root;
        TreeNode *l = root->left, *r = root->right;
        TreeNode *res = upsideDownBinaryTree(l);
        l->left = r;
        l->right = root;
        root->left = root->right = NULL;
        return res;
    }
};

```

7.3.5 Lowest Common Ancestor of a Binary Tree (M)

Given a binary tree, find the lowest common ancestor (LCA) of two given nodes in the tree.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def lowestCommonAncestor(self, root, p, q):
        """
        :type root: TreeNode
        :type p: TreeNode
        :type q: TreeNode
        :rtype: TreeNode
        """
        if not root or root == p or root == q:
            return root
        left = self.lowestCommonAncestor(root.left, p, q)
        right = self.lowestCommonAncestor(root.right, p, q)
        if left and right:
            return root
        if left: return left
        if right: return right

```

```

class Solution {
public:
    TreeNode* lowestCommonAncestor(TreeNode* root, TreeNode* p, TreeNode* q) {
        if (root == NULL || root == p || root == q)

```

```

        return root;

TreeNode *left = lowestCommonAncestor(root->left, p, q);
TreeNode *right = lowestCommonAncestor(root->right, p, q);

if (left == NULL) {
    return right;
} else {
    if (right == NULL) {
        return left;
    } else {
        return root;
    }
}
}
};

```

7.3.6 Binary Tree Longest Consecutive Sequence (M)

Given a binary tree, find the length of the longest consecutive sequence path.

The path refers to any sequence of nodes from some starting node to any node in the tree along the parent-child connections. The longest consecutive path need to be from parent to child (cannot be the reverse).

For example,

[1, *NULL*, 3, 2, 4, *NULL*, *NULL*, *NULL*, 5], Longest consecutive sequence path is 3-4-5, so return 3.

[2, *NULL*, 3, 2, *NULL*, 1, *NULL*], Longest consecutive sequence path is 2-3, not 3-2-1, so return 2.

```

class Solution {
public:
    int longestConsecutive(TreeNode* root) {
        if (!root) return 0;
        int res = 0;
        dfs(root, 1, res);
        return res;
    }
    void dfs(TreeNode *root, int len, int &res) {
        res = max(res, len);
        if (root->left) {
            if (root->left->val == root->val + 1)
                dfs(root->left, len + 1, res);
            else

```

```

        dfs(root->left, 1, res);
    }
    if (root->right) {
        if (root->right->val == root->val + 1)
            dfs(root->right, len + 1, res);
        else
            dfs(root->right, 1, res);
    }
}
};

```

7.3.7 Count Unival Subtrees (M)

Given a binary tree, count the number of uni-value subtrees. A Uni-value subtree means all nodes of the subtree have the same value.

For example: Given binary tree, [5,1,5,5,5,#,5], return 4.

```

class Solution {
public:
    int countUnivalSubtrees(TreeNode* root) {
        if (!root) return res;
        if (isUnival(root, root->val)) ++res;
        countUnivalSubtrees(root->left);
        countUnivalSubtrees(root->right);
        return res;
    }
private:
    int res = 0;
    bool isUnival(TreeNode *root, int val) {
        if (!root) return true;
        return root->val == val && isUnival(root->left, val) &&
            isUnival(root->right, val);
    }
};

```

7.3.8 Find Leaves of Binary Tree (M)

Given a binary tree, find all leaves and then remove those leaves. Then repeat the previous steps until the tree is empty.

Example:

Given binary tree [1, 2, 3, 4, 5], Returns [4, 5, 3], [2], [1].

```

class Solution {
public:
    vector<vector<int>> findLeaves(TreeNode* root) {
        vector<vector<int>> res;
        helper(root, res);
        return res;
    }

    int helper(TreeNode *root, vector<vector<int>> &res) {
        if (!root) return -1;
        int depth = 1 + max(helper(root->left, res), helper(root->right, res));

        if (depth >= res.size()) {
            // assign new level
            // or we can use: res.push_back(vector<int>())
            res.resize(depth + 1);
        }

        res[depth].push_back(root->val);
        return depth;
    }
};

```

7.3.9 Flatten Binary Tree to Linked List (M)

Given a binary tree, flatten it to a linked list in-place (Inorder traversal).

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def flatten(self, root):
        """
        :type root: TreeNode
        :rtype: None Do not return anything, modify root in-place instead.
        """
        if not root: return
        if root.left: self.flatten(root.left)
        if root.right: self.flatten(root.right)
        t = root.right
        root.right = root.left

```



```

        root->left = None
        while root->right: root = root->right
        root->right = t
    }
};

// 1. Recursion
class Solution {
public:
    void flatten(TreeNode *root) {
        if (!root) return;
        if (root->left) flatten(root->left);
        if (root->right) flatten(root->right);
        TreeNode *tmp = root->right;
        root->right = root->left;
        root->left = NULL;
        while (root->right) root = root->right;
        root->right = tmp;
    }
};

// 2. Non-recursion
class Solution {
public:
    void flatten(TreeNode *root) {
        TreeNode *cur = root;
        while (cur) {
            if (cur->left) {
                TreeNode *p = cur->left;
                while (p->right) p = p->right;
                p->right = cur->right;
                cur->right = cur->left;
                cur->left = NULL;
            }
            cur = cur->right;
        }
    }
};

// 3. Use stack
class Solution {
public:
    void flatten(TreeNode* root) {
        if (!root) return;
        stack<TreeNode*> s;
        s.push(root);
        while (!s.empty()) {
            TreeNode *t = s.top(); s.pop();
            if (t->left) {

```

```

        TreeNode *r = t->left;
        while (r->right) r = r->right;
        r->right = t->right;
        t->right = t->left;
        t->left = NULL;
    }
    if (t->right) s.push(t->right);
}
};

```

7.3.10 Balanced Binary Tree (E)

Given a binary tree, determine if it is height-balanced.

For this problem, a height-balanced binary tree is defined as a binary tree in which the depth of the two subtrees of every node never differ by more than 1.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def isBalanced(self, root):
        """
        :type root: TreeNode
        :rtype: bool
        """
        if not root: return True
        return abs(self.depth(root.left) - self.depth(root.right)) <= 1 and \
            self.isBalanced(root.left) and self.isBalanced(root.right)
    def depth(self, node):
        if not node: return 0
        return 1 + max(self.depth(node.left), self.depth(node.right))

```

```

class Solution {
public:
    bool isBalanced(TreeNode* root) {
        if (root == NULL)
            return true;

        return isBalanced(root->left) && isBalanced(root->right) &&

```

```

        abs(height(root->left) - height(root->right)) <= 1;
    }

    int height(TreeNode *node) {
        if (node != NULL)
            return 1 + max(height(node->left), height(node->right));
        else
            return 0;
    }
};

```

7.3.11 Check Completeness of a Binary Tree (M)

Given a binary tree, determine if it is a complete binary tree.

Definition of a complete binary tree from Wikipedia: In a complete binary tree every level, except possibly the last, is completely filled, and all nodes in the last level are as far left as possible. It can have between 1 and 2^h nodes inclusive at the last level h .

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def isCompleteTree(self, root):
        """
        :type root: TreeNode
        :rtype: bool
        """
        nodes = [(root, 1)]
        i = 0
        while i < len(nodes):
            node, v = nodes[i]
            i += 1
            if node:
                nodes.append((node.left, 2*v))
                nodes.append((node.right, 2*v+1))

        return nodes[-1][1] == len(nodes)

```

7.3.12 Count Complete Tree Nodes (M)

Given a complete binary tree, count the number of nodes.

In a complete binary tree every level, except possibly the last, is completely filled, and all nodes in the last level are as far left as possible. It can have between 2^{h-1} and 2^h nodes inclusive at the last level h .

A perfect binary tree is a complete tree, but a complete tree is not necessarily a perfect tree.

Notes:

Full Binary Tree: A Binary Tree is full if every node has 0 or 2 children.

[1, 2, 3, 4, 5, *Null*, *Null*, 6, 7]

Complete Binary Tree: A Binary Tree is complete Binary Tree if all levels are completely filled except possibly the last level and the last level has all keys as left as possible.

[1, 2, 3, 4, 5, 6, 7, 8, 9, 10]

Perfect Binary Tree: A Binary tree is Perfect Binary Tree in which all internal nodes have two children and all leaves are at same level.

[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]

```
# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def countNodes(self, root):
        """
        :type root: TreeNode
        :rtype: int
        """
        h_left, h_right = 0, 0
        p_left, p_right = root, root
        while p_left:
            h_left += 1
            p_left = p_left.left
        while p_right:
            h_right += 1
            p_right = p_right.right
        if h_left == h_right:
            return 2 ** h_left - 1
        return 1 + self.countNodes(root.left) + self.countNodes(root.right)
```

```

class Solution {
public:
    int countNodes(TreeNode* root) {
        int hLeft = 0, hRight = 0; // height of the left and right subtree
        TreeNode *pLeft = root, *pRight = root;
        while (pLeft) {
            ++hLeft;
            pLeft = pLeft->left;
        }
        while (pRight) {
            ++hRight;
            pRight = pRight->right;
        }
        if (hLeft == hRight) return pow(2, hLeft) - 1; // perfect binary tree
        return countNodes(root->left) + countNodes(root->right) + 1;
    }
};

```

7.3.13 Minimum Depth of Binary Tree (E)

Given a binary tree, find its minimum depth.

The minimum depth is the number of nodes along the shortest path from the root node down to the nearest leaf node.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

# Recursion
class Solution(object):
    def minDepth(self, root):
        """
        :type root: TreeNode
        :rtype: int
        """
        if not root: return 0
        if not root.left: return 1 + self.minDepth(root.right)
        if not root.right: return 1 + self.minDepth(root.left)
        return 1 + min(self.minDepth(root.left), self.minDepth(root.right))

# Iteration

```

```

class Solution(object):
    def minDepth(self, root):
        """
        :type root: TreeNode
        :rtype: int
        """
        if not root: return 0
        res = 0
        q = [root]
        while q:
            res += 1
            n = len(q)
            for i in range(n):
                if not q[-1].left and not q[-1].right:
                    return res
                if q[-1].left: q.insert(0, q[-1].left)
                if q[-1].right: q.insert(0, q[-1].right)
            q.pop()

```

```

class Solution {
public:
    int minDepth(TreeNode* root) {
        if (!root)
            return 0;
        if (!root->left)
            return 1 + minDepth(root->right);
        if (!root->right)
            return 1 + minDepth(root->left);

        return 1 + min(minDepth(root->left), minDepth(root->right));
    }
};

```

7.3.14 Maximum Depth of Binary Tree (E)

Given a binary tree, find its maximum depth.

The maximum depth is the number of nodes along the longest path from the root node down to the farthest leaf node.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None

```

```

#         self.right = None

# Recursion
class Solution(object):
    def maxDepth(self, root):
        """
        :type root: TreeNode
        :rtype: int
        """
        if not root: return 0
        return 1 + max(self.maxDepth(root.left), self.maxDepth(root.right))

# Iteration
class Solution(object):
    def maxDepth(self, root):
        """
        :type root: TreeNode
        :rtype: int
        """
        if not root: return 0
        res = 0
        q = [root]
        while q:
            res += 1
            n = len(q)
            for i in range(n):
                if q[-1].left: q.insert(0, q[-1].left)
                if q[-1].right: q.insert(0, q[-1].right)
            q.pop()
        return res

```

```

class Solution {
public:
    int maxDepth(TreeNode* root) {
        if (root != NULL)
            return 1 + max(maxDepth(root->left), maxDepth(root->right));
        else
            return 0;
    }
};

```

7.3.15 Maximum Depth of N-ary Tree (E)

Given a n-ary tree, find its maximum depth.

The maximum depth is the number of nodes along the longest path from the root node down

to the farthest leaf node.

```
"""
# Definition for a Node.
class Node(object):
    def __init__(self, val, children):
        self.val = val
        self.children = children
"""
class Solution(object):
    def maxDepth(self, root):
        """
        :type root: Node
        :rtype: int
        """
        if not root: return 0
        res = 1
        for c in root.children:
            res = max(res, 1 + self.maxDepth(c))
        return res
```

7.3.16 Maximum Width of Binary Tree (M)

Given a binary tree, write a function to get the maximum width of the given tree. The width of a tree is the maximum width among all levels. The binary tree has the same structure as a full binary tree, but some nodes are null.

The width of one level is defined as the length between the end-nodes (the leftmost and right most non-null nodes in the level, where the null nodes between the end-nodes are also counted into the length calculation).

```
# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

# The main idea in this question is to give each node a position value.
# If we go down the left neighbor, then position -> position * 2; and if we go
# down the right neighbor, then position -> position * 2 + 1.
# This makes it so that when we look at the position values L and R of two nodes
# with the same depth, the width will be R - L + 1.

class Solution(object):
```



```

def widthOfBinaryTree(self, root):
    """
    :type root: TreeNode
    :rtype: int
    """
    self.res = 0
    start = []
    depth, idx = 0, 1
    self.dfs(root, depth, idx, start)
    return self.res
def dfs(self, node, depth, idx, start):
    if not node: return
    if depth >= len(start):
        start.append(idx)
    self.res = max(self.res, idx - start[depth] + 1)
    self.dfs(node.left, depth+1, idx*2, start)
    self.dfs(node.right, depth+1, idx*2+1, start)

```

7.3.17 Diameter of Binary Tree (E)

Given a binary tree, you need to compute the length of the diameter of the tree. The diameter of a binary tree is the length of the longest path between any two nodes in a tree. This path may or may not pass through the root.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def diameterOfBinaryTree(self, root):
        """
        :type root: TreeNode
        :rtype: int
        """
        self.res = 0
        self.maxDepth(root)
        return self.res
    # maxDepth returns the max depth of current node
    def maxDepth(self, node):
        if not node: return 0
        # note left or right here is the max depth of each node
        left = self.maxDepth(node.left)
        right = self.maxDepth(node.right)

```

```

# so res is the max one from either old res or left+right
self.res = max(self.res, left + right)
return 1 + max(left, right)

```

7.3.18 Print Binary Tree (M)

Print a binary tree in an $m \times n$ 2D string array following these rules:

1. The row number m should be equal to the height of the given binary tree.
2. The column number n should always be an odd number.
3. The root node's value (in string format) should be put in the exactly middle of the first row it can be put. The column and the row where the root node belongs will separate the rest space into two parts (left-bottom part and right-bottom part). You should print the left subtree in the left-bottom part and print the right subtree in the right-bottom part. The left-bottom part and the right-bottom part should have the same size. Even if one subtree is none while the other is not, you don't need to print anything for the none subtree but still need to leave the space as large as that for the other subtree. However, if two subtrees are none, then you don't need to leave space for both of them.
4. Each unused space should contain an empty string `""`.
5. Print the subtrees following the same rules.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def printTree(self, root):
        """
        :type root: TreeNode
        :rtype: List[List[str]]
        """
        height = self.getHeight(root)
        width = pow(2, height) - 1
        res = [ ['' for j in range(width)] for i in range(height) ]
        left, right = 0, width - 1
        level = 0
        self.helper(root, left, right, level, res)
        return res

    # insert the value to the center of corresponding row
    def helper(self, node, left, right, level, res):
        if not node: return
        res[level][(left + right) / 2] = str(node.val)

```

```

        # update the left or right index for subtree
        self.helper(node.left, left, (left + right) / 2, level + 1, res)
        self.helper(node.right, (left + right) / 2 + 1, right, level + 1, res)
    # compute the height
    def getHeight(self, node):
        if not node: return 0
        return 1 + max(self.getHeight(node.left), self.getHeight(node.right))

```

7.3.19 Maximum Binary Tree (M)

Given an integer array with no duplicates. A maximum tree building on this array is defined as follow:

- 1.The root is the maximum number in the array.
- 2.The left subtree is the maximum tree constructed from left part subarray divided by the maximum number.
- 3.The right subtree is the maximum tree constructed from right part subarray divided by the maximum number.

Construct the maximum tree by the given array and output the root node of this tree.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def constructMaximumBinaryTree(self, nums):
        """
        :type nums: List[int]
        :rtype: TreeNode
        """
        if not nums: return None
        start, end = 0, len(nums)-1
        return self.helper(nums, start, end)
    def helper(self, nums, start, end):
        if start > end: return None
        mid = start
        for i in range(start+1, end+1):
            if nums[i] > nums[mid]:
                mid = i
        node = TreeNode(nums[mid])
        node.left = self.helper(nums, start, mid-1)

```

```
node.right = self.helper(nums, mid+1, end)
return node
```

7.3.20 Maximum Binary Tree II (M)

We are given the root node of a maximum tree: a tree where every node has a value greater than any other value in its subtree.

Just as in the previous problem, the given tree was constructed from an list A (root = Construct(A)) recursively with the following Construct(A) routine:

If A is empty, return null.

Otherwise, let A[i] be the largest element of A. Create a root node with value A[i].

The left child of root will be Construct([A[0], A[1], ..., A[i-1]])

The right child of root will be Construct([A[i+1], A[i+2], ..., A[A.length - 1]])

Return root.

Note that we were not given A directly, only a root node root = Construct(A).

Suppose B is a copy of A with the value val appended to it. It is guaranteed that B has unique values.

Return Construct(B).

```
# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

# The appended value can only be the right child of it's parent, and it could
# only have left children (Since it's the right-most element in the
# construction array).
class Solution(object):
    def insertIntoMaxTree(self, root, val):
        """
        :type root: TreeNode
        :type val: int
        :rtype: TreeNode
        """
        if not root: return TreeNode(val)
        if val > root.val:
            node = TreeNode(val)
            node.left = root
```

```

        return node
    root.right = self.insertIntoMaxTree(root.right, val)
    return root

```

7.3.21 Binary Tree Paths (E)

Given a binary tree, return all root-to-leaf paths.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def binaryTreePaths(self, root):
        """
        :type root: TreeNode
        :rtype: List[str]
        """
        if not root: return []
        path = ''
        res = []
        self.DFS(root, path, res)
        return res
    def DFS(self, node, path, res):
        path += str(node.val)
        if not node.left and not node.right:
            res.append(path)
            return
        if node.left: self.DFS(node.left, path+'->', res)
        if node.right: self.DFS(node.right, path+'->', res)

```

```

class Solution {
public:
    vector<string> binaryTreePaths(TreeNode *root) {
        vector<string> res;
        if (!root) return res;
        getTreePaths(root, res, to_string(root->val));
        return res;
    }

    void getTreePaths(TreeNode *root, vector<string> &res, string s) {
        if (!root->left && !root->right) { // push back to res until the end of

```

```

        the leaf
        res.push_back(s);
        return;
    }

    if (root->left)
        getTreePaths(root->left, res, s + ">" + to_string(root->left->val));
    if (root->right)
        getTreePaths(root->right, res, s + ">" +
            to_string(root->right->val));
}

};

```

7.3.22 Path Sum (E)

Given a binary tree and a sum, determine if the tree has a root-to-leaf path such that adding up all the values along the path equals the given sum.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def hasPathSum(self, root, sum):
        """
        :type root: TreeNode
        :type sum: int
        :rtype: bool
        """
        if not root: return False
        if not root.left and not root.right and root.val == sum:
            return True
        return self.hasPathSum(root.left, sum - root.val) or \
            self.hasPathSum(root.right, sum - root.val)

```

```

class Solution {
public:
    bool hasPathSum(TreeNode *root, int sum){
        if (!root) return false;

        if (!root->left && !root->right)

```

```

        return root->val == sum;

    return hasPathSum(root->left, sum-(root->val)) || hasPathSum(root->right,
        sum-(root->val));
}
};

```

7.3.23 Path Sum II (M)

Given a binary tree and a sum, find all root-to-leaf paths where each path's sum equals the given sum.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def pathSum(self, root, sum):
        """
        :type root: TreeNode
        :type sum: int
        :rtype: List[List[int]]
        """
        path, res = [], []
        self.DFS(root, sum, path, res)
        return res
    def DFS(self, node, sum, path, res):
        if not node: return
        path.append(node.val)
        if not node.left and not node.right and node.val == sum:
            res.append(list(path))
        self.DFS(node.left, sum - node.val, path, res)
        self.DFS(node.right, sum - node.val, path, res)
        path.pop()

```

```

class Solution {
public:
    vector<vector<int>> pathSum(TreeNode *root, int sum) {
        vector<vector<int>> res;
        vector<int> path;
        getPathSum(root, sum, res, path);
        return res;
    }

```

```

    }

    void getPathSum(TreeNode *root, int sum, vector<vector<int>> &res,
        vector<int> &path) {
        if (!root) return;

        path.push_back(root->val);           // add the current node to the path
        if (!root->left && !root->right) {
            if (root->val == sum)
                res.push_back(path);         // find a correct path's sum
        }

        getPathSum(root->left, sum-(root->val), res, path);
        getPathSum(root->right, sum-(root->val), res, path);

        path.pop_back();                     // delete the current node if no
                                            // correct path's sum has been found
    }
};

```

7.3.24 Path Sum III (E)

You are given a binary tree in which each node contains an integer value.

Find the number of paths that sum to a given value.

The path does not need to start or end at the root or a leaf, but it must go downwards (traveling only from parent nodes to child nodes).

The tree has no more than 1,000 nodes and the values are in the range -1,000,000 to 1,000,000.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def pathSum(self, root, sum):
        """
        :type root: TreeNode
        :type sum: int
        :rtype: int
        """

```



```

        out = []
        self.res = 0
        self.DFS(root, sum, 0, out)
        return self.res
def DFS(self, node, sum, subsum, out):
    if not node: return
    subsum += node.val
    out.append(node)
    if subsum == sum: self.res += 1
    t = subsum
    for i in range(len(out)-1):
        t -= out[i].val
        if t == sum: self.res += 1
    self.DFS(node.left, sum, subsum, out)
    self.DFS(node.right, sum, subsum, out)
    out.pop()

```

7.3.25 Sum Root to Leaf Numbers (M)

Given a binary tree containing digits from 0-9 only, each root-to-leaf path could represent a number. An example is the root-to-leaf path 1 → 2 → 3 which represents the number 123. Find the total sum of all root-to-leaf numbers.

For example:

The root-to-leaf path 1 → 2 represents the number 12. The root-to-leaf path 1 → 3 represents the number 13. Return the sum = 12 + 13 = 25.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def sumNumbers(self, root):
        """
        :type root: TreeNode
        :rtype: int
        """
        return self.DFS(root, 0)
    def DFS(self, node, sum):
        if not node: return 0
        sum = sum * 10 + node.val
        if not node.left and not node.right:

```

```

        return sum
    return self.DFS(node.left, sum) + self.DFS(node.right, sum)

```

```

class Solution {
public:
    int sumNumbers(TreeNode *root) {
        return sumTreePaths(root, 0);
    }

    int sumTreePaths(TreeNode *root, int sum) {
        if (!root) return 0;

        sum = 10 * sum + root->val;           // e.g. 1->2: 1 * 10 + 2 = 12

        if (!root->left && !root->right) {
            return sum;
        } else {
            return sumTreePaths(root->left, sum) + sumTreePaths(root->right, sum);
        }
    }
};

```

7.3.26 Binary Tree Maximum Path Sum (H)

Given a binary tree, find the maximum path sum. For this problem, a path is defined as any sequence of nodes from some starting node to any node in the tree along the parent-child connections. The path does not need to go through the root.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def maxPathSum(self, root):
        """
        :type root: TreeNode
        :rtype: int
        """
        self.res = float('-inf')
        self.maxpath(root)
        return self.res
# maxpath to the current node, either left or right tree plus node

```

```

def maxpath(self, node):
    if not node: return 0
    left = max(self.maxpath(node.left), 0)
    right = max(self.maxpath(node.right), 0)
    self.res = max(self.res, left + right + node.val)
    return max(left, right) + node.val

```

```

class Solution {
public:
    int maxPathSum(TreeNode* root) {
        int sum = INT_MIN;
        maxSum(root, sum);
        return sum;
    }

    int maxSum(TreeNode *root, int &sum) {
        if (!root) return 0;

        int left = max(0, maxSum(root->left, sum));
        int right = max(0, maxSum(root->right, sum));
        sum = max(sum, left + right + root->val); // total sum = root + left
                                                subtree + right subtree
        return max(left, right) + root->val;      // subtree sum = root +
                                                max(left subtree, right subtree)
    }
};

```

7.3.27 Binary Tree Path Sum of Two Nodes (Philips on-sight 2016.09)

Find distance between two nodes in a binary tree. Distance between two nodes is defined as the number of edges in shortest path from one node to other.

```

class Node:

    # Constructor to create a new node
    def __init__(self, data):
        self.data = data
        self.left = None
        self.right = None

    def __repr__(self):
        return str(self.data)

def findLevel(root, node, level):
    if not root:

```

```

        return None

    if root.data == node:
        return level + 1

    left = findLevel(root.left, node, level + 1)
    right = findLevel(root.right, node, level + 1)

    if not left and not right:
        return None
    elif left:
        return left
    else:
        return right

# Function to find lowest common ancestor of given nodes n1 and n2 where
# both n1 and n2 are present in the binary tree.
def find_lca_node(root, n1, n2):
    if not root or n1 == root.data or root.data == n2:
        return root

    lca_left = find_lca_node(root.left, n1, n2)
    lca_right = find_lca_node(root.right, n1, n2)

    if lca_left and lca_right:
        return root

    return lca_right if lca_right else lca_left

# Function to find distance between two nodes in a binary tree
def findDistance(root, n1, n2):
    level_n1 = findLevel(root, n1, 0)
    if not level_n1:
        print("Node", n1, "does not exists in the binary tree")
        return

    level_n2 = findLevel(root, n2, 0)
    if not level_n2:
        print("Node", n2, "does not exists in the binary tree")
        return

    lca = find_lca_node(root, n1, n2)
    level_lca = findLevel(root, lca.data, 0)

    print("The distance between node", n1, "and node", n2, "is", \
          level_n1 + level_n2 - 2 * level_lca)

```

```

if __name__ == '__main__':

    root = Node(1)
    root.left = Node(2)
    root.right = Node(3)

    root.left.right = Node(4)
    root.right.left = Node(5)
    root.right.right = Node(6)

    root.right.left.left = Node(7)
    root.right.left.right = Node(8)

    findDistance(root, 7, 6)
    findDistance(root, 5, 9)

```

7.4 Binary Search Tree

7.4.1 Lowest Common Ancestor of a Binary Search Tree (E)

Given a binary search tree (BST), find the lowest common ancestor (LCA) of two given nodes in the BST.

According to the definition of LCA on Wikipedia: “The lowest common ancestor is defined between two nodes v and w as the lowest node in T that has both v and w as descendants (where we allow a node to be a descendant of itself).”

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def lowestCommonAncestor(self, root, p, q):
        """
        :type root: TreeNode
        :type p: TreeNode
        :type q: TreeNode
        :rtype: TreeNode
        """
        if not root or root == p or root == q:
            return root
        if p.val < root.val and q.val < root.val:

```

```

        return self.lowestCommonAncestor(root.left, p, q)
    elif p.val > root.val and q.val > root.val:
        return self.lowestCommonAncestor(root.right, p, q)
    else:
        return root

```

```

class Solution {
public:
    TreeNode* lowestCommonAncestor(TreeNode* root, TreeNode* p, TreeNode* q) {
        if (p->val < root->val && q->val < root->val) {
            return lowestCommonAncestor(root->left, p, q);
        } else if (p->val > root->val && q->val > root->val) {
            return lowestCommonAncestor(root->right, p, q);
        } else {
            return root;
        }
    }
};

```

7.4.2 Validate Binary Search Tree (M)

Given a binary tree, determine if it is a valid binary search tree (BST).

Assume a BST is defined as follows:

The left subtree of a node contains only nodes with keys less than the node's key.

The right subtree of a node contains only nodes with keys greater than the node's key.

Both the left and right subtrees must also be binary search trees.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

# Recursion
class Solution(object):
    def isValidBST(self, root):
        """
        :type root: TreeNode
        :rtype: bool
        """
        minval = float('-inf')
        maxval = float('inf')
        return self.helper(root, minval, maxval)

```

```

def helper(self, node, minval, maxval):
    if not node: return True
    if node.val <= minval or node.val >= maxval:
        return False
    return self.helper(node.left, minval, node.val) and \
           self.helper(node.right, node.val, maxval)

# Iteration with inorder traversal
class Solution(object):
    def isValidBST(self, root):
        """
        :type root: TreeNode
        :rtype: bool
        """
        s = []
        p = root
        val = float('-inf')
        while s or p:
            if p:
                s.append(p)
                p = p.left
            else:
                if s[-1].val <= val: return False
                val = s[-1].val
                p = s[-1].right
                s.pop()
        return True

```

```

// 1. Recursion without inorder traversal
class Solution {
public:
    bool isValidBST(TreeNode *root) {
        return isValidBST(root, LONG_MIN, LONG_MAX);
    }
    bool isValidBST(TreeNode *root, long mn, long mx) {
        if (!root) return true;
        if (root->val <= mn || root->val >= mx) return false;
        return isValidBST(root->left, mn, root->val) && isValidBST(root->right,
            root->val, mx);
    }
};

```

```

// 2. Recursion with inorder traversal
class Solution {
public:
    bool isValidBST(TreeNode *root) {
        if (!root) return true;

```

```

        vector<int> vals;
        inorder(root, vals);
        for (int i = 0; i < vals.size() - 1; ++i) {
            if (vals[i] >= vals[i + 1]) return false;
        }
        return true;
    }
    void inorder(TreeNode *root, vector<int> &vals) {
        if (!root) return;
        inorder(root->left, vals);
        vals.push_back(root->val);
        inorder(root->right, vals);
    }
};

```

7.4.3 Trim a Binary Search Tree (M)

Given a binary search tree and the lowest and highest boundaries as L and R, trim the tree so that all its elements lies in [L, R] ($R \neq L$). You might need to change the root of the tree, so the result should return the new root of the trimmed binary search tree.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def trimBST(self, root, L, R):
        """
        :type root: TreeNode
        :type L: int
        :type R: int
        :rtype: TreeNode
        """
        if not root: return root
        if root.val > R:
            return self.trimBST(root.left, L, R)
        if root.val < L:
            return self.trimBST(root.right, L, R)
        root.left = self.trimBST(root.left, L, R)
        root.right = self.trimBST(root.right, L, R)
        return root

```

7.4.4 Binary Search Tree Iterator (M)

Implement an iterator over a binary search tree (BST). Your iterator will be initialized with the root node of a BST. Calling `next()` will return the next smallest number in the BST.

Note: `next()` and `hasNext()` should run in average $O(1)$ time and uses $O(h)$ memory, where h is the height of the tree.

```
# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class BSTIterator(object):

    def __init__(self, root):
        """
        :type root: TreeNode
        """
        self.stack = []
        while root:
            self.stack.append(root)
            root = root.left

    def next(self):
        """
        @return the next smallest number
        :rtype: int
        """
        node = self.stack.pop()
        r = node.right
        while r:
            self.stack.append(r)
            r = r.left
        return node.val

    def hasNext(self):
        """
        @return whether we have a next smallest number
        :rtype: bool
        """
        return len(self.stack) != 0

# Your BSTIterator object will be instantiated and called as such:
```

```

# obj = BSTIterator(root)
# param_1 = obj.next()
# param_2 = obj.hasNext()

```

```

/**
 * Definition for binary tree
 * struct TreeNode {
 *     int val;
 *     TreeNode *left;
 *     TreeNode *right;
 *     TreeNode(int x) : val(x), left(NULL), right(NULL) {}
 * };
 */
class BSTIterator {
public:
    BSTIterator(TreeNode *root) {
        pushLeft(root);
    }

    void pushLeft(TreeNode *root) {
        TreeNode *p = root;
        while (p) {
            s.push(p);
            p = p->left;
        }
    }

    /** @return whether we have a next smallest number */
    bool hasNext() {
        return !s.empty();
    }

    /** @return the next smallest number */
    int next() {
        TreeNode *p = s.top();
        s.pop();
        if (p->right)
            pushLeft(p->right);
        return p->val;
    }

private:
    stack<TreeNode*> s;
};

/**
 * Your BSTIterator will be called like this:

```

```
* BSTIterator i = BSTIterator(root);
* while (i.hasNext()) cout << i.next();
*/
```

7.4.5 Recover Binary Search Tree (H)

Two elements of a binary search tree (BST) are swapped by mistake. Recover the tree without changing its structure.

Note: A solution using $O(n)$ space is pretty straight forward. Could you devise a constant space solution?

```
// 1. O(n) space complexity
class Solution {
public:
    void recoverTree(TreeNode *root) {
        vector<TreeNode*> list;
        vector<int> vals;
        inorder(root, list, vals);
        sort(vals.begin(), vals.end());
        for (int i = 0; i < list.size(); ++i) {
            list[i]->val = vals[i];
        }
    }
    void inorder(TreeNode *root, vector<TreeNode*> &list, vector<int> &vals) {
        if (!root) return;
        inorder(root->left, list, vals);
        list.push_back(root);
        vals.push_back(root->val);
        inorder(root->right, list, vals);
    }
};
```

```
// 2. O(1) space complexity
class Solution {
public:
    void recoverTree(TreeNode *root) {
        TreeNode *first = NULL, *second = NULL, *parent = NULL;
        TreeNode *cur, *pre;
        cur = root;
        while (cur) {
            if (!cur->left) {
                if (parent && parent->val > cur->val) {
                    if (!first) first = parent;
                    second = cur;
                }
                parent = cur;
                cur = cur->right;
            } else {
                pre = cur->left;
                cur->left = NULL;
                cur = pre;
            }
        }
        if (first && second) {
            swap(first->val, second->val);
        }
    }
};
```

```

    }
    parent = cur;
    cur = cur->right;
} else {
    pre = cur->left;
    while (pre->right && pre->right != cur) pre = pre->right;
    if (!pre->right) {
        pre->right = cur;
        cur = cur->left;
    } else {
        pre->right = NULL;
        if (parent->val > cur->val) {
            if (!first) first = parent;
            second = cur;
        }
        parent = cur;
        cur = cur->right;
    }
}
}
if (first && second) swap(first->val, second->val);
}
};

```

7.4.6 Kth Smallest Element in a BST (M)

Given a binary search tree, write a function `kthSmallest` to find the `k`th smallest element in it.

Note: You may assume `k` is always valid, $1 \leq k \leq \text{BST's total elements}$.

Follow up: What if the BST is modified (insert/delete operations) often and you need to find the `k`th smallest frequently? How would you optimize the `kthSmallest` routine?

Hint:

Try to utilize the property of a BST.

What if you could modify the BST node's structure?

The optimal runtime complexity is $O(\text{height of BST})$.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

```

Time: $O(H+k)$ Balanced tree: $O(\log N+k)$ Completely unbalanced tree: $O(N+k)$
 # Space: $O(H+k)$ Worst case: $O(N+k)$ Average case: $O(\log N+k)$

```
class Solution(object):
    def kthSmallest(self, root, k):
        """
        :type root: TreeNode
        :type k: int
        :rtype: int
        """
        s = []
        p = root
        cnt = 0
        while s or p:
            if p:
                s.append(p)
                p = p.left
            else:
                p = s[-1].right
                cnt += 1
                if cnt == k:
                    return s[-1].val
                s.pop()
```

```
class Solution {
public:
    int kthSmallest(TreeNode* root, int k) {
        int count = CountNodes(root->left);
        if (k <= count)
            return kthSmallest(root->left, k);
        else if (k > count + 1)
            return kthSmallest(root->right, k-1-count);
        return root->val;
    }

    int CountNodes(TreeNode *node) {
        if (!node) return 0;
        return 1 + CountNodes(node->left) + CountNodes(node->right);
    }
};
```

// Inorder traversal of BST provides a sorted array of the BST

```
class Solution {
public:
    int kthSmallest(TreeNode* root, int k) {
        return kthSmallestDFS(root, k);
    }
    int kthSmallestDFS(TreeNode* root, int &k) {
```

```

        if (!root) return -1;
        int val = kthSmallestDFS(root->left, k);
        if (k == 0) return val;
        --k;
        if (k == 0) return root->val;
        return kthSmallestDFS(root->right, k);
    }
};

```

7.4.7 Verify Preorder Sequence in Binary Search Tree (M)

Given an array of numbers, verify whether it is the correct preorder traversal sequence of a binary search tree.

You may assume each number in the sequence is unique.

Follow up: Could you do it using only constant space complexity?

```

// e.g. [4, 2, 1, 3, 6, 5, 7]
class Solution {
public:
    bool verifyPreorder(vector<int>& preorder) {
        return helper(preorder, 0, preorder.size() - 1, INT_MIN, INT_MAX);
    }
    bool helper(vector<int> &preorder, int start, int end, int lower, int upper) {
        if (start > end) return true;
        int val = preorder[start], i = 0; // save root value to val
        if (val <= lower || val >= upper) return false;
        for (i = start + 1; i <= end; ++i) {
            if (preorder[i] >= val) break; // break if found the right tree node
        }
        // verify if both the left subtree and the right subtree are valid
        return helper(preorder, start + 1, i - 1, lower, val) && helper(preorder,
            i, end, val, upper);
    }
};

```

7.4.8 Inorder Successor in BST (M)

Given a binary search tree and a node in it, find the in-order successor of that node in the BST.

Note: If the given node has no in-order successor in the tree, return null.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

# Iteration
class Solution(object):
    def inorderSuccessor(self, root, p):
        s = []
        q = root
        flag = 0
        while s or q:
            if q:
                s.append(q)
                q = q.left
            else:
                if s[-1].val == p.val:
                    flag = 1
                if flag == 1:
                    return s[-1]
                q = s[-1].right
                s.pop()
        return None

# Iteration with BST nature
class Solution(object):
    def inorderSuccessor(self, root, p):
        res = None
        while root:
            if root.val > p.val:
                res = root
                root = root.left
            else:
                root = root.right
        return res

# Recursion with BST nature
class Solution(object):
    def inorderSuccessor(self, root, p):
        if not root: return None
        if root.val <= p.val:
            return self.inorderSuccessor(root.right, p)
        else:
            left = self.inorderSuccessor(root.left, p)
            if not left:

```

```

        return root
    else:
        return left

```

```

class Solution {
public:
    TreeNode* inorderSuccessor(TreeNode* root, TreeNode* p) {
        TreeNode *res = NULL;
        while (root) {
            if (p->val < root->val) {
                res = root; // root could be the in-order successor of p
                root = root->left; // or the successor could exist in the left
                               subtree of root
            } else { // otherwise, the successor will definitely exist in the
                // right subtree of root
                root = root->right;
            }
        }
        return res;
    }
};

```

7.4.9 Inorder Successor in BST II (M)

Given a binary search tree and a node in it, find the in-order successor of that node in the BST.

The successor of a node *p* is the node with the smallest key greater than *p.val*.

You will have direct access to the node but not to the root of the tree. Each node will have a reference to its parent node.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def inorderSuccessor(self, node, parent):
        if not node: return None
        res = None
        if node.right:
            res = node.right

```



```

        while res and res.left:
            res = res.left
    else:
        res = node.parent
        while res and res.val < node.val:
            res = res.parent
    return res

```

7.4.10 Largest BST Subtree (M)

Given a binary tree, find the largest subtree which is a Binary Search Tree (BST), where largest means subtree with largest number of nodes in it.

Note: A subtree must include all of its descendants.

Here's an example: [10, 5, 15, 1, 8, #, 7]

The Largest BST Subtree in this case is the highlighted one.

The return value is the subtree's size, which is 3.

Hint: You can recursively use algorithm similar to 98. Validate Binary Search Tree at each node of the tree, which will result in $O(n \log n)$ time complexity.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def largestBSTSubtree(self, root):
        if not root: return 0
        if isValid(root, float('-inf'), float('inf')):
            return count(root)
        return max(self.largestBSTSubtree(root.left), \
                    self.largestBSTSubtree(root.right))
    def isValid(self, node, minval, maxval):
        if not node: return True
        if node.val <= minval or node.val >= maxval:
            return False
        return self.isValid(node.left, minval, node.val) and \
               self.isValid(node.right, node.val, maxval)
    def count(self, node):
        if not root: return 0
        return self.count(node.left) + self.count(node.right) + 1

```

```

class Solution {
public:
    int largestBSTSubtree(TreeNode* root) {
        int res = 0;
        dfs(root, res);
        return res;
    }
    void dfs(TreeNode *root, int &res) {
        if (!root) return;
        int d = countBFS(root, INT_MIN, INT_MAX);
        if (d != -1) {
            res = max(res, d);
            return;
        }
        dfs(root->left, res);
        dfs(root->right, res);
    }
    int countBFS(TreeNode *root, int mn, int mx) {
        if (!root) return 0;
        if (root->val < mn || root->val > mx) return -1;
        int left = countBFS(root->left, mn, root->val);
        if (left == -1) return -1;
        int right = countBFS(root->right, root->val, mx);
        if (right == -1) return -1;
        return left + right + 1;
    }
};

```

7.4.11 Unique Binary Search Trees (M)

Given n, how many structurally unique BST's (binary search trees) that store values 1...n?

```

class Solution(object):
    def numTrees(self, n):
        """
        :type n: int
        :rtype: int
        """
        dp = [0] * (n+1)
        dp[0], dp[1] = 1, 1
        for i in range(2, n+1):
            for j in range(0, i):
                dp[i] += dp[j] * dp[i-j-1]
        return dp[n]

```

```

// Catalan number
// dp[2] = dp[0] * dp[1] + dp[1] * dp[0];
// dp[3] = dp[0] * dp[2] + dp[1] * dp[1] + dp[2] * dp[0];
class Solution {
public:
    int numTrees(int n) {
        vector<int> dp(n + 1, 0);
        dp[0] = 1;
        dp[1] = 1;
        for (int i = 2; i <= n; ++i) {
            for (int j = 0; j < i; ++j) {
                dp[i] += dp[j] * dp[i - j - 1];
            }
        }
        return dp[n];
    }
};

```

7.4.12 Unique Binary Search Trees II (M)

Given an integer n, generate all structurally unique BST's (binary search trees) that store values 1...n.

```

class Solution {
public:
    vector<TreeNode*> generateTrees(int n) {
        if (n == 0) return {};
        return generateTreesDFS(1, n);
    }
    vector<TreeNode*> generateTreesDFS(int start, int end) {
        vector<TreeNode*> subTree;
        if (start > end) {
            subTree.push_back(NULL);
            return subTree;
        }
        for (int k = start; k <= end; k++) {
            vector<TreeNode*> leftSubTree = generateTreesDFS(start, k - 1);
            vector<TreeNode*> rightSubTree = generateTreesDFS(k + 1, end);
            for (int i = 0; i < leftSubTree.size(); ++i) {
                for (int j = 0; j < rightSubTree.size(); ++j) {
                    TreeNode *node = new TreeNode(k);
                    node->left = leftSubTree[i];
                    node->right = rightSubTree[j];
                    subTree.push_back(node);
                }
            }
        }
        return subTree;
    }
};

```

```

        return subTree;
    }
};

```

7.4.13 Convert Sorted Array to Binary Search Tree (M)

Given an array where elements are sorted in ascending order, convert it to a height balanced BST.

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def sortedArrayToBST(self, nums):
        """
        :type nums: List[int]
        :rtype: TreeNode
        """
        if not nums: return None
        start = 0
        end = len(nums) - 1
        return self.convert(nums, start, end)
    def convert(self, nums, start, end):
        if start > end: return None
        mid = start + (end - start) // 2
        node = TreeNode(nums[mid])
        node.left = self.convert(nums, start, mid-1)
        node.right = self.convert(nums, mid+1, end)
        return node

```

```

class Solution {
public:
    TreeNode *sortedArrayToBST(vector<int> &nums) {
        return sortedArrayToBST(nums, 0, nums.size()-1);
    }
    TreeNode *sortedArrayToBST(vector<int> &nums, int left, int right) {
        if (left > right) return NULL;
        int mid = left + (right - left) / 2;
        TreeNode *root = new TreeNode(nums[mid]);
        root->left = sortedArrayToBST(nums, left, mid-1);
        root->right = sortedArrayToBST(nums, mid+1, right);
    }
};

```

```

        return root;
    }
};

```

7.4.14 Convert Sorted List to Binary Search Tree (M)

Given a singly linked list where elements are sorted in ascending order, convert it to a height balanced BST.

```

# Definition for singly-linked list.
# class ListNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.next = None

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

class Solution(object):
    def sortedListToBST(self, head):
        """
        :type head: ListNode
        :rtype: TreeNode
        """
        if not head: return None
        return self.convert(head, None)
    def convert(self, head, tail):
        if head == tail: return None
        slow, fast = head, head
        while fast != tail and fast.next != tail:
            slow = slow.next
            fast = fast.next.next
        node = TreeNode(slow.val)
        node.left = self.convert(head, slow)
        node.right = self.convert(slow.next, tail)
        return node

```

```

class Solution {
public:
    TreeNode *sortedListToBST(ListNode *head) {
        if (!head) return NULL;

```

```

    if (!head->next) return new TreeNode (head->val);
    ListNode *left, *mid, *right;
    left = mid = right = head;
    while (right->next && right->next->next) {
        left = mid; // update the tail of left
        mid = mid->next;
        right = right->next->next;
    }
    right = mid->next; // get the right list
    left->next = NULL; // break the left list
    TreeNode *root = new TreeNode(mid->val);
    if (head != mid) root->left = sortedListToBST(head);
    root->right = sortedListToBST(right);
    return root;
}
};

```

7.4.15 Convert Binary Search Tree to Sorted Doubly Linked List (M)

Convert a BST to a sorted circular doubly-linked list in-place. Think of the left and right pointers as synonymous to the previous and next pointers in a doubly-linked list.

```

class Solution {
public:
    Node* treeToDoublyList(Node* root) {
        if (!root) return NULL;
        Node *head = NULL, *pre = NULL;
        inorder(root, pre, head);
        pre->right = head;
        head->left = pre;
        return head;
    }
    void inorder(Node* node, Node*& pre, Node*& head) {
        if (!node) return;
        inorder(node->left, pre, head);
        if (!head) {
            head = node;
            pre = node;
        } else {
            pre->right = node;
            node->left = pre;
            pre = node;
        }
        inorder(node->right, pre, head);
    }
}

```

```
};
```

7.4.16 Closest Binary Search Tree Value (E)

Given a non-empty binary search tree and a target value, find the value in the BST that is closest to the target.

Note:

Given target value is a floating point.

You are guaranteed to have only one unique value in the BST that is closest to the target.

```
class Solution {
public:
    int closestValue(TreeNode* root, double target) {
        int res = root->val;
        while (root) {
            if (abs(root->val - target) < abs(res - target)) { // find a shorter
                distance
                res = root->val;                               // update value;
            }

            if (target < root->val) {
                root = root->left;
            } else {
                root = root->right;
            }
        }
        return res;
    }
};
```

7.4.17 Closest Binary Search Tree Value II (H)

Given a non-empty binary search tree and a target value, find k values in the BST that are closest to the target.

Note:

Given target value is a floating point.

You may assume k is always valid, that is: $k \leq \text{total nodes}$.

You are guaranteed to have only one unique set of k values in the BST that are closest to the target.

Follow up: Assume that the BST is balanced, could you solve it in less than $O(n)$ runtime (where $n = \text{total nodes}$)?

Hint:

1. Consider implementing these two helper functions:
 - i. `getPredecessor(N)`, which returns the next smaller node to `N`.
 - ii. `getSuccessor(N)`, which returns the next larger node to `N`.
2. Try to assume that each node has a parent pointer, it makes the problem much easier.
3. Without parent pointer we just need to keep track of the path from the root to the current node using a stack.
4. You would need two stacks to track the path in finding predecessor and successor node separately.

```
class Solution {
public:
    vector<int> closestKValues(TreeNode* root, double target, int k) {
        vector<int> res, v;
        inorder(root, v);
        int idx = 0;
        double diff = numeric_limits<double>::max();
        for (int i = 0; i < v.size(); ++i) {
            if (diff >= abs(target - v[i])) {
                diff = abs(target - v[i]);
                idx = i;
            }
        }
        int left = idx - 1, right = idx + 1;
        for (int i = 0; i < k; ++i) {
            res.push_back(v[idx]);
            if (left >= 0 && right < v.size()) {
                if (abs(v[left] - target) > abs(v[right] - target)) {
                    idx = right;
                    ++right;
                } else {
                    idx = left;
                    --left;
                }
            } else if (left >= 0) {
                idx = left;
                --left;
            } else if (right < v.size()) {
                idx = right;
                ++right;
            }
        }
        return res;
    }
    void inorder(TreeNode *root, vector<int> &v) {
```



```

        if (!root) return;
        inorder(root->left, v);
        v.push_back(root->val);
        inorder(root->right, v);
    }
};

```

7.4.18 Range Sum BST (E)

Given the root node of a binary search tree, return the sum of values of all nodes with value between L and R (inclusive).

The binary search tree is guaranteed to have unique values.

Example 1:

Input: root = [10,5,15,3,7,null,18], L = 7, R = 15 Output: 32

Example 2:

Input: root = [10,5,15,3,7,13,18,1,null,6], L = 6, R = 10 Output: 23

Note:

The number of nodes in the tree is at most 10000. The final answer is guaranteed to be less than 2^{31} .

```

# Definition for a binary tree node.
# class TreeNode(object):
#     def __init__(self, x):
#         self.val = x
#         self.left = None
#         self.right = None

# recursion
class Solution(object):
    def rangeSumBST(self, root, L, R):
        """
        :type root: TreeNode
        :type L: int
        :type R: int
        :rtype: int
        """
        self.res = 0
        self.dfs(root, L, R)
        return self.res
    def dfs(self, node, L, R):
        if not node: return
        if L <= node.val <= R:
            self.res += node.val
        if L < node.val:
            self.dfs(node.left, L, R)
        if node.val < R:

```

```

        self.dfs(node.right, L, R)

# iteration
class Solution(object):
    def rangeSumBST(self, root, L, R):
        """
        :type root: TreeNode
        :type L: int
        :type R: int
        :rtype: int
        """
        res = 0
        stack = [root]
        while stack:
            node = stack.pop()
            if node:
                if L <= node.val <= R:
                    res += node.val
                if L < node.val:
                    stack.append(node.left)
                if node.val < R:
                    stack.append(node.right)
        return res

```

Chapter 8

Sorting

8.1 Largest Number (M)

Given a list of non negative integers, arrange them such that they form the largest number. For example, given [3, 30, 34, 5, 9], the largest formed number is 9534330.

Note: The result may be very large, so you need to return a string instead of an integer.

```
class Solution {
public:
    string largestNumber(vector<int>& nums) {
        string res;
        // if ab > ba, then put a before b
        // e.g. compare 9 and 34, since 934 > 349, 9 needs to be put before 34
        sort(nums.begin(), nums.end(), [](int a, int b) {
            return to_string(a) + to_string(b) > to_string(b) + to_string(a);
        });
        for (int i = 0; i < nums.size(); ++i) {
            res += to_string(nums[i]);
        }
        return res[0] == '0' ? "0" : res;
    }
};
```

8.2 Sort Colors (M)

Given an array with n objects colored red, white or blue, sort them so that objects of the same color are adjacent, with the colors in the order red, white and blue. Here, we will use the integers 0, 1, and 2 to represent the color red, white, and blue respectively.

Note: You are not suppose to use the library's sort function for this problem.

Follow up:

A rather straight forward solution is a two-pass algorithm using counting sort.

First, iterate the array counting number of 0's, 1's, and 2's, then overwrite array with total number of 0's, then 1's and followed by 2's.

Could you come up with an one-pass algorithm using only constant space?

```
# Two pass sort
class Solution(object):
    def sortColors(self, nums):
        """
        :type nums: List[int]
        :rtype: None Do not return anything, modify nums in-place instead.
        """
        cnt = [0, 0, 0]
        for n in nums:
            cnt[n] += 1
        for i in range(len(nums)):
            if i < cnt[0]: nums[i] = 0
            elif i < cnt[0] + cnt[1]: nums[i] = 1
            else: nums[i] = 2
```

```
# One pass sort
class Solution(object):
    def sortColors(self, nums):
        """
        :type nums: List[int]
        :rtype: None Do not return anything, modify nums in-place instead.
        """
        n = len(nums)
        left, right, cur = 0, n - 1, 0
        while cur <= right:
            if nums[cur] == 0:
                nums[cur], nums[left] = nums[left], nums[cur]
                cur += 1
                left += 1
            elif nums[cur] == 2:
                nums[cur], nums[right] = nums[right], nums[cur]
                right -= 1
            else:
                cur += 1
```

```
// 1. Count and Sort
class Solution {
public:
    void sortColors(vector<int> &nums) {
```

```

    int count[3] = {0}, idx = 0;
    // Count the number of each color
    for (int i = 0; i < nums.size(); ++i) ++count[nums[i]];
    // Sort the array by assigning correct number of colors based on counts
    for (int i = 0; i < 3; ++i) {
        for (int j = 0; j < count[i]; ++j) {
            nums[idx++] = i;
        }
    }
}
};

// 2. Two pointers
class Solution {
public:
    void sortColors(vector<int> &nums) {
        int red = 0, blue = nums.size()-1, i = 0;
        while (i < blue + 1) {
            if (nums[i] == 0) swap(nums[i++], nums[red++]);
            // nums[i] still need to be checked in the next loop after swap
            else if (nums[i] == 2) swap(nums[i], nums[blue--]);
            else ++i;
        }
    }
};

```

8.3 Wiggle Sort (M)

Given an unsorted array `nums`, reorder it in-place such that $nums[0] \leq nums[1] \geq nums[2] \leq nums[3] \dots$

For example, given `nums = [3, 5, 2, 1, 6, 4]`, one possible answer is `[1, 6, 2, 5, 3, 4]`.

```

// Wiggle Sort O(nlogn)
class Solution {
public:
    void wiggleSort(vector<int>& nums) {
        sort(nums.begin(), nums.end());
        if (nums.size() <= 2) return;
        for (int i = 2; i < num.size(); i += 2) {
            swap(nums[i], nums[i-1]);
        }
    }
};

```

```

// Wiggle Sort O(n)
class Solution {
public:
    void wiggleSort(vector<int>& nums) {
        if (nums.size() <= 1) return;
        for (int i = 1; i < nums.size(); ++i) {
            if ( (i % 2 == 1 && nums[i] < nums[i-1]) ||
                (i % 2 == 0 && nums[i] > nums[i-1]) ) {
                swap(nums[i], nums[i-1]);
            }
        }
    }
};

```

8.4 Wiggle Sort II (M)

Given an unsorted array *nums*, reorder it such that $nums[0] < nums[1] > nums[2] < nums[3] \dots$

Example:

- (1) Given *nums* = [1, 5, 1, 1, 6, 4], one possible answer is [1, 4, 1, 5, 1, 6].
- (2) Given *nums* = [1, 3, 2, 2, 3, 1], one possible answer is [2, 3, 1, 3, 1, 2].

Note: You may assume all input has valid answer.

Follow Up: Can you do it in $O(n)$ time and/or in-place with $O(1)$ extra space?

```

// Wiggle Sort II Time: O(nlogn) Space: O(n)
class Solution {
public:
    void wiggleSort(vector<int>& nums) {
        vector<int> tmp = nums;
        int n = nums.size(), k = (n+1)/2, j = n;
        sort(tmp.begin(), tmp.end());
        for (int i = 0; i < n; ++i) {
            if (i % 2 == 0) {
                nums[i] = tmp[--k];
            } else {
                nums[i] = tmp[--j];
            }
        }
    }
};

```

```

// O(1) space
class Solution {
public:
    void wiggleSort(vector<int>& nums) {
        #define A(i) nums[(1 + 2 * i) % (n | 1)]
        int n = nums.size(), i = 0, j = 0, k = n - 1;
        auto midptr = nums.begin() + n / 2;
        nth_element(nums.begin(), midptr, nums.end());
        int mid = *midptr;
        while (j <= k) {
            if (A(j) > mid) swap(A(i++), A(j++));
            else if (A(j) < mid) swap(A(j), A(k--));
            else ++j;
        }
    }
};

```

8.5 Wiggle Subsequence (M)

A sequence of numbers is called a wiggle sequence if the differences between successive numbers strictly alternate between positive and negative. The first difference (if one exists) may be either positive or negative. A sequence with fewer than two elements is trivially a wiggle sequence.

For example, $[1,7,4,9,2,5]$ is a wiggle sequence because the differences $(6,-3,5,-7,3)$ are alternately positive and negative. In contrast, $[1,4,7,2,5]$ and $[1,7,4,5,5]$ are not wiggle sequences, the first because its first two differences are positive and the second because its last difference is zero.

Given a sequence of integers, return the length of the longest subsequence that is a wiggle sequence. A subsequence is obtained by deleting some number of elements (eventually, also zero) from the original sequence, leaving the remaining elements in their original order.

Examples:

Input: $[1,7,4,9,2,5]$

Output: 6

The entire sequence is a wiggle sequence.

Input: $[1,17,5,10,13,15,10,5,16,8]$

Output: 7

There are several subsequences that achieve this length. One is $[1,17,10,13,10,16,8]$.

Input: [1,2,3,4,5,6,7,8,9]

Output: 2

Follow up: Can you do it in $O(n)$ time?

```
// O(n^2)
class Solution {
public:
    int wiggleMaxLength(vector<int>& nums) {
        if (nums.empty()) return 0;
        int n = nums.size();
        vector<int> p(n, 1);
        vector<int> q(n, 1);

        for (int i = 1; i < n; ++i) {
            for (int j = 0; j < i; ++j) {
                if (nums[i] > nums[j]) {
                    p[i] = max(p[i], q[j] + 1);
                } else if (nums[i] < nums[j]) {
                    q[i] = max(q[i], p[j] + 1);
                } else {
                    continue;
                }
            }
        }

        return max(p.back(), q.back());
    }
};

// O(n)
class Solution {
public:
    int wiggleMaxLength(vector<int>& nums) {
        int p = 1, q = 1, n = nums.size();

        for (int i = 1; i < n; ++i) {
            if (nums[i] > nums[i - 1]){
                p = q + 1;
            } else if (nums[i] < nums[i - 1]) {
                q = p + 1;
            }
        }

        return min(n, max(p, q));
    }
};
```

8.6 Sort List (M)

Sort a linked list in $O(n \log n)$ time using constant space complexity.

```
// Merge Sort
class Solution {
public:
    ListNode *sortList(ListNode *head) {
        if (!head || !head->next) return head;
        ListNode *p1 = head, *p2 = head;
        while (p2->next && p2->next->next) {
            p1 = p1->next;
            p2 = p2->next->next;
        }
        p2 = sortList(p1->next);
        p1->next = NULL;
        p1 = sortList(head);
        return mergeList(p1, p2);
    }
    ListNode *mergeList(ListNode *p1, ListNode *p2) {
        ListNode *new_head = new ListNode(0);
        ListNode *tmp = new_head;
        while (p1 && p2) {
            if (p1->val < p2->val) {
                tmp->next = p1;
                p1 = p1->next;
            } else {
                tmp->next = p2;
                p2 = p2->next;
            }
            tmp = tmp->next;
        }
        if (p1) tmp->next = p1;
        if (p2) tmp->next = p2;
        return new_head->next;
    }
};
```

8.7 Insertion Sort List (M)

Sort a linked list using insertion sort.

```
class Solution {
public:
    ListNode* insertionSortList(ListNode* head) {
        if (!head || !head->next) return head;
        ListNode *new_head = new ListNode(0);
        ListNode *cur, *next;
        while (head) {
            cur = new_head; // reset cur to the beginning for each iteration
            next = head->next; // next point to the next position of head
            // search the correct position to insert head
            while (cur->next && cur->next->val <= head->val) {
                cur = cur->next;
            }
            head->next = cur->next; // add head after cur
            cur->next = head; // update cur->next
            head = next; // update head
        }
        return new_head->next;
    }
};
```

Chapter 9

Binary Search

9.1 First Bad Version (E)

You are a product manager and currently leading a team to develop a new product. Unfortunately, the latest version of your product fails the quality check. Since each version is developed based on the previous version, all the versions after a bad version are also bad.

Suppose you have n versions $[1, 2, \dots, n]$ and you want to find out the first bad one, which causes all the following ones to be bad. You are given an API `bool isBadVersion(version)` which will return whether version is bad. Implement a function to find the first bad version. You should minimize the number of calls to the API.

```
# The isBadVersion API is already defined for you.
# @param version, an integer
# @return a bool
# def isBadVersion(version):
```

```
class Solution(object):
    def firstBadVersion(self, n):
        """
        :type n: int
        :rtype: int
        """
        left, right = 1, n
        while left < right:
            mid = left + (right - left) / 2
            if isBadVersion(mid):
                right = mid
            else:
                left = mid + 1
        return right
```

```
// Forward declaration of isBadVersion API.
```

```

bool isBadVersion(int version);

class Solution {
public:
    int firstBadVersion(int n) {
        int start = 1, end = n, mid;
        while (start < end) {
            mid = start + (end - start) / 2;
            if (!isBadVersion(mid))
                start = mid + 1;
            else
                end = mid;           // the current mid could be the first bad version
        }
        return start;
    }
};

```

9.2 Find the Duplicate Number (H)

Given an array `nums` containing $n + 1$ integers where each integer is between 1 and n (inclusive), prove that at least one duplicate number must exist. Assume that there is only one duplicate number, find the duplicate one.

Note: You must not modify the array (assume the array is read only).

You must use only constant, $O(1)$ extra space.

Your runtime complexity should be less than $O(n^2)$.

There is only one duplicate number in the array, but it could be repeated more than once.

```

class Solution {
public:
    int findDuplicate(vector<int>& nums) {
        int low = 1, high = nums.size() - 1;
        // Use the mid of 1~n, not the mid of nums[0]~nums[nums.size()-1]
        while (low < high) {
            int mid = low + (high - low) / 2;
            int cnt = 0;
            for (int i = 0; i < nums.size(); ++i) {
                if (nums[i] <= mid) {
                    ++cnt;
                }
            }
            if (cnt <= mid) {
                low = mid + 1;
            } else {
                high = mid;
            }
        }
    }
};

```

```

    }
    }
    return low;
}
};

```

9.3 Search for a Range (M)

Given a sorted array of integers, find the starting and ending position of a given target value. Your algorithm's runtime complexity must be in the order of $O(\log n)$. If the target is not found in the array, return $[-1, -1]$.

For example, Given $[5, 7, 7, 8, 8, 10]$ and target value 8, return $[3, 4]$.

```

// 1. Recursive
class Solution {
public:
    vector<int> searchRange(vector<int>& nums, int target) {
        int n = nums.size();
        vector<int> res = {n, -1};
        searchRange(nums, target, res, 0, n-1);
        if (res[0] > res[1]) res[0] = -1; // target is not found
        return res;
    }
    void searchRange(vector<int>& nums, int target, vector<int>& res, int start,
        int end) {
        if (start > end) return;
        int mid = start + (end - start) / 2;
        if (target == nums[mid]) {
            if (mid < res[0]) { // search the left part
                res[0] = mid; // update the start index
                searchRange(nums, target, res, start, mid-1);
            }
            if (mid > res[1]) { // search the right part
                res[1] = mid; // update the end index
                searchRange(nums, target, res, mid+1, end);
            }
        } else if (target > nums[mid]) {
            searchRange(nums, target, res, mid+1, end);
        } else {
            searchRange(nums, target, res, start, mid-1);
        }
    }
};

```

```

// 2. Iteration
class Solution {
public:
    vector<int> searchRange(vector<int>& nums, int target) {
        int start = 0, end = nums.size() - 1;
        vector<int> res = {-1, -1};
        // find the start index
        while (start < end) {
            int mid = start + (end - start) / 2;
            if (target > nums[mid]) {
                start = mid + 1;
            } else {
                end = mid;
            }
        }
        if (target != nums[start]) {
            return res;
        } else {
            res[0] = start; // update the start index
        }
        end = nums.size() - 1;
        // find the end index
        while (start < end) {
            int mid = start + (end - start) / 2 + 1;
            if (target < nums[mid]) {
                end = mid - 1;
            } else {
                start = mid;
            }
        }
        res[1] = end; // update the end index
        return res;
    }
};

```

9.4 Search Insert Position (M)

Given a sorted array and a target value, return the index if the target is found. If not, return the index where it would be if it were inserted in order. You may assume no duplicates in the array.

Here are few examples.

[1, 3, 5, 6], 5 → 2

[1, 3, 5, 6], 2 → 1

[1, 3, 5, 6], 7 → 4

[1,3,5,6], 0 - > 0

```
class Solution {
public:
    int searchInsert(vector<int>& nums, int target) {
        int left = 0, right = nums.size() - 1;
        while (left <= right) {
            int mid = left + (right - left) / 2;
            if (target < nums[mid]) {
                right = mid - 1;
            } else if (target > nums[mid]) {
                left = mid + 1;
            } else {
                return mid;
            }
        }
        return left;
    }
};
```

9.5 Find Peak Element (M)

A peak element is an element that is greater than its neighbors.

Given an input array where $\text{num}[i] \neq \text{num}[i+1]$, find a peak element and return its index. The array may contain multiple peaks, in that case return the index to any one of the peaks is fine. You may imagine that $\text{num}[-1] = \text{num}[n] = -\infty$.

For example, in array [1, 2, 3, 1], 3 is a peak element and your function should return the index number 2.

```
# O(N)
class Solution(object):
    def findPeakElement(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        for i in range(1, len(nums)):
            if nums[i] > nums[i - 1]:
                return i - 1
        return len(nums) - 1

# O(logN)
```

```

class Solution(object):
    def findPeakElement(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        left, right = 0, len(nums) - 1
        while left < right:
            mid = left + (right - left) / 2
            if nums[mid] < nums[mid + 1]:
                left = mid + 1
            else:
                right = mid
        return right

```

```

class Solution {
public:
    int findPeakElement(vector<int>& nums) {
        int start = 0, end = nums.size()-1;
        while (start < end) {
            int mid = start + (end - start) / 2;
            if (nums[mid] > nums[mid+1]) {
                end = mid;
            } else if (nums[mid] < nums[mid+1]) {
                start = mid + 1;
            }
        }
        return start;
    }
};

```

9.6 Search a 2D Matrix (M)

Write an efficient algorithm that searches for a value in an m x n matrix. This matrix has the following properties:

Integers in each row are sorted from left to right.

The first integer of each row is greater than the last integer of the previous row.

For example, Consider the following matrix: [[1, 3, 5, 7], [10, 11, 16, 20], [23, 30, 34, 50]]

Given target = 3, return true.

```

class Solution {
public:
    bool searchMatrix(vector<vector<int>>& matrix, int target) {

```



```

    int m = matrix.size(), n = matrix[0].size();
    int left = 0, right = m * n - 1;
    while (left <= right) {
        int mid = left + (right - left) / 2;
        int val = matrix[mid/n][mid%n]; // convert 1D index to 2D index
        if (target == val)
            return true;
        else if (target > val)
            left = mid + 1;
        else
            right = mid - 1;
    }
    return false;
}
};

```

9.7 Search a 2D Matrix II (M)

Write an efficient algorithm that searches for a value in an $m \times n$ matrix. This matrix has the following properties:

Integers in each row are sorted in ascending from left to right.

Integers in each column are sorted in ascending from top to bottom.

For example, Consider the following matrix: [[1, 4, 7, 11, 15], [2, 5, 8, 12, 19], [3, 6, 9, 16, 22], [10, 13, 14, 17, 24], [18, 21, 23, 26, 30]]

Given target = 5, return true. Given target = 20, return false.

```

// 1. Binary search for each row: O(MlogN)
class Solution {
public:
    bool searchMatrix(vector<vector<int>> &matrix, int target) {
        int m = matrix.size(), n = matrix[0].size();
        bool res = false;
        for (int i = 0; i < m; ++i) {
            if (matrix[i][0] <= target && target <= matrix[i][n-1]) {
                res = binarySearch(matrix, target, i, n);
                if (res == true) break;
            }
        }
        return res;
    }
    bool binarySearch(vector<vector<int>> &matrix, int target, int row, int
length) {
        int left = 0, right = length-1;
        while (left <= right) {

```

```

        int mid = left + (right - left) / 2;
        if (target == matrix[row][mid]) {
            return true;
        } else if (target > matrix[row][mid]) {
            left = mid + 1;
        } else {
            right = mid - 1;
        }
    }
    return false;
}
};

// 2. O(M+N) solution
// Starting from a corner of matrix,
// if one direction is ascending and another is decending,
// then this method works!
// e.g. for this case, starting from the bottom left corner or upper right corner
class Solution {
public:
    bool searchMatrix(vector<vector<int>>& matrix, int target) {
        int m = matrix.size(), n = matrix[0].size();
        int i = 0, j = n - 1;
        // starting from the upper right corner
        while(i < m && j >= 0) {
            if (target == matrix[i][j])
                return true;
            else if (target < matrix[i][j])
                --j;
            else
                ++i;
        }
        return false;
    }
};

```

9.8 Guess Number Higher or Lower (E)

We are playing the Guess Game. The game is as follows: I pick a number from 1 to n. You have to guess which number I picked. Every time you guess wrong, I'll tell you whether the number is higher or lower.

You call a pre-defined API `guess(int num)` which returns 3 possible results (-1, 1, or 0):

-1 : My number is lower

1 : My number is higher

0 : Congrats! You got it!

Example:

n = 10, I pick 6.

Return 6.

```
// Forward declaration of guess API.  
// @param num, your guess  
// @return -1 if my number is lower, 1 if my number is higher, otherwise return 0  
int guess(int num);  
  
class Solution {  
public:  
    int guessNumber(int n) {  
        int start = 1, end = n;  
  
        while (start <= end) {  
            int mid = start + (end - start) / 2;  
            int res = guess(mid);  
  
            if (res == 0)  
                return mid;  
            else if (res == 1)  
                start = mid + 1;  
            else  
                end = mid - 1;  
        }  
  
        return start;  
    }  
};
```

9.9 Guess Number Higher or Lower II (M)

We are playing the Guess Game. The game is as follows: I pick a number from 1 to n. You have to guess which number I picked. Every time you guess wrong, I'll tell you whether the number I picked is higher or lower. However, when you guess a particular number x, and you guess wrong, you pay \$x. You win the game when you guess the number I picked.

Example:

n = 10, I pick 8.

First round: You guess 5, I tell you that it's higher. You pay \$5.

Second round: You guess 7, I tell you that it's higher. You pay \$7.

Third round: You guess 9, I tell you that it's lower. You pay \$9.

Game over. 8 is the number I picked.
You end up paying $\$5 + \$7 + \$9 = \21 .

Given a particular $n \geq 1$, find out how much money you need to have to guarantee a win.

```
class Solution {
public:
    int getMoneyAmount(int n) {
        vector<vector<int>> dp(n+1, vector<int>(n+1, 0));
        return solver(dp, 1, n);
    }

    int solver(vector<vector<int>> &dp, int L, int R) {
        if (L >= R) return 0;
        if (dp[L][R]) return dp[L][R];

        dp[L][R] = INT_MAX;

        // f(x) = x + max(solver(L,x-1),solver(x+1,n))
        // get the minimum f(x) for x = 1~n
        for (int i = L; i <= R; ++i) {
            dp[L][R] = min(dp[L][R], i + max(solver(dp, L, i-1), solver(dp, i+1,
                R)));
        }

        return dp[L][R];
    }
};
```

9.10 Find Minimum in Rotated Sorted Array (M)

Suppose a sorted array is rotated at some pivot unknown to you beforehand. (i.e., 0 1 2 4 5 6 7 might become 4 5 6 7 0 1 2). Find the minimum element. You may assume no duplicate exists in the array.

```
class Solution(object):
    def findMin(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        if len(nums) == 1:
            return nums[0]
        left, right = 0, len(nums) - 1
```

```

# array is not rotated
if nums[right] > nums[0]:
    return nums[0]
# array is rotated
while left <= right:
    mid = left + (right - left) / 2
    # return the changing point
    if nums[mid] > nums[mid+1]:
        return nums[mid+1]
    if nums[mid - 1] > nums[mid]:
        return nums[mid]
    # compare with the first element
    if nums[mid] > nums[0]:
        left = mid + 1
    else:
        right = mid - 1

class Solution(object):
    def findMin(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        left, right = 0, len(nums)-1
        while left < right and nums[left] > nums[right]:
            mid = left + (right - left) / 2
            if nums[mid] > nums[right]:
                left = mid + 1
            else:
                right = mid
        return nums[left]

```

```

class Solution {
public:
    int findMin(vector<int> &nums) {
        int left = 0, right = nums.size()-1;
        // If nums[left] > nums[right], then the array/subarray must be rotated
        // Otherwise, the array/subarray is not rotated and nums[left] is the
        minimum
        while (left < right && nums[left] > nums[right]) {
            int mid = left + (right - left) / 2;
            if (nums[mid] > nums[right]) { //min must exist in right part
                left = mid + 1;
            } else { //otherwise min is in the left part
                right = mid;
            }
        }
    }
}

```

```

        return nums[left];
    }
};

```

9.11 Find Minimum in Rotated Sorted Array II (H)

Suppose a sorted array is rotated at some pivot unknown to you beforehand. (i.e., 0 1 2 4 5 6 7 might become 4 5 6 7 0 1 2). Find the minimum element. The array may contain duplicates.

```

class Solution(object):
    def findMin(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        left, right = 0, len(nums) - 1
        while left < right and nums[left] >= nums[right]:
            mid = left + (right - left) - 1
            if nums[mid] > nums[right]:
                left = mid + 1
            elif nums[mid] < nums[right]:
                right = mid
            else:
                left += 1
        return nums[left]

```

```

class Solution {
public:
    int findMin(vector<int>& nums) {
        int left = 0, right = nums.size()-1;
        while (left < right && nums[left] >= nums[right]) { //consider duplicates
            int mid = left + (right - left) / 2;
            if (nums[mid] > nums[right])
                left = mid + 1;
            else if (nums[mid] < nums[right])
                right = mid;
            else //if duplicates exist, skip the leftmost element and procees to
                the next
                left = left + 1;
        }
        return nums[left];
    }
};

```

9.12 Search in Rotated Sorted Array (M)

Suppose a sorted array is rotated at some pivot unknown to you beforehand. (i.e., 0 1 2 4 5 6 7 might become 4 5 6 7 0 1 2). You are given a target value to search. If found in the array return its index, otherwise return -1. You may assume no duplicate exists in the array.

```
class Solution(object):
    def search(self, nums, target):
        """
        :type nums: List[int]
        :type target: int
        :rtype: int
        """
        left = 0
        right = len(nums) - 1
        while left <= right:
            mid = left + (right - left) / 2
            if nums[mid] == target:
                return mid
            # the right part of array is sorted
            if nums[mid] < nums[right]:
                if nums[mid] < target and target <= nums[right]:
                    left = mid + 1
                else:
                    right = mid - 1
            # the left part of array is sorted
            else:
                if nums[left] <= target and target < nums[mid]:
                    right = mid - 1
                else:
                    left = mid + 1
        return -1
```

```
class Solution {
public:
    int search(vector<int>& nums, int target) {
        int left = 0, right = nums.size()-1;
        while (left <= right) {
            int mid = left + (right - left) / 2;
            if (nums[mid] == target) {
                return mid;
            } else if (nums[mid] < nums[right]) { //right part is sorted
                if (nums[mid] < target && target <= nums[right]) { //target exists
                    in the right part
                    left = mid + 1;
                } else {
```

```

        right = mid - 1;
    }
} else { //left part is sorted
    if (nums[left] <= target && target < nums[mid]) { //target exists
        in the left part
        right = mid - 1;
    } else {
        left = mid + 1;
    }
}
}
return -1;
};

```

9.13 Search in Rotated Sorted Array II (M)

Follow up for "Search in Rotated Sorted Array": What if duplicates are allowed? Would this affect the run-time complexity? How and why? Write a function to determine if a given target is in the array.

```

class Solution(object):
    def search(self, nums, target):
        """
        :type nums: List[int]
        :type target: int
        :rtype: bool
        """
        left, right = 0, len(nums) - 1
        while left <= right:
            mid = left + (right - left) / 2
            if nums[mid] == target:
                return True
            elif nums[mid] < nums[right]:
                if nums[mid] < target and target <= nums[right]:
                    left = mid + 1
                else:
                    right = mid - 1
            elif nums[mid] > nums[right]:
                if nums[left] <= target and target < nums[mid]:
                    right = mid - 1
                else:
                    left = mid + 1
            # if nums[mid] == nums[right] for duplicates, move right to the left
        else:

```



```

        right -= 1
    return False

```

```

class Solution {
public:
    bool search(vector<int> &nums, int target) {
        int left = 0, right = nums.size()-1;
        while (left <= right) {
            int mid = left + (right - left) / 2;
            if (nums[mid] == target) {
                return true;
            } else if (nums[mid] < nums[right]) {
                if (nums[mid] < target && target <= nums[right]) {
                    left = mid + 1;
                } else {
                    right = mid - 1;
                }
            } else if (nums[mid] > nums[right]) {
                if (nums[left] <= target && target < nums[mid]) {
                    right = mid - 1;
                } else {
                    left = mid + 1;
                }
            } else { //skip duplicates by leftshift the right index
                --right;
            }
        }
        return false;
    }
};

```

9.14 Median of Two Sorted Arrays (H)

There are two sorted arrays `nums1` and `nums2` of size `m` and `n` respectively. Find the median of the two sorted arrays. The overall run time complexity should be $O(\log(m+n))$.

Example 1: `nums1 = [1, 3]` `nums2 = [2]` The median is 2.0

Example 2: `nums1 = [1, 2]` `nums2 = [3, 4]` The median is $(2 + 3)/2 = 2.5$

Python:

```

class Solution(object):
    def findMedianSortedArrays(self, nums1, nums2):
        """

```

```

:type nums1: List[int]
:type nums2: List[int]
:rtype: float
"""
# O(M+N)
# merge two lists
nums = []
ls1 = len(nums1) if nums1 else 0
ls2 = len(nums2) if nums2 else 0
p1, p2 = 0, 0
while p1 < ls1 and p2 < ls2:
    if nums1[p1] < nums2[p2]:
        nums.append(nums1[p1])
        p1 += 1
    else:
        nums.append(nums2[p2])
        p2 += 1
if p1 < ls1: nums += nums1[p1:ls1]
if p2 < ls2: nums += nums2[p2:ls2]
# compute median
ls = len(nums)
if ls % 2 == 1:
    median = nums[ls / 2]
else:
    median = float(nums[ls / 2 - 1] + nums[ls / 2]) / 2
return median

```

C++:

```

class Solution {
public:
    double findMedianSortedArrays(vector<int>& nums1, vector<int>& nums2) {
        int total = nums1.size() + nums2.size();
        if (total % 2 == 1) { // odd elements, return the mid element
            return findKth(nums1, 0, nums2, 0, total / 2 + 1);
        } else { // even elements, return the average of two mid elements
            return (findKth(nums1, 0, nums2, 0, total / 2) + findKth(nums1, 0,
                nums2, 0, total / 2 + 1)) / 2;
        }
    }

    double findKth(vector<int> &nums1, int i, vector<int> &nums2, int j, int k) {
        if (nums1.size() - i > nums2.size() - j) return findKth(nums2, j, nums1,
            i, k);
        if (nums1.size() == i) return nums2[j + k - 1];
        if (k == 1) return min(nums1[i], nums2[j]);
        int pa = min(i + k / 2, int(nums1.size())), pb = j + k - pa + i;
        if (nums1[pa - 1] < nums2[pb - 1])
            return findKth(nums1, pa, nums2, j, k - pa + i);
    }
}

```

```
    else if (nums1[pa - 1] > nums2[pb - 1])
        return findKth(nums1, i, nums2, pb, k - pb + j);
    else
        return nums1[pa - 1];
}
};
```

Chapter 10

DFS and BFS

10.1 Subset (M)

Given a set of distinct integers, `nums`, return all possible subsets.

Note: The solution set must not contain duplicate subsets.

For example, If `nums = [1,2,3]`, a solution is: `[[3], [1], [2], [1,2,3], [1,3], [2,3], [1,2], []]`

```
class Solution(object):
    def subsets(self, nums):
        """
        :type nums: List[int]
        :rtype: List[List[int]]
        """
        nums.sort()
        out, res = [], []
        idx = 0
        self.dfs(nums, idx, out, res)
        return res
    def dfs(self, nums, idx, out, res):
        # always add out to res in recursion to get all subsets
        res.append(list(out))
        for i in range(idx, len(nums)):
            out.append(nums[i])
            self.dfs(nums, i + 1, out, res)
            out.pop()
```

```
// 1. Recursive
class Solution {
public:
    vector<vector<int>> subsets(vector<int> &nums) {
        vector<vector<int>> res;
        vector<int> out;
        sort(nums.begin(), nums.end());
```

```

        getSubsets(nums, res, out, 0);
        return res;
    }
    void getSubsets(vector<int> &nums, vector<vector<int>> &res, vector<int>
        &out, int pos) {
        res.push_back(out);
        for (int i = pos; i < nums.size(); ++i) {
            out.push_back(nums[i]);
            getSubsets(nums, res, out, i+1);
            out.pop_back();
        }
    }
};

// 2. Iterative
class Solution {
public:
    vector<vector<int>> subsets(vector<int>& nums) {
        sort(nums.begin(), nums.end());
        vector<vector<int>> res(1, vector<int>());
        for (int i = 0; i < nums.size(); ++i) {
            int n = res.size();
            for (int j = 0; j < n; ++j) {
                res.push_back(res[j]);
                res.back().push_back(nums[i]);
            }
        }
        return res;
    }
};

```

10.2 Subset II (M)

Given a collection of integers that might contain duplicates, `nums`, return all possible subsets.

Note: The solution set must not contain duplicate subsets.

For example, If `nums = [1,2,2]`, a solution is: `[[2], [1], [1,2,2], [2,2], [1,2], []]`

```

class Solution(object):
    def subsetsWithDup(self, nums):
        """
        :type nums: List[int]
        :rtype: List[List[int]]
        """
        nums.sort()

```

```

        out, res = [], []
        idx = 0
        self.dfs(nums, idx, out, res)
        return res
    def dfs(self, nums, idx, out, res):
        # always add out to res in recursion to get all subsets
        res.append(list(out))
        for i in range(idx, len(nums)):
            # skip duplicate
            if i > idx and nums[i] == nums[i-1]: continue
            out.append(nums[i])
            self.dfs(nums, i+1, out, res)
            out.pop()

```

```

class Solution {
public:
    vector<vector<int>> subsetsWithDup(vector<int>& nums) {
        sort(nums.begin(), nums.end());
        vector<vector<int>> res;
        vector<int> out;
        getSubsets(nums, res, out, 0);
        return res;
    }
    void getSubsets(vector<int>& nums, vector<vector<int>>& res, vector<int>&
        out, int pos) {
        res.push_back(out);
        for (int i = pos; i < nums.size(); ++i) {
            if (i == pos || nums[i] != nums[i-1]) {
                out.push_back(nums[i]);
                getSubsets(nums, res, out, i+1);
                out.pop_back();
            }
        }
    }
};

```

10.3 Permutations (M)

Given a collection of distinct numbers, return all possible permutations.

For example, [1,2,3] have the following permutations: [[1,2,3], [1,3,2], [2,1,3], [2,3,1], [3,1,2], [3,2,1]]

```

class Solution(object):

```

```

def permute(self, nums):
    """
    :type nums: List[int]
    :rtype: List[List[int]]
    """
    level = 0
    n = len(nums)
    out, res = [], []
    visited = [0] * n
    self.dfs(nums, level, visited, out, res)
    return res

def dfs(self, nums, level, visited, out, res):
    if level == len(nums):
        res.append(list(out))
    # DFS checks the whole list, skipping the visited one
    # For combination, DFS starts with the level idx,
    # and it does not check the whole list to avoid duplication
    for i in range(len(nums)):
        if visited[i] == 1: continue
        visited[i] = 1
        out.append(nums[i])
        self.dfs(nums, level+1, visited, out, res)
        out.pop()
        visited[i] = 0

```

```

// 1. Use visited vector

```

```

class Solution {
public:
    vector<vector<int>> permute(vector<int> &num) {
        vector<vector<int>> res;
        vector<int> out;
        vector<int> visited(num.size(), 0); // save visited states
        permuteDFS(num, 0, visited, out, res);
        return res;
    }

    void permuteDFS(vector<int> &num, int level, vector<int> &visited,
        vector<int> &out, vector<vector<int>> &res) {
        if (level == num.size()) res.push_back(out);
        else {
            for (int i = 0; i < num.size(); ++i) {
                if (visited[i] == 0) {
                    visited[i] = 1;
                    out.push_back(num[i]);
                    permuteDFS(num, level + 1, visited, out, res);
                    out.pop_back();
                    visited[i] = 0;
                }
            }
        }
    }
}

```

```

    }
    }
}

};

// 2. Use swap function
class Solution {
public:
    vector<vector<int>> permute(vector<int>& nums) {
        vector<vector<int>> res;
        permuteDFS(nums, 0, nums.size()-1, res);
        return res;
    }
    void permuteDFS(vector<int>& nums, int start, int end, vector<vector<int>>
        &res) {
        if (start > end) {
            res.push_back(nums);
            return;
        }
        for (int i = start; i <= end; ++i) {
            swap(nums[start], nums[i]);
            permuteDFS(nums, start+1, end, res);
            swap(nums[start], nums[i]);
        }
    }
};

```

10.4 Permutations II (M)

Given a collection of numbers that might contain duplicates, return all possible unique permutations.

For example, [1,1,2] have the following unique permutations: [[1,1,2], [1,2,1], [2,1,1]]

```

class Solution(object):
    def permuteUnique(self, nums):
        """
        :type nums: List[int]
        :rtype: List[List[int]]
        """
        level = 0
        out, res = [], []
        visited = [0] * len(nums)
        nums.sort()
        self.dfs(nums, level, visited, out, res)

```



```

        return res
def dfs(self, nums, level, visited, out, res):
    if level == len(nums):
        res.append(list(out))
        return
    for i in range(len(nums)):
        if visited[i] == 1: continue
        # duplicated permuation needs to be skipped if the new permutation
        # starts with a number that is the same as the last permutation
        if i > 0 and nums[i] == nums[i-1] and visited[i-1] == 0: continue
        visited[i] = 1
        out.append(nums[i])
        self.dfs(nums, level+1, visited, out, res)
        out.pop()
        visited[i] = 0

```

```

class Solution {
public:
    vector<vector<int>> permuteUnique(vector<int> &num) {
        vector<vector<int>> res;
        vector<int> out;
        vector<int> visited(num.size(), 0);
        sort(num.begin(), num.end());
        permuteUniqueDFS(num, 0, visited, out, res);
        return res;
    }
    void permuteUniqueDFS(vector<int> &num, int level, vector<int> &visited,
        vector<int> &out, vector<vector<int>> &res) {
        if (level >= num.size()) res.push_back(out);
        else {
            for (int i = 0; i < num.size(); ++i) {
                if (visited[i] == 0) {
                    // skip duplicates
                    if (i > 0 && num[i] == num[i-1] && visited[i-1] == 0) continue;
                    visited[i] = 1;
                    out.push_back(num[i]);
                    permuteUniqueDFS(num, level + 1, visited, out, res);
                    out.pop_back();
                    visited[i] = 0;
                }
            }
        }
    }
};

```

```

class Solution {
public:

```

```

vector<vector<int>> permuteUnique(vector<int>& nums) {
    sort(nums.begin(), nums.end());
    vector<vector<int>> res;
    permuteUniqueDFS(nums, 0, nums.size()-1, res);
    return res;
}
// Do not use reference of nums and do not swap back after recursion
void permuteUniqueDFS(vector<int> nums, int start, int end,
    vector<vector<int>> &res) {
    if (start > end) {
        res.push_back(nums);
        return;
    }
    for (int i = start; i <= end; ++i) {
        if (i != start && nums[start] == nums[i]) continue;
        swap(nums[start], nums[i]);
        permuteUniqueDFS(nums, start+1, end, res);
    }
}
};

```

10.5 Next Permutation (M)

Implement next permutation, which rearranges numbers into the lexicographically next greater permutation of numbers. If such arrangement is not possible, it must rearrange it as the lowest possible order (ie, sorted in ascending order). The replacement must be in-place, do not allocate extra memory.

Here are some examples. Inputs are in the left-hand column and its corresponding outputs are in the right-hand column.

```

1,2,3 -> 1,3,2
3,2,1 -> 1,2,3
1,1,5 -> 1,5,1

```

```

class Solution(object):
    def nextPermutation(self, nums):
        """
        :type nums: List[int]
        :rtype: None Do not return anything, modify nums in-place instead.
        """
        n = len(nums)
        for i in range(n - 2, -1, -1):
            # find the first decreasing element i from right to left
            if nums[i+1] > nums[i]:

```

```

        # find the next larger element than i
        for j in range(n - 1, i, -1):
            if nums[j] > nums[i]: break
        # swap i and j
        nums[i], nums[j] = nums[j], nums[i]
        # reverse all elements after i
        nums[i+1:] = reversed(nums[i+1:])
        return
    # if no next larger permutation, reverse the nums as the next permutation
    nums.reverse()

```

```

// 1. Find the first num that is smaller than 7:
//    1  2# 7  4  3  1
// 2. Find the first num that is larger than 2:
//    1  2  7  4  3# 1
// 3. Swap 2 and 3:
//    1  3# 7  4  2# 1
// 4. Reverse the left numbers after 3:
//    1  3  1# 2# 4# 7#
class Solution {
public:
    void nextPermutation(vector<int> &num) {
        int i, j, n = num.size();
        for (i = n - 2; i >= 0; --i) {
            if (num[i + 1] > num[i]) { // step 1
                for (j = n - 1; j >= i; --j) {
                    if (num[j] > num[i]) break; // step 2
                }
                swap(num[i], num[j]); // step 3
                reverse(num.begin() + i + 1, num.end()); // step 4
                return;
            }
        }
        reverse(num.begin(), num.end()); // reverse nums if no next permutation
    }
};

```

10.6 Permutation Sequence (M)

The set $[1, 2, 3, \dots, n]$ contains a total of $n!$ unique permutations. By listing and labeling all of the permutations in order, We get the following sequence (i.e., for $n = 3$): "123"

"132"

"213"

"231"

"312"

"321"

Given n and k, return the kth permutation sequence.

Note: Given n will be between 1 and 9 inclusive.

```
class Solution {
public:
    string getPermutation(int n, int k) {
        string res;
        string num = "123456789";
        vector<int> f(n, 1);
        for (int i = 1; i < n; ++i) {
            f[i] = f[i - 1] * i; // compute 1!, 2!, ...
        }
        --k; // align index
        for (int i = n; i >= 1; --i) {
            int j = k / f[i - 1];
            k %= f[i - 1];
            res.push_back(num[j]);
            num.erase(j, 1);
        }
        return res;
    }
};
```

10.7 Combinations (M)

Given two integers n and k, return all possible combinations of k numbers out of 1 ... n.

For example, If n = 4 and k = 2, a solution is: [[2,4], [3,4], [2,3], [1,2], [1,3], [1,4]]

```
class Solution(object):
    def combine(self, n, k):
        """
        :type n: int
        :type k: int
        :rtype: List[List[int]]
        """
        out, res = [], []
        self.helper(n, k, 1, out, res)
        return res
    def helper(self, n, k, idx, out, res):
        if len(out) == k:
            res.append(list(out))
            return
```

```

        for i in range(idx, n+1):
            out.append(i)
            self.helper(n, k, i+1, out, res)
            out.pop()

```

```

class Solution {
public:
    vector<vector<int>> combine(int n, int k) {
        vector<vector<int>> res;
        vector<int> out;
        if (k > n) return res;
        combineDFS(res, out, 1, n, k);
        return res;
    }
    void combineDFS(vector<vector<int>> &res, vector<int> &out, int start, int
        end, int k) {
        if (k == 0) res.push_back(out);
        for (int i = start; i <= end; ++i) {
            out.push_back(i);
            combineDFS(res, out, i+1, end, k-1);
            out.pop_back();
        }
    }
};

```

10.8 Combination Sum (M)

Given a set of candidate numbers (C) and a target number (T), find all unique combinations in C where the candidate numbers sums to T. The same repeated number may be chosen from C unlimited number of times.

Note:

All numbers (including target) will be positive integers.

The solution set must not contain duplicate combinations.

For example, given candidate set [2, 3, 6, 7] and target 7, A solution set is: [[7], [2, 2, 3]]

```

class Solution(object):
    def combinationSum(self, candidates, target):
        """
        :type candidates: List[int]
        :type target: int
        :rtype: List[List[int]]
        """

```

```

        res = []
        out = []
        self.comb(candidates, target, 0, out, res)
        return res
def comb(self, candidates, target, idx, out, res):
    if target < 0: return
    if target == 0:
        # It's needed to append a list to res for creating a list of lists
        res.append(list(out))
        return
    for i in range(idx, len(candidates), 1):
        out.append(candidates[i])
        self.comb(candidates, target-candidates[i], i, out, res)
        out.pop()

```

```

class Solution {
public:
    vector<vector<int>> combinationSum(vector<int>& candidates, int target) {
        vector<vector<int>> res;
        vector<int> out;
        sort(candidates.begin(), candidates.end());
        combinationSumDFS(candidates, target, out, res, 0);
        return res;
    }
    void combinationSumDFS(vector<int>& candidates, int target, vector<int>& out,
        vector<vector<int>> &res, int index) {
        if (target < 0) {
            return;
        } else if (target == 0) {
            res.push_back(out);
        } else {
            for (int i = index; i < candidates.size(); ++i) {
                out.push_back(candidates[i]);
                combinationSumDFS(candidates, target-candidates[i], out, res, i);
                out.pop_back();
            }
        }
    }
};

```

10.9 Combination Sum II (M)

Given a collection of candidate numbers (C) and a target number (T), find all unique combinations in C where the candidate numbers sums to T. Each number in C may only be used once in the combination.

Note:

All numbers (including target) will be positive integers.

The solution set must not contain duplicate combinations.

For example, given candidate set [10, 1, 2, 7, 6, 1, 5] and target 8, A solution set is: [[1, 7], [1, 2, 5], [2, 6], [1, 1, 6]]

```
class Solution(object):
    def combinationSum2(self, candidates, target):
        """
        :type candidates: List[int]
        :type target: int
        :rtype: List[List[int]]
        """
        out, res = [], []
        candidates.sort()
        self.comb(candidates, target, 0, out, res)
        return res
    def comb(self, candidates, target, idx, out, res):
        if target < 0: return
        if target == 0:
            res.append(list(out))
            return
        for i in range(idx, len(candidates)):
            # remove duplicates
            if i > idx and candidates[i] == candidates[i-1]: continue
            out.append(candidates[i])
            self.comb(candidates, target-candidates[i], i+1, out, res)
            out.pop()
```

```
class Solution {
public:
    vector<vector<int>> combinationSum2(vector<int>& candidates, int target) {
        vector<vector<int>> res;
        vector<int> out;
        sort(candidates.begin(), candidates.end());
        combinationSum2DFS(candidates, target, out, res, 0);
        return res;
    }
    void combinationSum2DFS(vector<int>& candidates, int target, vector<int>& out, vector<vector<int>> &res, int index) {
        if (target < 0) {
            return;
        } else if (target == 0) {
            res.push_back(out);
        }
    }
};
```

```

    } else {
        for (int i = index; i < candidates.size(); ++i) {
            if (i == index || candidates[i] != candidates[i-1]) { //skip
                duplicates
                out.push_back(candidates[i]);
                combinationSum2DFS(candidates, target-candidates[i], out, res,
                    i+1); //update i to i+1
                out.pop_back();
            }
        }
    }
}
};

```

10.10 Combination Sum III (M)

Find all possible combinations of k numbers that add up to a number n, given that only numbers from 1 to 9 can be used and each combination should be a unique set of numbers.

Example 1:

Input: k = 3, n = 7

Output: [[1,2,4]]

Example 2:

Input: k = 3, n = 9

Output: [[1,2,6], [1,3,5], [2,3,4]]

```

class Solution(object):
    def combinationSum3(self, k, n):
        """
        :type k: int
        :type n: int
        :rtype: List[List[int]]
        """
        out, res = [], []
        self.comb(k, n, 1, out, res)
        return res
    def comb(self, k, n, idx, out, res):
        if k < 0 or n < 0: return
        if k == 0 and n == 0:
            res.append(list(out))
            return
        for i in range(idx, 10):
            out.append(i)

```



```
        self.comb(k-1, n-i, i+1, out, res)
        out.pop()
```

```
class Solution {
public:
    vector<vector<int>> combinationSum3(int k, int n) {
        vector<vector<int>> res;
        vector<int> out;
        combinationSum3DFS(k, n, out, res, 1);
        return res;
    }
    void combinationSum3DFS(int k, int n, vector<int>& out, vector<vector<int>>
        &res, int index) {
        if (n < 0) {
            return;
        } else if (k == 0 && n == 0) {
            res.push_back(out);
        } else {
            for (int i = index; i <= 9; ++i) {
                out.push_back(i);
                combinationSum3DFS(k-1, n-i, out, res, i+1);
                out.pop_back();
            }
        }
    }
};
```

10.11 Combination Sum IV (M)

Given an integer array with all positive numbers and no duplicates, find the number of possible combinations that add up to a positive integer target.

Example:

nums = [1, 2, 3]

target = 4

The possible combination ways are:

(1, 1, 1, 1)

(1, 1, 2)

(1, 2, 1)

(1, 3)

(2, 1, 1)

(2, 2)

(3, 1)

Note that different sequences are counted as different combinations. Therefore the output is 7.

```
# Get all combinations and count
class Solution(object):
    def combinationSum4(self, nums, target):
        """
        :type nums: List[int]
        :type target: int
        :rtype: int
        """
        out, res = [], []
        self.comb(nums, target, 0, out, res)
        return len(res)
    def comb(self, nums, target, idx, out, res):
        if target < 0: return
        if target == 0:
            res.append(list(out))
            return
        for i in range(len(nums)):
            out.append(nums[i])
            self.comb(nums, target-nums[i], i, out, res)
            out.pop()

# Count combinations
class Solution(object):
    def combinationSum4(self, nums, target):
        """
        :type nums: List[int]
        :type target: int
        :rtype: int
        """
        if target == 0:
            return 1
        res = 0
        for i in range(len(nums)):
            if target >= nums[i]:
                res += self.combinationSum4(nums, target-nums[i])
        return res

# DP
class Solution(object):
    def combinationSum4(self, nums, target):
        """
        :type nums: List[int]
        :type target: int
```

```

:rtype: int
"""
dp = [0 for i in range(target+1)]
dp[0] = 1
for i in range(1, target+1):
    for j in nums:
        if i >= j: dp[i] += dp[i-j]
return dp[-1]

```

10.12 Target Sum (M)

You are given a list of non-negative integers, a_1, a_2, \dots, a_n , and a target, S . Now you have 2 symbols $+$ and $-$. For each integer, you should choose one from $+$ and $-$ as its new symbol.

Find out how many ways to assign symbols to make sum of integers equal to target S .

Example 1:

Input: nums is $[1, 1, 1, 1, 1]$, S is 3.

Output: 5

Explanation:

```

-1+1+1+1+1 = 3
+1-1+1+1+1 = 3
+1+1-1+1+1 = 3
+1+1+1-1+1 = 3
+1+1+1+1-1 = 3

```

There are 5 ways to assign symbols to make the sum of nums be target 3.

Note:

The length of the given array is positive and will not exceed 20.

The sum of elements in the given array will not exceed 1000.

Your output answer is guaranteed to be fitted in a 32-bit integer.

```

# Time:  $O(2^N)$  Space:  $O(N)$ 
class Solution(object):
    def findTargetSumWays(self, nums, S):
        """
        :type nums: List[int]
        :type S: int
        :rtype: int

```

```

    """
    idx = 0
    self.res = 0
    self.helper(nums, S, idx)
    return self.res
def helper(self, nums, S, idx):
    if idx == len(nums):
        if S == 0: self.res += 1
        return
    self.helper(nums, S - nums[idx], idx + 1)
    self.helper(nums, S + nums[idx], idx + 1)

```

10.13 Factor Combinations (M)

Numbers can be regarded as product of its factors. For example, $8 = 2 \times 2 \times 2 = 2 \times 4$.

Write a function that takes an integer n and return all possible combinations of its factors.

Note:

Each combination's factors must be sorted ascending, for example: The factors of 2 and 6 is [2, 6], not [6, 2].

You may assume that n is always positive.

Factors should be greater than 1 and less than n .

Examples:

input: 1 output: []

input: 37 output: []

input: 12 output: [[2, 6], [2, 2, 3], [3, 4]]

input: 32 output: [[2, 16], [2, 2, 8], [2, 2, 2, 4], [2, 2, 2, 2, 2], [2, 4, 4], [4, 8]]

```

class Solution {
public:
    vector<vector<int>> getFactors(int n) {
        vector<vector<int>> res;
        dfs(n, 2, {}, res);
        return res;
    }
    void dfs(int n, int start, vector<int> out, vector<vector<int>> &res) {
        if (n == 1) {
            if (out.size() > 1) res.push_back(out);
        } else {

```

```

        for (int i = start; i <= n; ++i) {
            if (n % i == 0) {
                out.push_back(i);
                dfs(n / i, i, out, res);
                out.pop_back();
            }
        }
    }
};

```

10.14 Letter Combinations of a Phone Number (M)

Given a digit string, return all possible letter combinations that the number could represent.

Input: Digit string "23"

Output: ["ad", "ae", "af", "bd", "be", "bf", "cd", "ce", "cf"].

Note: Although the above answer is in lexicographical order, your answer could be in any order you want.

```

class Solution(object):
    def letterCombinations(self, digits):
        """
        :type digits: str
        :rtype: List[str]
        """
        if not digits: return []
        idx = 0
        out = ''
        res = []
        d = {0:'', 1:'', 2:'abc', 3:'def', 4:'ghi', 5:'jkl',
              6:'mno', 7:'pqrs', 8:'tuv', 9:'wxyz'}
        self.dfs(digits, d, idx, out, res)
        return res
    def dfs(self, digits, d, idx, out, res):
        if idx == len(digits):
            res.append(out)
            return
        digit = int(digits[idx])
        letters = d[digit]
        for letter in letters:
            self.dfs(digits, d, idx + 1, out + letter, res)

```

```

// 1. Recursion
class Solution {
public:
    vector<string> letterCombinations(string digits) {
        vector<string> res;
        if (digits.empty()) return res;
        string dict[] = {"abc", "def", "ghi", "jkl", "mno", "pqrs", "tuv",
            "wxyz"};
        letterCombinationsDFS(digits, dict, 0, "", res);
        return res;
    }
    void letterCombinationsDFS(string digits, string dict[], int level, string
        out, vector<string> &res) {
        if (level == digits.size()) res.push_back(out);
        else {
            string str = dict[digits[level] - '2'];
            for (int i = 0; i < str.size(); ++i) {
                out.push_back(str[i]);
                letterCombinationsDFS(digits, dict, level + 1, out, res);
                out.pop_back();
            }
        }
    }
};

// 2. Iterative
class Solution {
public:
    vector<string> letterCombinations(string digits) {
        vector<string> res;
        if (digits.empty()) return res;
        string dict[] = {"abc", "def", "ghi", "jkl", "mno", "pqrs", "tuv",
            "wxyz"};
        res.push_back("");
        for (int i = 0; i < digits.size(); ++i) {
            int n = res.size();
            string str = dict[digits[i] - '2'];
            for (int j = 0; j < n; ++j) {
                string tmp = res.front();
                res.erase(res.begin());
                for (int k = 0; k < str.size(); ++k) {
                    res.push_back(tmp + str[k]);
                }
            }
        }
        return res;
    }
};

```

```

};

// 3. Iterative 2
class Solution {
public:
    vector<string> letterCombinations(string digits) {
        vector<string> res;
        if (digits.empty()) return res;
        vector<string> str = {"", "", "abc", "def", "ghi", "jkl", "mno", "pqrs",
            "tuv", "wxyz"};
        res.push_back("");
        for (int i = 0; i < digits.size(); ++i) {
            vector<string> tmp;
            int index = digits[i] - '0';
            for (int j = 0; j < str[index].size(); ++j) {
                for (int k = 0; k < res.size(); ++k) {
                    tmp.push_back(res[k]+str[index][j]);
                }
            }
            res = tmp;
        }
        return res;
    }
};

```

10.15 Walls and Gates (M)

You are given a $m \times n$ 2D grid initialized with these three possible values.

-1 - A wall or an obstacle.

0 - A gate.

INF - Infinity means an empty room. We use the value $231 - 1 = 2147483647$ to represent INF as you may assume that the distance to a gate is less than 2147483647.

Fill each empty room with the distance to its nearest gate. If it is impossible to reach a gate, it should be filled with INF.

For example, given the 2D grid:

```

INF -1 0 INF
INF INF INF -1
INF -1 INF -1
0 -1 INF INF

```

After running your function, the 2D grid should be:

```

3 -1 0 1
2 2 1 -1

```

```
1 -1 2 -1
0 -1 3 4
```

```
def wallsAndGates(self, rooms):
    dist = 0
    for i in range(len(rooms)):
        for j in range(len(rooms[0])):
            # start the dfs search from the gate
            if rooms[i][j] == 0: self.dfs(rooms, i, j, dist)
def self.dfs(self, rooms, i, j, dist):
    if i < 0 or i >= len(rooms) or \
        j < 0 or j >= len(rooms[0]) or \
        rooms[i][j] < dist:
        return
    # update the current room val based on
    # the distance between the current room and the gate
    rooms[i][j] = dist
    # search 4 directions from the current room and increase the distance
    self.dfs(rooms, i + 1, j, dist + 1)
    self.dfs(rooms, i - 1, j, dist + 1)
    self.dfs(rooms, i, j + 1, dist + 1)
    self.dfs(rooms, i, j - 1, dist + 1)
```

```
class Solution {
public:
    void wallsAndGates(vector<vector<int>>& rooms) {
        for (int i = 0; i < rooms.size(); ++i) {
            for (int j = 0; j < rooms[i].size(); ++j) {
                if (rooms[i][j] == 0) {
                    dfs(rooms, i, j, 0);
                }
            }
        }
    }
    void dfs(vector<vector<int>> &rooms, int i, int j, int val) {
        if (i < 0 || i >= rooms.size() || j < 0 || j >= rooms[i].size() ||
            rooms[i][j] < val) return;
        rooms[i][j] = val;
        dfs(rooms, i + 1, j, val + 1);
        dfs(rooms, i - 1, j, val + 1);
        dfs(rooms, i, j + 1, val + 1);
        dfs(rooms, i, j - 1, val + 1);
    }
};
```

10.16 Shortest Path in Binary Matrix (M)

In an N by N square grid, each cell is either empty (0) or blocked (1). Return the length of the shortest such clear path from top-left to bottom-right. If such a path does not exist, return -1.

```
class Solution(object):
    def shortestPathBinaryMatrix(self, grid):
        """
        :type grid: List[List[int]]
        :rtype: int
        """
        n = len(grid)
        if grid[0][0] == 1 or grid[n-1][n-1] == 1:
            return -1
        q = [(0, 0, 1)]
        # search coordinates (i, j) and the depth d with BFS
        for i, j, d in q:
            # reach the bottom-right, d is the shortest path
            if i == n-1 and j == n-1: return d
            # search 8 directions
            for x, y in ((i-1, j-1), (i-1, j), (i-1, j+1), \
                        (i, j-1), (i, j+1), \
                        (i+1, j-1), (i+1, j), (i+1, j+1)):
                if 0 <= x < n and 0 <= y < n and grid[x][y] == 0:
                    grid[x][y] = 1 # for visited grid, set its value to 1
                    q.append((x, y, d+1)) # add the path to q
        return -1

# Standard BFS
class Solution(object):
    def shortestPathBinaryMatrix(self, grid):
        """
        :type grid: List[List[int]]
        :rtype: int
        """
        n = len(grid)
        if grid[0][0] == 1 or grid[n-1][n-1] == 1:
            return -1
        q = [(0, 0, 1)]
        visited = [[False for j in range(n)] for i in range(n)]
        while q:
            i, j, d = q.pop()
            if i == n-1 and j == n-1: return d
            for x, y in ((i-1, j-1), (i-1, j), (i-1, j+1), \
                        (i, j-1), (i, j+1), \
                        (i+1, j-1), (i+1, j), (i+1, j+1)):
```

```

        if 0 <= x < n and 0 <= y < n and \
            grid[x][y] == 0 and visited[x][y] == False:
                visited[x][y] = True
                q.insert(0, (x, y, d+1))
    return -1

```

10.17 Surrounded Regions (M)

Given a 2D board containing 'X' and 'O' (the letter O), capture all regions surrounded by 'X'. A region is captured by flipping all 'O's into 'X's in that surrounded region.

For example,

```

X X X X
X O O X
X X O X
X O X X

```

After running your function, the board should be:

```

X X X X
X X X X
X X X X
X O X X

```

```

class Solution {
public:
    void solve(vector<vector<char> >& board) {
        // if 0 exists on the most outside rows and columns of the board,
        // the 0 will never be surrounded by X
        for (int i = 0; i < board.size(); ++i) {
            for (int j = 0; j < board[i].size(); ++j) {
                if ((i == 0 || i == board.size() - 1 || j == 0 || j ==
                    board[i].size() - 1)
                    && board[i][j] == 'O')
                    solveDFS(board, i, j);
            }
        }
        // flip all 0 to X, flip all N to 0
        for (int i = 0; i < board.size(); ++i) {
            for (int j = 0; j < board[i].size(); ++j) {
                if (board[i][j] == 'O') board[i][j] = 'X';
                if (board[i][j] == 'N') board[i][j] = 'O';
            }
        }
    }
}

```

```

// search if there are any 0's connected to the current 0
// set all of them to N
void solveDFS(vector<vector<char> > &board, int i, int j) {
    if (board[i][j] == '0') {
        board[i][j] = 'N';
        if (i > 0 && board[i - 1][j] == '0')
            solveDFS(board, i - 1, j);
        if (i < board.size() - 1 && board[i + 1][j] == '0')
            solveDFS(board, i + 1, j);
        if (j > 1 && board[i][j - 1] == '0')
            solveDFS(board, i, j - 1);
        if (j < board[i].size() - 1 && board[i][j + 1] == '0')
            solveDFS(board, i, j + 1);
    }
}
};

```

10.18 Battleships in a Board (M)

Given an 2D board, count how many battleships are in it. The battleships are represented with 'X's, empty slots are represented with '.'s. You may assume the following rules:

You receive a valid board, made of only battleships or empty slots.

Battleships can only be placed horizontally or vertically. In other words, they can only be made of the shape 1xN (1 row, N columns) or Nx1 (N rows, 1 column), where N can be of any size.

At least one horizontal or vertical cell separates between two battleships - there are no adjacent battleships.

```

# Find the first X of the battleship
# skip all . and intermediate X
class Solution(object):
    def countBattleships(self, board):
        """
        :type board: List[List[str]]
        :rtype: int
        """
        res = 0
        m = len(board)
        n = len(board[0])
        for i in range(m):
            for j in range(n):
                if (board[i][j] == '.' or \
                    (i > 0 and board[i-1][j] == 'X') or \

```

```

        (j > 0 and board[i][j-1] == 'X'):
            continue
        res += 1
    return res

```

10.19 Number of Islands (M)

Given a 2d grid map of '1's (land) and '0's (water), count the number of islands. An island is surrounded by water and is formed by connecting adjacent lands horizontally or vertically. You may assume all four edges of the grid are all surrounded by water.

Example 1:

11110

11010

11000

00000

Answer: 1

Example 2:

11000

11000

00100

00011

Answer: 3

```

class Solution(object):
    def numIslands(self, grid):
        """
        :type grid: List[List[str]]
        :rtype: int
        """
        if not grid or not grid[0]: return 0
        m, n = len(grid), len(grid[0])
        visited = [[False for j in range(n)] for i in range(m)]
        res = 0
        for i in range(m):
            for j in range(n):
                if grid[i][j] == '0' or visited[i][j]: continue
                self.dfs(grid, visited, i, j)
                res += 1
        return res
    def dfs(self, grid, visited, i, j):
        if i < 0 or i >= len(grid) or j < 0 or j >= len(grid[0]) or \
            grid[i][j] == '0' or visited[i][j]: return

```

```

        visited[i][j] = True
        self.dfs(grid, visited, i - 1, j)
        self.dfs(grid, visited, i + 1, j)
        self.dfs(grid, visited, i, j - 1)
        self.dfs(grid, visited, i, j + 1)

```

```

class Solution {
public:
    int numIslands(vector<vector<char> > &grid) {
        if (grid.empty() || grid[0].empty()) return 0;
        int m = grid.size(), n = grid[0].size(), res = 0;
        vector<vector<bool> > visited(m, vector<bool>(n, false));
        for (int i = 0; i < m; ++i) {
            for (int j = 0; j < n; ++j) {
                if (grid[i][j] == '1' && !visited[i][j]) {
                    numIslandsDFS(grid, visited, i, j);
                    ++res;
                }
            }
        }
        return res;
    }
    void numIslandsDFS(vector<vector<char> > &grid, vector<vector<bool> >
        &visited, int x, int y) {
        if (x < 0 || x >= grid.size()) return;
        if (y < 0 || y >= grid[0].size()) return;
        if (grid[x][y] != '1' || visited[x][y]) return;
        visited[x][y] = true; // grid[x][y] is visited now
        // search other 4 direction of grid[x][y]
        numIslandsDFS(grid, visited, x - 1, y);
        numIslandsDFS(grid, visited, x + 1, y);
        numIslandsDFS(grid, visited, x, y - 1);
        numIslandsDFS(grid, visited, x, y + 1);
    }
};

```

10.20 Number of Islands II (H)

A 2d grid map of m rows and n columns is initially filled with water. We may perform an `addLand` operation which turns the water at position (row, col) into a land. Given a list of positions to operate, count the number of islands after each `addLand` operation. An island is surrounded by water and is formed by connecting adjacent lands horizontally or vertically. You may assume all four edges of the grid are all surrounded by water.

Example:

Given $m = 3$, $n = 3$, $\text{positions} = [[0,0], [0,1], [1,2], [2,1]]$.

Initially, the 2d grid `grid` is filled with water. (Assume 0 represents water and 1 represents land).

```
0 0 0
0 0 0
0 0 0
```

Operation #1: `addLand(0, 0)` turns the water at `grid[0][0]` into a land.

```
1 0 0
0 0 0 Number of islands = 1
0 0 0
```

Operation #2: `addLand(0, 1)` turns the water at `grid[0][1]` into a land.

```
1 1 0
0 0 0 Number of islands = 1
0 0 0
```

Operation #3: `addLand(1, 2)` turns the water at `grid[1][2]` into a land.

```
1 1 0
0 0 1 Number of islands = 2
0 0 0
```

Operation #4: `addLand(2, 1)` turns the water at `grid[2][1]` into a land.

```
1 1 0
0 0 1 Number of islands = 3
0 1 0
```

We return the result as an array: `[1, 1, 2, 3]`

Challenge: Can you do it in time complexity $O(k \log mn)$, where k is the length of the positions?

```
class Solution {
public:
    vector<int> numIslands2(int m, int n, vector<pair<int, int>>& positions) {
        vector<int> res;
        if (m <= 0 || n <= 0) return res;
        vector<int> roots(m * n, -1);
        int cnt = 0;
        vector<vector<int>> dirs{{0, -1}, {-1, 0}, {0, 1}, {1, 0}};
        for (auto a : positions) {
            int id = n * a.first + a.second;
            roots[id] = id;
            ++cnt;
        }
    }
};
```

```

        for (auto d : dirs) {
            int x = a.first + d[0], y = a.second + d[1];
            int cur_id = n * x + y;
            if (x < 0 || x >= m || y < 0 || y >= n || roots[cur_id] == -1)
                continue;
            int new_id = findRoots(roots, cur_id);
            if (id != new_id) {
                roots[id] = new_id;
                id = new_id;
                --cnt;
            }
        }
        res.push_back(cnt);
    }
    return res;
}

int findRoots(vector<int> &roots, int id) {
    while (id != roots[id]) {
        roots[id] = roots[roots[id]];
        id = roots[id];
    }
    return id;
}
};

```

10.21 Word Search (M)

Given a 2D board and a word, find if the word exists in the grid. The word can be constructed from letters of sequentially adjacent cell, where "adjacent" cells are those horizontally or vertically neighboring. The same letter cell may not be used more than once.
 For example, Given board = [['A','B','C','E'], ['S','F','C','S'], ['A','D','E','E']]

word = "ABCCED", returns true,
 word = "SEE", returns true,
 word = "ABCB", returns false.

```

class Solution(object):
    def exist(self, board, word):
        """
        :type board: List[List[str]]
        :type word: str
        :rtype: bool
        """
        m, n = len(board), len(board[0])
        visited = [[False for j in range(n)] for i in range(m)]

```

```

    idx, res = 0, 0
    for i in range(m):
        for j in range(n):
            if self.search(board, word, idx, i, j, visited): return True
    return False
def search(self, board, word, idx, i, j, visited):
    if idx == len(word): return True
    if i < 0 or i >= len(visited) or j < 0 or j >= len(visited[0]) or \
        visited[i][j] or board[i][j] != word[idx]:
        return False
    visited[i][j] = True
    # if we can find the next char in any direction, then res is true
    res = self.search(board, word, idx+1, i+1, j, visited) or \
        self.search(board, word, idx+1, i, j+1, visited) or \
        self.search(board, word, idx+1, i-1, j, visited) or \
        self.search(board, word, idx+1, i, j-1, visited)
    # reset visited status
    visited[i][j] = False
    return res

```

```

class Solution {
public:
    bool exist(vector<vector<char> > &board, string word) {
        if (word.empty()) return true;
        if (board.empty() || board[0].empty()) return false;
        vector<vector<bool> > visited(board.size(), vector<bool>(board[0].size(),
            false));
        for (int i = 0; i < board.size(); ++i) {
            for (int j = 0; j < board[i].size(); ++j) {
                if (search(board, word, 0, i, j, visited)) return true;
            }
        }
        return false;
    }
    bool search(vector<vector<char> > &board, string word, int idx, int i, int j,
        vector<vector<bool> > &visited) {
        if (idx == word.size()) return true;
        if (i < 0 || j < 0 || i >= board.size() || j >= board[0].size() ||
            visited[i][j] || board[i][j] != word[idx]) return false;
        visited[i][j] = true;
        bool res = search(board, word, idx + 1, i - 1, j, visited)
            || search(board, word, idx + 1, i + 1, j, visited)
            || search(board, word, idx + 1, i, j - 1, visited)
            || search(board, word, idx + 1, i, j + 1, visited);
        visited[i][j] = false;
        return res;
    }
}

```



```
};
```

10.22 Word Search debugging (Microsoft phone interview 2019.5.31)

```
def dfs(matrix, target, row, col, path, results, visited):
    # bug 4
    if target == '':
        results.append(path)
        return
    m = len(matrix)
    n = len(matrix[0])
    # bug 1: skip corner conditions
    if row < 0 or col < 0 or row >= m or col >= n: return
    if target[0] != matrix[row][col]:
        return
    # bug 1: skip visited element
    if visited[row][col]:
        return
    # bug 3: update visited array
    visited[row][col] = True
    dfs(matrix, target[1:], row-1, col, path + [(row, col)], results, visited)
    dfs(matrix, target[1:], row+1, col, path + [(row, col)], results, visited)
    dfs(matrix, target[1:], row, col-1, path + [(row, col)], results, visited)
    dfs(matrix, target[1:], row, col+1, path + [(row, col)], results, visited)
    visited[row][col] = False

def findWords(matrix, target):
    m = len(matrix)
    n = len(matrix[0])
    results = []
    # bug 2: need to add a visited 2d array
    visited = [ [ False for col in range(n) ] for row in range(m) ]
    for row in range(m):
        for col in range(n):
            dfs(matrix, target, row, col, [], results, visited)
    return results

if __name__ == '__main__':
    matrix = [ 'OMIC',
               'OSOR',
               'FTAZ',
               'BYWK' ]
    target = 'MICROSOFT'
    print(findWords(matrix, target))
```

10.23 Word Search II (H)

Given a 2D board and a list of words from the dictionary, find all words in the board. Each word must be constructed from letters of sequentially adjacent cell, where "adjacent" cells are those horizontally or vertically neighboring. The same letter cell may not be used more than once in a word.

For example, Given words = ["oath","pea","eat","rain"] and board = [['o','a','a','n'], ['e','t','a','e'], ['i','h','k','r'], ['i','f','l','v']]

Return ["eat","oath"].

Note: You may assume that all inputs are consist of lowercase letters a-z.

You would need to optimize your backtracking to pass the larger test. Could you stop backtracking earlier?

If the current candidate does not exist in all words' prefix, you could stop backtracking immediately. What kind of data structure could answer such query efficiently? Does a hash table work? Why or why not? How about a Trie? If you would like to learn how to implement a basic trie, please work on this problem: Implement Trie (Prefix Tree) first.

```
class Solution {
public:
    struct TrieNode {
        TrieNode *child[26];
        string str;
        TrieNode() : str("") {
            for (auto &a : child) a = NULL;
        }
    };
    struct Trie {
        TrieNode *root;
        Trie() : root(new TrieNode()) {}
        void insert(string s) {
            TrieNode *p = root;
            for (auto &a : s) {
                int i = a - 'a';
                if (!p->child[i]) p->child[i] = new TrieNode();
                p = p->child[i];
            }
            p->str = s;
        }
    };
};
```

```

};
vector<string> findWords(vector<vector<char> >& board, vector<string>& words)
{
    vector<string> res;
    if (words.empty() || board.empty() || board[0].empty()) return res;
    vector<vector<bool> > visit(board.size(), vector<bool>(board[0].size(),
        false));
    Trie T;
    for (auto &a : words) T.insert(a);
    for (int i = 0; i < board.size(); ++i) {
        for (int j = 0; j < board[i].size(); ++j) {
            if (T.root->child[board[i][j] - 'a']) {
                search(board, T.root->child[board[i][j] - 'a'], i, j, visit,
                    res);
            }
        }
    }
    return res;
}

void search(vector<vector<char> > &board, TrieNode *p, int i, int j,
    vector<vector<bool> > &visit, vector<string> &res) {
    if (!p->str.empty()) {
        res.push_back(p->str);
        p->str.clear();
    }
    int d[][2] = {{-1, 0}, {1, 0}, {0, -1}, {0, 1}};
    visit[i][j] = true;
    for (auto &a : d) {
        int nx = a[0] + i, ny = a[1] + j;
        if (nx >= 0 && nx < board.size() && ny >= 0 && ny < board[0].size()
            && !visit[nx][ny] && p->child[board[nx][ny] - 'a']) {
            search(board, p->child[board[nx][ny] - 'a'], nx, ny, visit, res);
        }
    }
    visit[i][j] = false;
}

};

```

10.24 Accounts Merge (M)

Given a list accounts, each element accounts[i] is a list of strings, where the first element accounts[i][0] is a name, and the rest of the elements are emails representing emails of the account.

Now, we would like to merge these accounts. Two accounts definitely belong to the same

person if there is some email that is common to both accounts. Note that even if two accounts have the same name, they may belong to different people as people could have the same name. A person can have any number of accounts initially, but all of their accounts definitely have the same name.

After merging the accounts, return the accounts in the following format: the first element of each account is the name, and the rest of the elements are emails in sorted order. The accounts themselves can be returned in any order.

Example 1:

Input:

```
accounts = [{"John", "johnsmith@mail.com", "john00@mail.com"}, {"John", "johnnybravo@mail.com"}, {"John", "john00@mail.com", "john_ewyork@mail.com", "johnsmith@mail.com"}, {"John", "johnnybravo@mail.com"}]
```

Explanation:

The first and third John's are the same person as they have the common email "johnsmith@mail.com". The second John and Mary are different people as none of their email addresses are used by other accounts.

We could return these lists in any order, for example the answer `[["Mary", "mary@mail.com"], ["John", "johnsmith@mail.com", "john00@mail.com"], ["John", "johnnybravo@mail.com"]]` would still be accepted.

Note:

The length of accounts will be in the range [1, 1000].

The length of accounts[i] will be in the range [1, 10].

The length of accounts[i][j] will be in the range [1, 30].

-
- # 1. Give each account an ID, based on the index of it within the list of accounts.
 - # 2. Build an emails_accounts_map that maps an email to a list of accounts, which can be used to track which email is linked to which account. This is essentially our graph.
 - # 3. Perform a DFS on each account in accounts list and look up emails_accounts_map to tell which accounts are linked to that particular account via common emails. This will make sure we visit each account only once. This is a recursive process and we should collect all the emails that we encounter along the way.
 - # 4 Sort the collected emails and add it to final results, res along with the name.

```
class Solution(object):
    def accountsMerge(self, accounts):
        """
        :type accounts: List[List[str]]
        :rtype: List[List[str]]
        """
        visited = [False] * len(accounts)
```

```

emails_accounts_map = {}
res = []
# Build the mapping between email and account idx in accounts
for idx, account in enumerate(accounts):
    for j in range(1, len(account)):
        email = account[j]
        if email in emails_accounts_map:
            emails_accounts_map[email].append(idx)
        else:
            emails_accounts_map[email] = [idx]
# Perform DFS for accounts and add to results.
for idx, account in enumerate(accounts):
    if visited[idx]: continue
    name, emails = account[0], set()
    self.dfs(idx, emails, visited, accounts, emails_accounts_map)
    res.append([name] + sorted(emails))
return res

def dfs(self, i, emails, visited, accounts, emails_accounts_map):
    if visited[i]: return
    visited[i] = True
    for j in range(1, len(accounts[i])):
        email = accounts[i][j]
        emails.add(email)
        for idx in emails_accounts_map[email]:
            self.dfs(idx, emails, visited, accounts, emails_accounts_map)

```

10.25 Word Ladder (M)

Given two words (beginWord and endWord), and a dictionary's word list, find the length of shortest transformation sequence from beginWord to endWord, such that:

Only one letter can be changed at a time

Each intermediate word must exist in the word list

For example,

Given: beginWord = "hit" endWord = "cog" wordList = ["hot","dot","dog","lot","log"] As one shortest transformation is "hit" -> "hot" -> "dot" -> "dog" -> "cog", return its length 5.

Note:

Return 0 if there is no such transformation sequence.

All words have the same length.

All words contain only lowercase alphabetic characters.

```

class Solution(object):

```

```

def ladderLength(self, beginWord, endWord, wordList):
    """
    :type beginWord: str
    :type endWord: str
    :type wordList: List[str]
    :rtype: int
    """
    wordList = set(wordList) #avoid TLE
    q = [(beginWord, 1)]
    visited = set()
    alpha = string.ascii_lowercase #'abcd...z'
    while q:
        word, length = q.pop()
        if word == endWord:
            return length
        # for each char in word, iterate it from a to z
        for i in range(len(word)):
            for ch in alpha:
                new_word = word[:i] + ch + word[i+1:]
                # if any combination exists in wordList and it's not visited
                if new_word in wordList and new_word not in visited:
                    # save that combination to queue and increase the length
                    q.insert(0, (new_word, length + 1))
                    # update visited
                    visited.add(new_word)

    return 0

```

```

class Solution {
public:
    int ladderLength(string beginWord, string endWord, unordered_set<string>&
wordDict) {
        unordered_map<string, int> m;
        queue<string> q;
        m[beginWord] = 1;
        q.push(beginWord);
        while (!q.empty()) {
            string word = q.front(); q.pop();
            for (int i = 0; i < word.size(); ++i) {
                string newWord = word;
                for (char ch = 'a'; ch <= 'z'; ++ch) {
                    newWord[i] = ch;
                    if (newWord == endWord) return m[word] + 1;
                    if (wordDict.find(newWord) != wordDict.end() &&
m.find(newWord) == m.end()) {
                        q.push(newWord);
                        m[newWord] = m[word] + 1;
                    }
                }
            }
        }
    }
}

```

```

    }
    }
    }
    return 0;
}
};

```

10.26 Word Ladder II (H)

Given two words (beginWord and endWord), and a dictionary's word list, find all shortest transformation sequence(s) from beginWord to endWord, such that:

Only one letter can be changed at a time

Each intermediate word must exist in the word list

For example,

Given: beginWord = "hit" endWord = "cog" wordList = ["hot","dot","dog","lot","log"]

Return [["hit","hot","dot","dog","cog"], ["hit","hot","lot","log","cog"]]

Note:

All words have the same length.

All words contain only lowercase alphabetic characters.

```

class Solution {
public:
    vector<vector<string> > findLadders(string start, string end,
        unordered_set<string> &dict) {
        vector<vector<string> > res;
        dict.insert(end);
        vector<string> p;
        p.push_back(start);
        queue<vector<string> > paths;
        paths.push(p);
        int level = 1, minLevel = INT_MAX;
        unordered_set<string> words;
        while (!paths.empty()) {
            vector<string> path = paths.front();
            paths.pop();
            if (path.size() > level) {
                for (string w : words) dict.erase(w);
                words.clear();
                level = path.size();
                if (level > minLevel) break;
            }
        }
    }
}

```

```

        string last = path.back();
        for (int i = 0; i < last.size(); ++i) {
            string newLast = last;
            for (char ch = 'a'; ch <= 'z'; ++ch) {
                newLast[i] = ch;
                if (dict.find(newLast) != dict.end()) {
                    words.insert(newLast);
                    vector<string> nextPath = path;
                    nextPath.push_back(newLast);
                    if (newLast == end) {
                        res.push_back(nextPath);
                        minLevel = level;
                    } else paths.push(nextPath);
                }
            }
        }
    }
    return res;
}
};

```

10.27 Course Schedule (M)

There are a total of n courses you have to take, labeled from 0 to $n-1$.

Some courses may have prerequisites, for example to take course 0 you have to first take course 1, which is expressed as a pair: [0,1]

Given the total number of courses and a list of prerequisite pairs, is it possible for you to finish all courses?

Example 1:

Input: 2, [[1,0]] Output: true Explanation: There are a total of 2 courses to take. To take course 1 you should have finished course 0. So it is possible.

Example 2:

Input: 2, [[1,0],[0,1]] Output: false Explanation: There are a total of 2 courses to take. To take course 1 you should have finished course 0, and to take course 0 you should also have finished course 1. So it is impossible.

Note:

The input prerequisites is a graph represented by a list of edges, not adjacency matrices. Read more about how a graph is represented. You may assume that there are no duplicate edges in the input prerequisites.

Detecting if there is a cycle in the directed graph represented by prerequisites

We need to transform it to the adjacency-list representation. If course u is a prerequisite of course v , then the adjacency list of u will contain v .


```

# BFS: the number of visited nodes should be equal to the number of courses,
# otherwise a cycle exists
class Solution(object):
    def canFinish(self, numCourses, prerequisites):
        """
        :type numCourses: int
        :type prerequisites: List[List[int]]
        :rtype: bool
        """
        # create graph and indegree list
        # graph is a dict that mapping a node and a list of its prerequisites
        graph = {i: [] for i in range(numCourses)}
        indegree = [0 for i in range(numCourses)]
        # x -> y in graph
        # so x is the prerequisite of y, and the indegree of y is added by 1
        for x, y in prerequisites:
            graph[y].append(x)
            indegree[x] += 1

        # create queue that saves all courses without prerequisites
        # i.e. indegree = 0
        queue = []
        for i in range(numCourses):
            if indegree[i] == 0:
                queue.insert(0, i)

        # perform BFS
        visited = 0
        while queue:
            node = queue.pop()
            visited += 1
            for v in graph[node]:
                # for each visited node, reduce the indegree of all its neighbors
                # by 1
                indegree[v] -= 1
                # if any node with 0 indegree, add it to queue
                if indegree[v] == 0: queue.insert(0, v)

        # all nodes should be visited if no cycle, otherwise a cycle exists
        return visited == numCourses

# # DFS: in each visit, we start from a node and keep visiting its neighbors,
# # if at a time we return to a visited node, there is a cycle.
# # Otherwise, start again from another unvisited node and repeat this process.
# class Solution(object):
#     def canFinish(self, numCourses, prerequisites):

```

```

#         """
#         :type numCourses: int
#         :type prerequisites: List[List[int]]
#         :rtype: bool
#         """

```

10.28 Course Schedule II (M)

There are a total of n courses you have to take, labeled from 0 to $n-1$.

Some courses may have prerequisites, for example to take course 0 you have to first take course 1, which is expressed as a pair: $[0,1]$

Given the total number of courses and a list of prerequisite pairs, return the ordering of courses you should take to finish all courses.

There may be multiple correct orders, you just need to return one of them. If it is impossible to finish all courses, return an empty array.

Example 1:

Input: 2, $[[1,0]]$ Output: $[0,1]$ Explanation: There are a total of 2 courses to take. To take course 1 you should have finished course 0. So the correct course order is $[0,1]$.

Example 2:

Input: 4, $[[1,0],[2,0],[3,1],[3,2]]$ Output: $[0,1,2,3]$ or $[0,2,1,3]$ Explanation: There are a total of 4 courses to take. To take course 3 you should have finished both courses 1 and 2. Both courses 1 and 2 should be taken after you finished course 0. So one correct course order is $[0,1,2,3]$. Another correct ordering is $[0,2,1,3]$.

Note:

The input prerequisites is a graph represented by a list of edges, not adjacency matrices. Read more about how a graph is represented. You may assume that there are no duplicate edges in the input prerequisites.

```

# Detecting if there is a cycle in the directed graph represented by
# prerequisites
# We need to transform it to the adjacency-list representation. If course u is a
# prerequisite of course v, then the adjacency list of u will contain v.

# BFS: the number of visited nodes should be equal to the number of courses,
# otherwise a cycle exists
class Solution(object):
    def findOrder(self, numCourses, prerequisites):
        """
        :type numCourses: int
        :type prerequisites: List[List[int]]
        :rtype: List[int]
        """
        # create graph and indegree list
        # graph is a dict that mapping a node and a set of its prerequisites
        graph = {i: [] for i in range(numCourses)}

```

```

indegree = [0 for i in range(numCourses) ]
# x -> y in graph
# so x is the prerequisite of y, and the indegree of y is added by 1
for x, y in prerequisites:
    graph[y].append(x)
    indegree[x] += 1

# create queue that saves all courses without prerequisites
# i.e. indegree = 0
queue = []
for i in range(numCourses):
    if indegree[i] == 0:
        queue.insert(0, i)

# perform BFS
visited = 0
res = []
while queue:
    node = queue.pop()
    res.append(node)
    visited += 1
    for v in graph[node]:
        # for each visited node, reduce the indegree of all its neighbors
        # by 1
        indegree[v] -= 1
        # if any node with 0 indegree, add it to queue
        if indegree[v] == 0: queue.insert(0, v)

# all nodes should be visited if no cycle, otherwise a cycle exists
if visited == numCourses:
    return res
else:
    return []

```

10.29 Course Schedule III (H)

There are n different online courses numbered from 1 to n . Each course has some duration(course length) t and closed on d th day. A course should be taken continuously for t days and must be finished before or on the d th day. You will start at the 1st day.

Given n online courses represented by pairs (t,d) , your task is to find the maximal number of courses that can be taken.

Example:

Input: $[[100, 200], [200, 1300], [1000, 1250], [2000, 3200]]$ Output: 3 Explanation: There're totally 4 courses, but you can take 3 courses at most: First, take the 1st course, it costs 100 days so you will finish it on the 100th day, and ready to take the next course on the 101st

day. Second, take the 3rd course, it costs 1000 days so you will finish it on the 1100th day, and ready to take the next course on the 1101st day. Third, take the 2nd course, it costs 200 days so you will finish it on the 1300th day. The 4th course cannot be taken now, since you will finish it on the 3300th day, which exceeds the closed date.

Note:

The integer $1 \leq d, t, n \leq 10,000$. You can't take two courses simultaneously.

10.30 Alien Dictionary (H)

There is a new alien language which uses the latin alphabet. However, the order among letters are unknown to you. You receive a list of non-empty words from the dictionary, where words are sorted lexicographically by the rules of this new language. Derive the order of letters in this language.

Example 1:

Input: ["wrt", "wrf", "er", "ett", "rftt"]

Output: "wertf"

Example 2:

Input: ["z", "x"]

Output: "zx"

Example 3:

Input: ["z", "x", "z"]

Output: ""

Explanation: The order is invalid, so return "".

Note:

You may assume all letters are in lowercase. You may assume that if a is a prefix of b, then a must appear before b in the given dictionary. If the order is invalid, return an empty string. There may be multiple valid order of letters, return any one of them is fine.

```
class Solution {
public:
    string alienOrder(vector<string>& words) {
        set<pair<char, char>> st;
        unordered_set<char> ch;
        vector<int> in(256, 0);
        queue<char> q;
        string res = "";
        for (auto a : words) ch.insert(a.begin(), a.end());
        for (int i = 0; i < (int)words.size() - 1; ++i) {
            int mn = min(words[i].size(), words[i + 1].size()), j = 0;
            for (; j < min(words[i].size(), words[i + 1].size()); ++j) {
                if (words[i][j] != words[i + 1][j]) {
                    st.insert(make_pair(words[i][j], words[i + 1][j]));
                    break;
                }
            }
        }
    }
}
```

```

    }
    if (j == mn && words[i].size() > words[i + 1].size()) return "";
}
for (auto a : st) ++in[a.second];
for (auto a : ch) {
    if (in[a] == 0) {
        q.push(a);
        res += a;
    }
}
while (!q.empty()) {
    char c = q.front(); q.pop();
    for (auto a : st) {
        if (a.first == c) {
            --in[a.second];
            if (in[a.second] == 0) {
                q.push(a.second);
                res += a.second;
            }
        }
    }
}
return res.size() == ch.size() ? res : "";
}
};

```

Chapter 11

Dynamic Programming

11.1 Gas Station (M)

There are N gas stations along a circular route, where the amount of gas at station i is $gas[i]$. You have a car with an unlimited gas tank and it costs $cost[i]$ of gas to travel from station i to its next station $(i+1)$. You begin the journey with an empty tank at one of the gas stations. Return the starting gas station's index if you can travel around the circuit once, otherwise return -1.

Note: The solution is guaranteed to be unique.

```
// Solution 1
class Solution {
public:
    int canCompleteCircuit(vector<int> &gas, vector<int> &cost) {
        int total = 0, sum = 0, start = 0;
        for (int i = 0; i < gas.size(); ++i) {
            total += gas[i] - cost[i];
            sum += gas[i] - cost[i];
            if (sum < 0) {
                start = i + 1;
                sum = 0;
            }
        }
        if (total < 0) return -1;
        else return start;
    }
};
```

```
// Solution 2
class Solution {
public:
    int canCompleteCircuit(vector<int>& gas, vector<int>& cost) {
```

```

int total_gas = 0, total_cost = 0, tank = 0, index = 0;
// If car starts at A and can not reach B, any station between A and B
// can not reach B
for (int i = 0; i < gas.size(); ++i) {
    total_gas += gas[i];
    total_cost += cost[i];
    tank += gas[i] - cost[i];
    if (tank < 0) {
        index = i + 1;
        tank = 0;
    }
}
// If the total number of gas is bigger than the total number of cost,
// there must be a solution
if (total_gas < total_cost) return -1;
else return index;
}
};

```

11.2 Combination Sum IV (M)

Given an integer array with all positive numbers and no duplicates, find the number of possible combinations that add up to a positive integer target.

Example: nums = [1, 2, 3], target = 4

The possible combination ways are:

(1, 1, 1, 1) (1, 1, 2) (1, 2, 1) (1, 3) (2, 1, 1) (2, 2) (3, 1)

Note that different sequences are counted as different combinations. Therefore the output is 7.

Follow up:

What if negative numbers are allowed in the given array?

How does it change the problem?

What limitation we need to add to the question to allow negative numbers?

```

class Solution {
public:
    int combinationSum4(vector<int>& nums, int target) {
        vector<int> dp(target+1);
        dp[0] = 1;
        for (int i = 1; i <= target; ++i) {
            for (auto a : nums) {
                if (i >= a) dp[i] += dp[i-a];
            }
        }
    }
};

```

```

    }
}
return dp.back();
}
};

```

11.3 Perfect Squares (M)

Given a positive integer n , find the least number of perfect square numbers (for example, 1, 4, 9, 16, ...) which sum to n .

For example, given $n = 12$, return 3 because $12 = 4 + 4 + 4$; given $n = 13$, return 2 because $13 = 4 + 9$.

```

class Solution {
public:
    int numSquares(int n) {
        vector<int> dp(n + 1, INT_MAX);
        dp[0] = 0;

        // if x = a + b * b, the least number of perfect square numbers which sum
        // to x is dp[x], then
        // case1: dp[x] = dp[a] + 1, because b * b is a perfect square number
        // case2: dp[x] = dp[a + b*b], because a + b * b is a perfect square
        // number
        // dp[x] = min(case1, case2)
        for (int i = 0; i <= n; ++i) {
            for (int j = 1; i + j * j <= n; ++j) {
                dp[i + j * j] = min(dp[i + j * j], dp[i] + 1);
            }
        }
        return dp[n];
    }
};

```

11.4 Coin Change (M)

You are given coins of different denominations and a total amount of money amount. Write a function to compute the fewest number of coins that you need to make up that amount. If that amount of money cannot be made up by any combination of the coins, return -1.

Example 1: coins = [1, 2, 5], amount = 11 return 3 (11 = 5 + 5 + 1)

Example 2: coins = [2], amount = 3 return -1.

Note: You may assume that you have an infinite number of each kind of coin.

```
// Non-recursion
class Solution {
public:
    int coinChange(vector<int>& coins, int amount) {
        vector<int> dp(amount + 1, amount + 1);
        dp[0] = 0;
        for (int i = 1; i <= amount; ++i) {
            for (int j = 0; j < coins.size(); ++j) {
                if (coins[j] <= i) {
                    dp[i] = min(dp[i], dp[i - coins[j]] + 1);
                }
            }
        }
        return dp[amount] > amount ? -1 : dp[amount];
    }
};

// Recursion
class Solution {
public:
    int coinChange(vector<int>& coins, int amount) {
        vector<int> dp(amount + 1, INT_MAX);
        dp[0] = 0;
        return coinChangeDFS(coins, amount, dp);
    }
    int coinChangeDFS(vector<int> &coins, int amount, vector<int> &dp) {
        if (amount < 0) return -1;
        if (dp[amount] != INT_MAX) return dp[amount];
        for (int i = 0; i < coins.size(); ++i) {
            int tmp = coinChangeDFS(coins, amount - coins[i], dp);
            if (tmp >= 0) dp[amount] = min(dp[amount], tmp + 1);
        }
        return dp[amount] == INT_MAX ? -1 : dp[amount];
    }
};
```

11.5 Largest Divisible Subset (M)

Given a set of distinct positive integers, find the largest subset such that every pair (Si, Sj) of elements in this subset satisfies: $S_i \% S_j = 0$ or $S_j \% S_i = 0$. If there are multiple solutions, return any subset is fine.

Example 1: nums: [1,2,3] Result: [1,2] (of course, [1,3] will also be ok)

Example 2: nums: [1,2,4,8] Result: [1,2,4,8]

```
class Solution {
public:
    vector<int> largestDivisibleSubset(vector<int>& nums) {
        sort(nums.begin(), nums.end());
        vector<int> dp(nums.size(), 0), parent(nums.size(), 0), res;
        int mx = 0, mx_idx = 0;
        for (int i = nums.size() - 1; i >= 0; --i) {
            for (int j = i; j < nums.size(); ++j) {
                if (nums[j] % nums[i] == 0 && dp[i] < dp[j] + 1) {
                    dp[i] = dp[j] + 1;
                    parent[i] = j;
                    if (mx < dp[i]) {
                        mx = dp[i];
                        mx_idx = i;
                    }
                }
            }
        }
        for (int i = 0; i < mx; ++i) {
            res.push_back(nums[mx_idx]);
            mx_idx = parent[mx_idx];
        }
        return res;
    }
};
```

11.6 Climbing Stairs (E)

You are climbing a stair case. It takes n steps to reach to the top.

Each time you can either climb 1 or 2 steps. In how many distinct ways can you climb to the top?

```
class Solution {
public:
    int climbStairs(int n) {
        vector<int> steps(n,0);
        steps[0] = 1;
        steps[1] = 2;
```

```

        // the number of distinct ways to reach level n is the sum of number of
        // distinct ways to reach level n-1 and n-2.
        for(int i = 2; i < n; i++)
            steps[i] = steps[i-2] + steps[i-1];
        return steps[n-1];
    }
};

```

11.7 Decode Ways (M)

A message containing letters from A-Z is being encoded to numbers using the following mapping:

'A' -> 1
 'B' -> 2
 ...
 'Z' -> 26

Given an encoded message containing digits, determine the total number of ways to decode it.

For example, Given encoded message "12", it could be decoded as "AB" (1 2) or "L" (12). The number of ways decoding "12" is 2.

```

class Solution(object):
    def numDecodings(self, s):
        """
        :type s: str
        :rtype: int
        """
        if not s or s[0] == '0': return 0
        dp = [0 for i in range(len(s) + 1)]
        dp[0] = 1
        # number of ways to decode until the digit i
        for i in range(1, len(dp)):
            # s[i-1] and s[i] cannot form a digit
            if s[i-1] != '0':
                dp[i] += dp[i-1]
            # s[i-2] and s[i-1] can form a digit in range [10, 26]
            if i >= 2 and int(s[i-2:i]) >= 10 and int(s[i-2:i]) <= 26:
                dp[i] += dp[i-2]
        return dp[-1]

```

```

class Solution {
public:
    int numDecodings(string s) {

```

```

        if (s.empty()) return 0;
        int n = s.size();
        vector<int> dp(n + 2, 1);
        for (int i = 2; i < n + 2; ++i) {
            if (s[i - 2] == '0') dp[i] = 0;
            else dp[i] = dp[i - 1];
            if (i - 3 >= 0 && (s[i - 3] == '1' || (s[i - 3] == '2' && s[i - 2] <=
                '6')))) {
                dp[i] += dp[i - 2];
            }
        }
        return dp[n + 1];
    }
};

```

```

class Solution {
public:
    int numDecodings(string s) {
        if (s.empty()) return 0;
        vector<int> dp(s.size() + 1, 0);
        dp[0] = 1;
        for (int i = 1; i < dp.size(); ++i) {
            if (s[i - 1] != '0') dp[i] += dp[i - 1];
            if (i >= 2 && s.substr(i - 2, 2) <= "26" && s.substr(i - 2, 2) >=
                "10") {
                dp[i] += dp[i - 2];
            }
        }
        return dp.back();
    }
};

```

```

// Space O(1)
class Solution {
public:
    int numDecodings(string s) {
        if (s.empty() || s.front() == '0') return 0;
        int c1 = 1, c2 = 1;
        for (int i = 1; i < s.size(); ++i) {
            if (s[i] == '0') c1 = 0;
            if (s[i - 1] == '1' || (s[i - 1] == '2' && s[i] <= '6')) {
                c1 = c1 + c2;
                c2 = c1 - c2;
            } else {
                c2 = c1;
            }
        }
    }
};

```

```

        return c1;
    }
};

```

11.8 Number of ways for mapping integers to alphabets (The Climate Corporation phone screen 2016.9.22)

Define a mapping of integers to alphabets as follows: 1 = a, 2 = b, ..., 26 = z. Given any combination of the mapping numbers as a string, return the number of ways in which the input string can be split into sub-strings and represented as character strings.

For example:

"111" -> "aaa", "ak", "ka" -> 3 ways

"11" -> "aa", "k" -> 2 ways

"123" -> "abc", "lc", "aw" -> 3 ways

This question is the same as "Decode Ways".

```

#include <iostream>
#include <string>
#include <vector>
using namespace std;

int numOfWays(string);

int main() {
    string input = "123321";
    int res = numOfWays(input);
    cout << "String: " << input << "\n";
    cout << "Number of Combinations are: " << res << "\n";
    return 0;
}

int numOfWays(string s) {
    int n = s.size();
    vector<int> res(n);
    res[0] = 1;
    int tmp = (s[0] - '0') * 10 + (s[1] - '0');
    if (tmp <= 26) res[1] = 2;
    else res[1] = 1;

    for (int i = 2; i < n; ++i) {
        int tmp = (s[i-1] - '0') * 10 + (s[i] - '0');
        if (tmp <= 26) res[i] = res[i-2] + res[i-1];
    }
}

```

```

    else res[i] = res[i-1];
}

return res[n-1];
}

```

11.9 Jump Game (M)

Given an array of non-negative integers, you are initially positioned at the first index of the array. Each element in the array represents your maximum jump length at that position. Determine if you are able to reach the last index.

For example:

A = [2,3,1,1,4], return true.

A = [3,2,1,0,4], return false.

```

class Solution(object):
    def canJump(self, nums):
        """
        :type nums: List[int]
        :rtype: bool
        """
        max_reach = 0
        n = len(nums)
        for i in range(n):
            if i > max_reach or max_reach >= n - 1:
                break
            # i + nums[i] is the maximum step that can be reached at i
            max_reach = max(max_reach, i + nums[i])
        return max_reach >= n - 1

```

// 1. DP solution

```

class Solution {
public:
    bool canJump(vector<int>& nums) {
        int n = nums.size();
        // dp[i] is the maximum step that is left to jump at i
        vector<int> dp(n, 0);
        for (int i = 1; i < n; ++i) {
            dp[i] = max(dp[i - 1], nums[i - 1]) - 1;
            if (dp[i] < 0) return false;
        }
        return dp[n - 1] >= 0;
    }
}

```

```
};

// 2. Greedy solution
class Solution {
public:
    bool canJump(vector<int>& nums) {
        int maxIdx = 0, n = nums.size();
        for (int i = 0; i < n; ++i) {
            if (i > maxIdx || maxIdx >= n - 1) break;
            maxIdx = max(maxIdx, i + nums[i]);
        }
        return maxIdx >= n - 1;
    }
};
```

11.10 Jump Game II (M)

Given an array of non-negative integers, you are initially positioned at the first index of the array. Each element in the array represents your maximum jump length at that position. Your goal is to reach the last index in the minimum number of jumps.

For example: Given array A = [2,3,1,1,4], The minimum number of jumps to reach the last index is 2. (Jump 1 step from index 0 to 1, then 3 steps to the last index.)

Note: You can assume that you can always reach the last index.

```
/* Greedy solution
 * We use "last" to keep track of the maximum distance that has been reached
 * by using the minimum steps "res", whereas "curr" is the maximum distance
 * that can be reached by using "res+1" steps. Thus,
 * curr = max(i+nums[i]) where 0 <= i <= last.
 */
class Solution {
public:
    int jump(vector<int>& nums) {
        int res = 0, last = 0, cur = 0, n = nums.size();
        for (int i = 0; i < n; ++i) {
            if (i > last) {
                last = cur;
                ++res;
            }
            cur = max(cur, i + nums[i]);
        }
        return res;
    }
};
```

```
};
```

11.11 Best Time to Buy and Sell Stock (E)

Say you have an array for which the i -th element is the price of a given stock on day i . If you were only permitted to complete at most one transaction (ie, buy one and sell one share of the stock), design an algorithm to find the maximum profit.

```
class Solution(object):
    def maxProfit(self, prices):
        """
        :type prices: List[int]
        :rtype: int
        """
        buy = float('inf')
        profit = 0
        for price in prices:
            if price < buy:
                buy = price
            # there is no need to check profit if we buy a stock
            # so we use elif here
            elif profit < price - buy:
                profit = price - buy
        return profit
```

```
class Solution {
public:
    int maxProfit(vector<int>& prices) {
        if (prices.empty() || prices.size() < 2)
            return 0;

        int profit = 0;
        int low = prices[0];

        for (int i = 1; i < prices.size(); ++i) {
            profit = max(profit, prices[i] - low);
            low = min(low, prices[i]);
        }

        return profit;
    }
};
```

11.12 Best Time to Buy and Sell Stock II (E)

Say you have an array for which the i -th element is the price of a given stock on day i .

Design an algorithm to find the maximum profit. You may complete as many transactions as you like (ie, buy one and sell one share of the stock multiple times). However, you may not engage in multiple transactions at the same time (ie, you must sell the stock before you buy again).

```
class Solution(object):
    def maxProfit(self, prices):
        """
        :type prices: List[int]
        :rtype: int
        """
        profit = 0
        for i in range(1, len(prices)):
            if prices[i] > prices[i-1]:
                profit += prices[i] - prices[i-1]
        return profit
```

```
class Solution {
public:
    int maxProfit(vector<int>& prices) {
        if (prices.empty() || prices.size() < 2)
            return 0;

        int profit = 0;
        int diff;

        for (int i = 1; i < prices.size(); ++i) {
            diff = prices[i] - prices[i-1];
            if (diff > 0)
                profit += diff;
        }
        return profit;
    }
};
```

11.13 Best Time to Buy and Sell Stock with Cooldown (M)

Say you have an array for which the i -th element is the price of a given stock on day i .

Design an algorithm to find the maximum profit. You may complete as many transactions as you like (ie, buy one and sell one share of the stock multiple times) with the following restrictions:

You may not engage in multiple transactions at the same time (ie, you must sell the stock before you buy again).

After you sell your stock, you cannot buy stock on next day. (ie, cooldown 1 day)

```
class Solution {
public:
    int maxProfit(vector<int>& prices) {

        int buy = INT_MIN, sell = 0, rest = INT_MIN, cooldown = 0;

        for (int i = 0; i < prices.size(); ++i) {
            rest = max(rest, buy);
            buy = cooldown - prices[i];
            cooldown = max(sell, cooldown);
            sell = rest + prices[i];
        }

        return max(cooldown, sell);
    }
};
```

11.14 Best Time to Buy and Sell Stock with Transaction Fee (M)

You are given an array of integers prices, for which the i -th element is the price of a given stock on day i ; and a non-negative integer fee representing a transaction fee.

You may complete as many transactions as you like, but you need to pay the transaction fee for each transaction. You may not buy more than 1 share of a stock at a time (ie. you must sell the stock share before you buy again.)

Return the maximum profit you can make.

```

# class Solution(object):
#     def maxProfit(self, prices, fee):
#         """
#         :type prices: List[int]
#         :type fee: int
#         :rtype: int
#         """
#         n = len(prices)
#         sold = hold = [0] * n
#         hold[0] = -prices[0]
#         for i in range(1, n):
#             sold[i] = max(sold[i-1], hold[i-1] + prices[i] - fee)
#             hold[i] = max(hold[i-1], sold[i-1] - prices[i])
#         return sold[n-1]

class Solution(object):
    def maxProfit(self, prices, fee):
        cash, hold = 0, -prices[0]
        for i in range(1, len(prices)):
            cash = max(cash, hold + prices[i] - fee)
            hold = max(hold, cash - prices[i])
        return cash

```

11.15 Best Time to Buy and Sell Stock III (H)

Say you have an array for which the i -th element is the price of a given stock on day i .

Design an algorithm to find the maximum profit. You may complete at most two transactions. However, you may not engage in multiple transactions at the same time (ie, you must sell the stock before you buy again).

```

class Solution {
public:
    int maxProfit(vector<int>& prices) {
        if (prices.empty() || prices.size() < 2)
            return 0;

        vector<int> profit(prices.size());

        // compute the forward max profit and save it
        int buy = prices[0];
        profit[0] = 0;
        for (int i = 1; i < prices.size(); i++) {
            profit[i] = max(profit[i - 1], prices[i] - buy);
            buy = min(buy, prices[i]);
        }
    }
}

```

```

    }

    // The final max profit is the sum of max profit before day i (profit[i])
    // and after day i (sell - prices[i])
    int sell = prices[prices.size() - 1];
    int best = 0;
    for (int i = prices.size() - 2; i >= 0; i--) {
        best = max(best, sell - prices[i] + profit[i]);
        sell = max(sell, prices[i]);
    }

    return best;
}
};

```

11.16 Best Time to Buy and Sell Stock IV (H)

Say you have an array for which the i -th element is the price of a given stock on day i .

Design an algorithm to find the maximum profit. You may complete at most k transactions. However, you may not engage in multiple transactions at the same time (ie, you must sell the stock before you buy again).

```

class Solution {
public:
    int maxProfit(int k, vector<int> &prices) {
        if (prices.empty() || prices.size() < 2)
            return 0;
        if (k >= prices.size())
            return solveMaxProfit(prices);

        int global[k + 1] = {0};
        int local[k + 1] = {0};
        for (int i = 0; i < prices.size() - 1; ++i) {
            int diff = prices[i + 1] - prices[i];
            for (int j = k; j >= 1; --j) {
                local[j] = max(global[j - 1] + max(diff, 0), local[j] + diff);
                global[j] = max(global[j], local[j]);
            }
        }
        return global[k];
    }

    int solveMaxProfit(vector<int> &prices) {
        int profit = 0;
    }
}

```

```

        for (int i = 1; i < prices.size(); ++i) {
            if (prices[i] > prices[i - 1]) {
                profit += prices[i] - prices[i - 1];
            }
        }
        return profit;
    }
};

```

11.17 House Robber (E)

You are a professional robber planning to rob houses along a street. Each house has a certain amount of money stashed, the only constraint stopping you from robbing each of them is that adjacent houses have security system connected and it will automatically contact the police if two adjacent houses were broken into on the same night.

Given a list of non-negative integers representing the amount of money of each house, determine the maximum amount of money you can rob tonight without alerting the police.

```

class Solution(object):
    def rob(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        rob, not_rob = 0, 0
        n = len(nums)
        for i in range(n):
            pre_rob, pre_not_rob = rob, not_rob
            rob = pre_not_rob + nums[i]
            not_rob = max(pre_rob, pre_not_rob)
        return max(rob, not_rob)

```

```

class Solution {
public:
    int rob(vector<int>& nums) {
        int cur_rob = 0, prev_rob = 0, sum = 0;

        for (int i = 0; i < nums.size(); ++i) {
            cur_rob = prev_rob + nums[i];
            prev_rob = sum;
            sum = max(cur_rob, prev_rob);
        }
    }
}

```

```
        return sum;
    }
};
```

11.18 House Robber II (M)

After robbing those houses on that street, the thief has found himself a new place for his thievery so that he will not get too much attention. This time, all houses at this place are arranged in a circle. That means the first house is the neighbor of the last one. Meanwhile, the security system for these houses remain the same as for those in the previous street.

Given a list of non-negative integers representing the amount of money of each house, determine the maximum amount of money you can rob tonight without alerting the police.

```
class Solution {
public:
    int rob(vector<int>& nums) {
        int n = nums.size();
        if (n == 0) return 0;
        if (n == 1) return nums[0];
        return max(rob(nums, 0, n-2), rob(nums, 1, n-1)); // can not rob nums[0]
                                                           and nums[n-1] together
    }

    int rob(vector<int> &nums, int start, int end) {
        int cur_rob = 0, prev_rob = 0, sum = 0;

        for (int i = start; i <= end; ++i) {
            cur_rob = prev_rob + nums[i];
            prev_rob = sum;
            sum = max(cur_rob, prev_rob);
        }

        return sum;
    }
};
```

11.19 House Robber III (M)

The thief has found himself a new place for his thievery again. There is only one entrance to this area, called the "root." Besides the root, each house has one and only one parent house. After a tour, the smart thief realized that "all houses in this place forms a binary tree". It will automatically contact the police if two directly-linked houses were broken into on the

same night.

Determine the maximum amount of money the thief can rob tonight without alerting the police.

```
class Solution {
public:
    int rob(TreeNode *root) {
        vector<int> res = robber(root);
        return max(res[0], res[1]);
    }

    vector<int> robber(TreeNode *root) {
        vector<int> res(2,0);
        if (!root) return res;

        vector<int> left = robber(root->left);
        vector<int> right = robber(root->right);

        res[0] = max(left[0], left[1]) + max(right[0], right[1]); // if root is
                                                                    not robbed
        res[1] = root->val + left[0] + right[0];                    // if root is robbed

        return res;
    }
};
```

11.20 Paint Fence (E)

There is a fence with n posts, each post can be painted with one of the k colors. You have to paint all the posts such that no more than two adjacent fence posts have the same color. Return the total number of ways you can paint the fence.

Note: n and k are non-negative integers.

```
class Solution {
public:
    int numWays(int n, int k) {
        if (n == 0) return 0;
        if (n == 1) return k;
        vector<int> dp(n);

        dp[0] = k; // n = 1, k ways to paint
        dp[1] = k * (k - 1) + k; // n = 2, diff color: k*(k-1) ways + same
```

```

        color: k ways

    /** 1. If the color of the current post i is different from the color of
        the last post i-1,
        *     then there are dp[i] = dp[i - 1] * (k - 1) ways to paint the
            current post i
        * 2. If the color of the current post i is same as the color of the
            last post i-1,
        *     then the color of the post i and i-1 must be different from the
            color of the second last post i-2
        *     so there are dp[i] = dp[i - 2] * (k - 1) * 1 ways to paint the
            current post i
        * 3. The total num of ways is a combination of case 1 and 2
        */
    for (int i = 2; i < n; i++) {
        dp[i] = dp[i - 1] * (k - 1) + dp[i - 2] * (k - 1);
    }

    return dp[n - 1];
}
};

```

11.21 Paint House (M)

There are a row of n houses, each house can be painted with one of the three colors: red, blue or green. The cost of painting each house with a certain color is different. You have to paint all the houses such that no two adjacent houses have the same color.

The cost of painting each house with a certain color is represented by a $n \times 3$ cost matrix. For example, `costs[0][0]` is the cost of painting house 0 with color red; `costs[1][2]` is the cost of painting house 1 with color green, and so on... Find the minimum cost to paint all houses.

Note: All costs are positive integers.

```

class Solution {
public:
    int minCost(vector<vector<int>> &cost) {
        if (cost.empty() || cost[0].empty()) return 0;
        vector<vector<int>> dp = cost;
        for (int i = 1; i < dp.size(); ++i) {
            // dp[i][0] += min(dp[i - 1][1], dp[i - 1][2]);
            // dp[i][1] += min(dp[i - 1][0], dp[i - 1][2]);
            // dp[i][2] += min(dp[i - 1][0], dp[i - 1][1]);
            for (int j = 0; j < 3; ++j) {

```



```

        dp[i][j] += min(dp[i-1][(j+1)%3], dp[i-1][(j+2)%3]);
    }
}
return min(min(dp.back()[0], dp.back()[1]), dp.back()[2]);
}
};

```

11.22 Paint House II (H)

There are a row of n houses, each house can be painted with one of the k colors. The cost of painting each house with a certain color is different. You have to paint all the houses such that no two adjacent houses have the same color.

The cost of painting each house with a certain color is represented by a $n \times k$ cost matrix. For example, `costs[0][0]` is the cost of painting house 0 with color 0; `costs[1][2]` is the cost of painting house 1 with color 2, and so on... Find the minimum cost to paint all houses.

Note: All costs are positive integers.

Follow up: Could you solve it in $O(nk)$ runtime?

```

class Solution {
public:
    int minCostII(vector<vector<int>>& costs) {
        if(costs.empty() || costs[0].empty()) return 0;
        int n = costs.size(), k = costs[0].size(), res = INT_MAX;
        vector<vector<int>> dp = costs;
        for (int i = 1; i < n; ++i) {
            for (int j = 0; j < k; ++j) {
                int tmp = INT_MAX;
                // find the local min cost of using other color to paint the last house
                for (int d = 1; d < k; ++d) {
                    tmp = min(tmp, dp[i-1][(j+d)%k]);
                }
                dp[i][j] += tmp;
                // find the global min cost of painting all houses
                if (i == n-1) {
                    res = min(res, dp[i][j]);
                }
            }
        }
        return res;
    }
}

```

```

};

class Solution {
public:
    int minCostII(vector<vector<int>>& costs) {
        if (costs.empty() || costs[0].empty()) return 0;
        vector<vector<int>> dp = costs;
        int min1 = -1, min2 = -1;
        for (int i = 0; i < dp.size(); ++i) {
            int last1 = min1, last2 = min2;
            min1 = -1; min2 = -1;
            for (int j = 0; j < dp[i].size(); ++j) {
                if (j != last1) {
                    dp[i][j] += last1 < 0 ? 0 : dp[i - 1][last1];
                } else {
                    dp[i][j] += last2 < 0 ? 0 : dp[i - 1][last2];
                }
                if (min1 < 0 || dp[i][j] < dp[i][min1]) {
                    min2 = min1; min1 = j;
                } else if (min2 < 0 || dp[i][j] < dp[i][min2]) {
                    min2 = j;
                }
            }
        }
        return dp.back()[min1];
    }
};

```

11.23 Pascal's Triangle (E)

Given numRows, generate the first numRows of Pascal's triangle.

```

class Solution {
public:
    vector<vector<int>> generate(int numRows) {
        vector<vector<int>> res;
        if (numRows == 0) return res;

        res.push_back(vector<int> (1,1));           // first row

        for (int i = 2; i <= numRows; ++i) {
            vector<int> cur(i,1);                   // generate next row with all
            1s
            for (int j = 1; j < i-1; ++j)           // update elements from the
                cur[j] = res[i-2][j-1] + res[i-2][j]; // 2nd to the (i-1)-th
        }
        return res;
    }
};

```

```

        cur[j] = res[i-2][j-1] + res[i-2][j];
        res.push_back(cur);
    }

    return res;
}
};

```

11.24 Pascal's Triangle II (E)

Given an index k, return the k-th row of the Pascal's triangle.

```

class Solution {
public:
    vector<int> getRow(int rowIndex) {
        vector<int> res;

        for (int i = 0; i <= rowIndex; ++i) {
            for (int j = i - 1; j > 0; --j) {
                res[j] = res[j-1] + res[j]; // scrolling array
            }
            res.push_back(1);
        }

        return res;
    }
};

```

11.25 Range Sum Query - Immutable (E)

Given an integer array nums, find the sum of the elements between indices i and j ($i \leq j$), inclusive.

Example:

Given nums = [-2, 0, 3, -5, 2, -1]

sumRange(0, 2) = 1

sumRange(2, 5) = -1

sumRange(0, 5) = -3

Note:

You may assume that the array does not change.

There are many calls to sumRange function.

```
class NumArray(object):
```

```
    def __init__(self, nums):
        """
        :type nums: List[int]
        """
        self.dp = [0 for i in range(len(nums)+1)]
        for i in range(len(nums)):
            self.dp[i+1] = self.dp[i] + nums[i]
```

```
    def sumRange(self, i, j):
        """
        :type i: int
        :type j: int
        :rtype: int
        """
        return self.dp[j+1] - self.dp[i]
```

```
# Your NumArray object will be instantiated and called as such:
# obj = NumArray(nums)
# param_1 = obj.sumRange(i,j)
```

```
// Your NumArray object will be instantiated and called as such:
// NumArray numArray(nums);
// numArray.sumRange(0, 1);
// numArray.sumRange(1, 2);
```

```
class NumArray {
public:
    vector<int> sums = {0};           // save an initial 0 into sums

    NumArray(vector<int> &nums) {      // class constructor
        int sum = 0;
        for (int i = 0; i < nums.size(); ++i) {
            sum += nums[i];
            sums.push_back(sum);       // sums[] contains nums.size() + 1 elements
        }
    }

    int sumRange(int i, int j) {
        return sums[j+1] - sums[i];   // get the correct sum by considering the
                                       // offset in sums[]
    }
};
```

11.26 Range Sum Query - Mutable (M)

Given an integer array `nums`, find the sum of the elements between indices `i` and `j` ($i \leq j$), inclusive. The `update(i, val)` function modifies `nums` by updating the element at index `i` to `val`.

Example:

Given `nums = [1, 3, 5]` `sumRange(0, 2) = 9` `update(1, 2)` `sumRange(0, 2) = 8`

Note:

The array is only modifiable by the update function.

You may assume the number of calls to `update` and `sumRange` function is distributed evenly.

```
struct SegmentTreeNode {
    int start, end, sum;
    SegmentTreeNode* left;
    SegmentTreeNode* right;
    SegmentTreeNode(int a, int
        b):start(a),end(b),sum(0),left(nullptr),right(nullptr){}
};
class NumArray {
    SegmentTreeNode* root;
public:
    NumArray(vector<int> &nums) {
        int n = nums.size();
        root = buildTree(nums,0,n-1);
    }

    void update(int i, int val) {
        modifyTree(i,val,root);
    }

    int sumRange(int i, int j) {
        return queryTree(i, j, root);
    }
    SegmentTreeNode* buildTree(vector<int> &nums, int start, int end) {
        if(start > end) return nullptr;
        SegmentTreeNode* root = new SegmentTreeNode(start,end);
        if(start == end) {
            root->sum = nums[start];
            return root;
        }
        int mid = start + (end - start) / 2;
        root->left = buildTree(nums,start,mid);
        root->right = buildTree(nums,mid+1,end);
        root->sum = root->left->sum + root->right->sum;
        return root;
    }
};
```

```

    }
    int modifyTree(int i, int val, SegmentTreeNode* root) {
        if(root == nullptr) return 0;
        int diff;
        if(root->start == i && root->end == i) {
            diff = val - root->sum;
            root->sum = val;
            return diff;
        }
        int mid = (root->start + root->end) / 2;
        if(i > mid) {
            diff = modifyTree(i, val, root->right);
        } else {
            diff = modifyTree(i, val, root->left);
        }
        root->sum = root->sum + diff;
        return diff;
    }
    int queryTree(int i, int j, SegmentTreeNode* root) {
        if(root == nullptr) return 0;
        if(root->start == i && root->end == j) return root->sum;
        int mid = (root->start + root->end) / 2;
        if(i > mid) return queryTree(i, j, root->right);
        if(j <= mid) return queryTree(i, j, root->left);
        return queryTree(i, mid, root->left) + queryTree(mid+1, j, root->right);
    }
};

```

```

// Your NumArray object will be instantiated and called as such:
// NumArray numArray(nums);
// numArray.sumRange(0, 1);
// numArray.update(1, 10);
// numArray.sumRange(1, 2);

```

11.27 Range Sum Query 2D - Immutable (M)

Given a 2D matrix matrix, find the sum of the elements inside the rectangle defined by its upper left corner (row1, col1) and lower right corner (row2, col2).

Example:

Given matrix = [[3, 0, 1, 4, 2], [5, 6, 3, 2, 1], [1, 2, 0, 1, 5], [4, 1, 0, 1, 7], [1, 0, 3, 0, 5]]

sumRegion(2, 1, 4, 3) = 8

sumRegion(1, 1, 2, 2) = 11

sumRegion(1, 2, 2, 4) = 12

Note:

You may assume that the matrix does not change.

There are many calls to sumRegion function.

You may assume that $row1 \leq row2$ and $col1 \leq col2$.

```
class NumMatrix(object):

    def __init__(self, matrix):
        """
        :type matrix: List[List[int]]
        """
        if len(matrix) == 0 or len(matrix[0]) == 0: return
        m, n = len(matrix), len(matrix[0])
        self.dp = [ [0 for j in range(n+1)] for i in range(m+1) ]
        # note that the index in dp is 1 larger than the index in matrix
        for row in range(m):
            for col in range(n):
                self.dp[row+1][col+1] = self.dp[row+1][col] + self.dp[row][col+1] \
                    + matrix[row][col] - self.dp[row][col]

    def sumRegion(self, row1, col1, row2, col2):
        """
        :type row1: int
        :type col1: int
        :type row2: int
        :type col2: int
        :rtype: int
        """
        return self.dp[row2 + 1][col2 + 1] - self.dp[row1][col2 + 1] \
            - self.dp[row2 + 1][col1] + self.dp[row1][col1]

# Your NumMatrix object will be instantiated and called as such:
# obj = NumMatrix(matrix)
# param_1 = obj.sumRegion(row1,col1,row2,col2)
```

```
class NumMatrix {
public:
    int row, col;
    vector<vector<int>> sums;

    NumMatrix(vector<vector<int>> &matrix) {
        row = matrix.size();
        col = row > 0 ? matrix[0].size() : 0;
        sums = vector<vector<int>>(row+1, vector<int>(col+1, 0));
        for(int i = 1; i <= row; i++) {
```

```

        for(int j = 1; j <= col; j++) {
            sums[i][j] = sums[i-1][j] + sums[i][j-1] - sums[i-1][j-1] +
                matrix[i-1][j-1];
        }
    }

    int sumRegion(int row1, int col1, int row2, int col2) {
        return sums[row2+1][col2+1] - sums[row2+1][col1] - sums[row1][col2+1] +
            sums[row1][col1];
    }
};

// Your NumMatrix object will be instantiated and called as such:
// NumMatrix numMatrix(matrix);
// numMatrix.sumRegion(0, 1, 2, 3);
// numMatrix.sumRegion(1, 2, 3, 4);

```

11.28 Triangle (M)

Given a triangle, find the minimum path sum from top to bottom. Each step you may move to adjacent numbers on the row below.

For example, given the following triangle [[2], [3,4], [6,5,7], [4,1,8,3]] The minimum path sum from top to bottom is 11 (i.e., $2 + 3 + 5 + 1 = 11$).

Note: Bonus point if you are able to do this using only $O(n)$ extra space, where n is the total number of rows in the triangle.

```

// bottom-up approach
class Solution {
public:
    int minimumTotal(vector<vector<int>>& triangle) {
        vector<int> res = triangle.back();
        for (int i = triangle.size() - 2; i >= 0; --i) {
            for (int j = 0; j <= i; ++j) {
                res[j] = min(res[j], res[j+1]) + triangle[i][j];
            }
        }
        return res[0];
    }
};

```

11.29 Unique Paths (M)

A robot is located at the top-left corner of a $m \times n$ grid (marked 'Start' in the diagram below). The robot can only move either down or right at any point in time. The robot is trying to reach the bottom-right corner of the grid (marked 'Finish' in the diagram below). How many possible unique paths are there?

Note: m and n will be at most 100.

```
// 1. 2D DP solution
class Solution {
public:
    int uniquePaths(int m, int n) {
        vector<vector<int>> dp(m, vector<int>(n,1));
        for (int i = 1; i < m; ++i) {
            for (int j = 1; j < n; ++j) {
                dp[i][j] = dp[i-1][j] + dp[i][j-1];
            }
        }
        return dp[m-1][n-1];
    }
};

// 2. 1D DP solution
class Solution {
public:
    int uniquePaths(int m, int n) {
        vector<int> dp(n,1);
        for (int i = 1; i < m; ++i) {
            for (int j = 1; j < n; ++j) {
                dp[j] = dp[j] + dp[j-1];
            }
        }
        return dp[n-1];
    }
};
```

11.30 Unique Paths II (M)

Follow up for "Unique Paths":

Now consider if some obstacles are added to the grids. How many unique paths would there be? An obstacle and empty space is marked as 1 and 0 respectively in the grid.

For example, There is one obstacle in the middle of a 3×3 grid as illustrated below. [[0,0,0],

[0,1,0], [0,0,0]], The total number of unique paths is 2.

Note: m and n will be at most 100.

```
// 1. 2D DP
class Solution {
public:
    int uniquePathsWithObstacles(vector<vector<int>>& obstacleGrid) {
        if (obstacleGrid.empty() || obstacleGrid[0].empty()) return 0;
        int m = obstacleGrid.size(), n = obstacleGrid[0].size();
        if (obstacleGrid[0][0] == 1 || obstacleGrid[m-1][n-1] == 1) return 0;
        vector<vector<int>> dp(m, vector<int>(n, 0));
        for (int i = 0; i < m; ++i) {
            for (int j = 0; j < n; ++j) {
                if (obstacleGrid[i][j] == 1) {
                    dp[i][j] = 0;
                } else if (i == 0 && j == 0) {
                    dp[i][j] = 1;
                } else if (i == 0 && j > 0) {
                    dp[i][j] = dp[i][j-1];
                } else if (i > 0 && j == 0) {
                    dp[i][j] = dp[i-1][j];
                } else {
                    dp[i][j] = dp[i-1][j] + dp[i][j-1];
                }
            }
        }
        return dp[m-1][n-1];
    }
};
```

```
// 2. 1D DP
class Solution {
public:
    int uniquePathsWithObstacles(vector<vector<int>>& obstacleGrid) {
        if (obstacleGrid.empty() || obstacleGrid[0].empty()) return 0;
        int m = obstacleGrid.size(), n = obstacleGrid[0].size();
        if (obstacleGrid[0][0] == 1 || obstacleGrid[m-1][n-1] == 1) return 0;
        vector<int> dp(n, 0);
        dp[0] = 1;
        for (int i = 0; i < m; ++i) {
            for (int j = 0; j < n; ++j) {
                if (obstacleGrid[i][j] == 1) {
                    dp[j] = 0;
                } else if (j > 0) {
                    dp[j] = dp[j] + dp[j-1];
                }
            }
        }
    }
};
```

```

    }
}
return dp[n-1];
}
};

```

11.31 Minimum Path Sum (M)

Given a $m \times n$ grid filled with non-negative numbers, find a path from top left to bottom right which minimizes the sum of all numbers along its path.

Note: You can only move either down or right at any point in time.

```

// 1. 2D DP
class Solution {
public:
    int minPathSum(vector<vector<int>>& grid) {
        if (grid.size() == 0 || grid[0].size() == 0) return 0;
        int m = grid.size(), n = grid[0].size();
        int dp[m][n];
        // initializing
        dp[0][0] = grid[0][0];
        for (int i = 1; i < m; ++i) dp[i][0] = dp[i-1][0] + grid[i][0];
        for (int j = 1; j < n; ++j) dp[0][j] = dp[0][j-1] + grid[0][j];
        // get min
        for (int i = 1; i < m; ++i) {
            for (int j = 1; j < n; ++j) {
                dp[i][j] = grid[i][j] + min(dp[i-1][j], dp[i][j-1]);
            }
        }
        return dp[m-1][n-1];
    }
};

```

```

// 2. 1D DP
class Solution {
public:
    int minPathSum(vector<vector<int>>& grid) {
        if (grid.size() == 0 || grid[0].size() == 0) return 0;
        int m = grid.size(), n = grid[0].size();
        int dp[n];
        dp[0] = grid[0][0];
        for (int i = 1; i < n; ++i) dp[i] = dp[i-1] + grid[0][i];
        for (int i = 1; i < m; ++i) {
            dp[0] += grid[i][0]; // need to update dp[0] for each row

```

```

        for (int j = 1; j < n; ++j) {
            dp[j] = grid[i][j] + min(dp[j-1], dp[j]);
        }
    }
    return dp[n-1];
}
};

```

11.32 Dungeon Game (H)

The demons had captured the princess (P) and imprisoned her in the bottom-right corner of a dungeon. The dungeon consists of $M \times N$ rooms laid out in a 2D grid. Our valiant knight (K) was initially positioned in the top-left room and must fight his way through the dungeon to rescue the princess.

The knight has an initial health point represented by a positive integer. If at any point his health point drops to 0 or below, he dies immediately. Some of the rooms are guarded by demons, so the knight loses health (negative integers) upon entering these rooms; other rooms are either empty (0's) or contain magic orbs that increase the knight's health (positive integers).

In order to reach the princess as quickly as possible, the knight decides to move only rightward or downward in each step. Write a function to determine the knight's minimum initial health so that he is able to rescue the princess.

Notes:

The knight's health has no upper bound.

Any room can contain threats or power-ups, even the first room the knight enters and the bottom-right room where the princess is imprisoned.

```

class Solution {
public:
    int calculateMinimumHP(vector<vector<int>>& dungeon) {
        int m = dungeon.size(), n = dungeon[0].size();
        int dp[m][n];
        // Initialize K's health as K has to be alive when K reaches P
        // 1. If the current room can increase K's HP,
        // then the minimum HP for K to reach the room is 1
        // 2. If the current room can reduce K's HP,
        // then the minimum HP for K to reach the room must be 1 - damage
        dp[m-1][n-1] = max(1, 1 - dungeon[m-1][n-1]);
        // initializing the last column
        for (int i = m - 2; i >= 0; --i) {
            dp[i][n-1] = max(1, dp[i+1][n-1] - dungeon[i][n-1]);
        }
    }
};

```

```

    }
    // initializing the last row
    for (int j = n - 2; j >= 0; --j) {
        dp[m-1][j] = max(1, dp[m-1][j+1] - dungeon[m-1][j]);
    }
    for (int i = m - 2; i >= 0; --i) {
        for (int j = n - 2; j >= 0; --j) {
            dp[i][j] = max(1, min(dp[i+1][j], dp[i][j+1]) - dungeon[i][j]);
        }
    }
    return dp[0][0];
}
};

```

11.33 Increasing Triplet Subsequence (M)

Given an unsorted array return whether an increasing subsequence of length 3 exists or not in the array.

Formally the function should:

Return true if there exists i, j, k

such that $arr[i] < arr[j] < arr[k]$ given $0 \leq i < j < k \leq n - 1$ else return false.

Your algorithm should run in $O(n)$ time complexity and $O(1)$ space complexity.

Examples:

Given $[1, 2, 3, 4, 5]$, return true.

Given $[5, 4, 3, 2, 1]$, return false.

```

# # DP: the same as Longest Increasing Subsequence
# class Solution(object):
#     def increasingTriplet(self, nums):
#         """
#         :type nums: List[int]
#         :rtype: bool
#         """
#         n = len(nums)
#         dp = [1] * n
#         for i in range(n):
#             for j in range(i):
#                 if nums[j] < nums[i]:
#                     dp[i] = max(dp[i], dp[j] + 1)
#                 if dp[i] == 3: return True
#         return False

```

```
# O(N)
class Solution(object):
    def increasingTriplet(self, nums):
        """
        :type nums: List[int]
        :rtype: bool
        """
        mx1 = mx2 = float('inf')
        for num in nums:
            if num <= mx1: mx1 = num
            elif num <= mx2: mx2 = num
            else: return True
        return False
```

```
// 1. DP solution: Time O(N^2), Space O(N)
class Solution {
public:
    bool increasingTriplet(vector<int>& nums) {
        vector<int> dp(nums.size(), 1);
        for (int i = 0; i < nums.size(); ++i) {
            for (int j = 0; j < i; ++j) {
                if (nums[j] < nums[i]) {
                    dp[i] = max(dp[i], dp[j] + 1);
                    if (dp[i] == 3) return true;
                }
            }
        }
        return false;
    }
};
```

```
// 2. Two minimum values: Time O(N), Space O(1)
class Solution {
public:
    bool increasingTriplet(vector<int>& nums) {
        int c1 = INT_MAX, c2 = INT_MAX;
        for (int i = 0; i < nums.size(); ++i) {
            if (nums[i] <= c1) c1 = nums[i]; // the first minimum
            else if (nums[i] <= c2) c2 = nums[i]; // the second minimum
            else return true; // the third value
        }
        return false;
    }
};
```

11.34 Longest Continuous Increasing Subsequence (E)

Given an unsorted array of integers, find the length of longest continuous increasing subsequence (subarray).

Example 1:

Input: [1,3,5,4,7]

Output: 3

Explanation: The longest continuous increasing subsequence is [1,3,5], its length is 3.

Even though [1,3,5,7] is also an increasing subsequence, it's not a continuous one where 5 and 7 are separated by 4.

Example 2:

Input: [2,2,2,2,2]

Output: 1

Explanation: The longest continuous increasing subsequence is [2], its length is 1.

Note: Length of the array will not exceed 10,000.

```
class Solution(object):
    def findLengthOfLCIS(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        cnt, res = 0, 0
        for i in range(len(nums)):
            if i == 0 or nums[i-1] < nums[i]:
                cnt += 1
                res = max(res, cnt)
            else:
                cnt = 1 # reset cnt if the continuous increasing stops
        return res
```

11.35 Longest Increasing Subsequence (M)

Given an unsorted array of integers, find the length of longest increasing subsequence.

For example, Given [10, 9, 2, 5, 3, 7, 101, 18], The longest increasing subsequence is [2, 3, 7, 101], therefore the length is 4. Note that there may be more than one LIS combination, it is only necessary for you to return the length.

Your algorithm should run in $O(n^2)$ complexity.

Follow up: Could you improve it to $O(n \log n)$ time complexity?

```
class Solution(object):
    def lengthOfLIS(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        n = len(nums)
        dp = [1] * n
        res = 0
        for i in range(n):
            for j in range(i):
                if nums[j] < nums[i]:
                    dp[i] = max(dp[i], dp[j] + 1)
            res = max(res, dp[i])
        return res
```

```
// 1. DP solution: Time  $O(N^2)$ , Space  $O(N)$ 
class Solution {
public:
    int lengthOfLIS(vector<int>& nums) {
        vector<int> dp(nums.size(), 1);
        int res = 0;
        for (int i = 0; i < nums.size(); ++i) {
            for (int j = 0; j < i; ++j) {
                if (nums[j] < nums[i]) {
                    dp[i] = max(dp[i], dp[j] + 1);
                }
            }
            res = max(res, dp[i]);
        }
        return res;
    }
};
```

```
// 2. Binary search: Time  $O(N \log N)$ , Space  $O(N)$ 
class Solution {
public:
    int lengthOfLIS(vector<int>& nums) {
        if (nums.empty()) return 0;
        vector<int> res = {nums[0]};
        for (int i = 1; i < nums.size(); ++i) {
            if (nums[i] < res[0]) { // update minimum
```



```

        res[0] = nums[i];
    } else if (nums[i] > res.back()) { // update maximum
        res.push_back(nums[i]);
    } else { // find values between the first and the last element of res
        and add them into res
        int left = 0, right = res.size() - 1;
        while (left < right) {
            int mid = left + (right - left) / 2;
            if (res[mid] < nums[i]) left = mid + 1;
            else right = mid;
        }
        res[right] = nums[i];
    }
}
return res.size(); // the res size is the length of LIS
};

```

11.36 Number of Longest Increasing Subsequence (M)

Given an unsorted array of integers, find the number of longest increasing subsequence.

Example 1:

Input: [1,3,5,4,7]

Output: 2

Explanation: The two longest increasing subsequence are [1, 3, 4, 7] and [1, 3, 5, 7].

Example 2:

Input: [2,2,2,2,2]

Output: 5

Explanation: The length of longest continuous increasing subsequence is 1, and there are 5 subsequences' length is 1, so output 5.

Note: Length of the given array will be not exceed 2000 and the answer is guaranteed to be fit in 32-bit signed int.

```

class Solution(object):
    def findNumberOfLIS(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """

```

```

mx, res = 0, 0
n = len(nums)
# length of the increasing subsequence (IS) at i
length = [1] * n
# count of the increasing subsequence at i
cnt = [1] * n
for i in range(n):
    for j in range(i):
        # skip if not IS
        if nums[i] <= nums[j]: continue
        # nums[i] can be added after the IS that is end at nums[j]
        # cnt[j] can be added into cnt[i]
        if length[i] == length[j] + 1:
            cnt[i] += cnt[j]
        # a longer IS exists at nums[i], so update length[i]
        if length[i] < length[j] + 1:
            length[i] = length[j] + 1
            cnt[i] = cnt[j]
    if mx == length[i]:
        res += cnt[i]
    elif mx < length[i]:
        mx = length[i]
        res = cnt[i]
return res

```

11.37 Longest Consecutive Sequence (H)

Given an unsorted array of integers, find the length of the longest consecutive elements sequence.

Your algorithm should run in $O(n)$ complexity.

Example:

Input: [100, 4, 200, 1, 3, 2]

Output: 4

Explanation: The longest consecutive elements sequence is [1, 2, 3, 4]. Therefore its length is 4.

```

# #  $O(N^3)$ 
# class Solution(object):
#     def longestConsecutive(self, nums):
#         """
#         :type nums: List[int]

```

```

#         :rtype: int
#         """
#         longest = 0
#         for num in nums:
#             cur_num = num
#             cur = 1
#             while cur_num + 1 in nums:
#                 cur_num += 1
#                 cur += 1
#             longest = max(longest, cur)
#         return longest

# O(NlogN)
class Solution(object):
    def longestConsecutive(self, nums):
        if not nums: return 0
        nums.sort()
        cur, longest = 1, 1
        for i in range(1, len(nums)):
            # skip duplicates
            if nums[i] != nums[i-1]:
                # find the consecutive sequence
                if nums[i] == nums[i-1] + 1:
                    cur += 1
                # otherwise update longest and reset cur
                else:
                    longest = max(longest, cur)
                    cur = 1
        return max(longest, cur)

# O(N)
class Solution(object):
    def longestConsecutive(self, nums):
        longest = 0
        num_set = set(nums)
        for num in num_set:
            # We only attempt to build sequences from numbers that are not already
            # part of a longer sequence. This is accomplished by first ensuring that
            # the number that would immediately precede the current number in a
            # sequence
            # is not present, as that number would necessarily be part of a longer
            # sequence.
            if num - 1 not in num_set:
                cur_num = num
                cur = 1
                while cur_num + 1 in num_set:
                    cur_num += 1

```

```

        cur +=1
        longest = max(longest, cur)
    return longest

```

11.38 Longest Increasing Path in a Matrix (M)

Given an integer matrix, find the length of the longest increasing path. From each cell, you can either move to four directions: left, right, up or down. You may NOT move diagonally or move outside of the boundary (i.e. wrap-around is not allowed).

Example 1:

nums = [[9,9,4], [6,6,8], [2,1,1]], Return 4, The longest increasing path is [1, 2, 6, 9].

Example 2:

nums = [[3,4,5], [3,2,6], [2,2,1]], Return 4, The longest increasing path is [3, 4, 5, 6]. Moving diagonally is not allowed.

```

class Solution {
public:
    int longestIncreasingPath(vector<vector<int>> &matrix) {
        if (matrix.empty() || matrix[0].empty()) return 0;
        int res = 1, m = matrix.size(), n = matrix[0].size();
        vector<vector<int>> dp(m, vector<int>(n, 0));
        for (int i = 0; i < m; ++i) {
            for (int j = 0; j < n; ++j) {
                res = max(res, dfs(matrix, dp, i, j));
            }
        }
        return res;
    }
    int dfs(vector<vector<int>> &matrix, vector<vector<int>> &dp, int i, int j)
    {
        if (dp[i][j]) return dp[i][j];
        // move left, up, right, down
        vector<vector<int>> dirs = {{0, -1}, {-1, 0}, {0, 1}, {1, 0}};
        int max_len = 1, m = matrix.size(), n = matrix[0].size();
        for (auto a : dirs) {
            int x = i + a[0], y = j + a[1]; // move (i,j) to next cell
            // avoid corner cases, look for the increasing path
            if (x < 0 || x >= m || y < 0 || y >= n || matrix[x][y] <=
                matrix[i][j]) continue;
            int len = 1 + dfs(matrix, dp, x, y);
            max_len = max(max_len, len);
        }
    }
}

```

```

        dp[i][j] = max_len;
        return max_len;
    }
};

```

11.39 Maximal Square (M)

Given a 2D binary matrix filled with 0's and 1's, find the largest square containing all 1's and return its area.

For example, given the following matrix:

```
1 0 1 0 0
```

```
1 0 1 1 1
```

```
1 1 1 1 1
```

```
1 0 0 1 0
```

Return 4.

```

class Solution {
public:
    int maximalSquare(vector<vector<char>>& matrix) {
        if(matrix.size() == 0) return 0;
        int maxSq = 0;
        int nRow = matrix.size();
        int nCol = matrix[0].size();
        vector<vector<int>> dp(nRow + 1, vector<int>(nCol + 1, 0));
        // dp[i][j] represents max square ending at position (i-1, j-1)
        // dp[i][j] = min(dp[i - 1][j], dp[i][j - 1], dp[i - 1][j - 1]) + 1
        for(int i = 1; i <= nRow; ++i){
            for(int j = 1; j <= nCol; ++j){
                if(matrix[i-1][j-1] == '1'){
                    dp[i][j] = min(min(dp[i][j-1], dp[i-1][j]), dp[i-1][j-1]) + 1;
                    maxSq = max(maxSq, dp[i][j]);
                }
            }
        }
        return maxSq * maxSq;
    }
};

```

11.40 Maximal Rectangle (H)

Given a 2D binary matrix filled with 0's and 1's, find the largest rectangle containing all ones and return its area.

For example, given the following matrix:

1 0 1 0 0

1 0 1 1 1

1 1 1 1 1

1 0 0 1 0

Return 6.

```
/** The DP solution proceeds row by row, starting from the first row.
 * Let the maximal rectangle area at row i and column j be computed by
 * [right(i,j) - left(i,j)] * height(i,j).
 *
 * left(i,j) = max(left(i-1,j), cur_left), cur_left can be determined from the
 * current row
 * right(i,j) = min(right(i-1,j), cur_right), cur_right can be determined from
 * the current row
 * height(i,j) = height(i-1,j) + 1, if matrix[i][j]=='1';
 * height(i,j) = 0, if matrix[i][j]=='0'
 */
class Solution {
public:
    int maximalRectangle(vector<vector<char>>& matrix) {
        if (matrix.empty() || matrix[0].empty()) return 0;
        int res = 0, m = matrix.size(), n = matrix[0].size();
        vector<int> height(n, 0), left(n, 0), right(n, n);
        for (int i = 0; i < m; ++i) {
            int cur_left = 0, cur_right = n;
            // compute height (can do this from either side)
            for (int j = 0; j < n; ++j) {
                if (matrix[i][j] == '1') ++height[j];
                else height[j] = 0;
            }
            // compute left (from left to right)
            for (int j = 0; j < n; ++j) {
                if (matrix[i][j] == '1') {
                    left[j] = max(left[j], cur_left);
                }
                else {
                    left[j] = 0;
                    cur_left = j + 1;
                }
            }
            // compute right (from right to left)
            for (int j = n - 1; j >= 0; --j) {
                if (matrix[i][j] == '1'){
                    right[j] = min(right[j], cur_right);
                }
            }
            for (int j = 0; j < n; ++j) {
                res = max(res, (right[j] - left[j]) * height[j]);
            }
        }
        return res;
    }
};
```

```
    }
    else {
        right[j] = n;
        cur_right = j;
    }
}
// compute the area of rectangle (can do this from either side)
for (int j = 0; j < n; ++j) {
    res = max(res, (right[j] - left[j]) * height[j]);
}
}
return res;
}
};
```

Chapter 12

Graph

12.1 Number of Connected Components in an Undirected Graph (M)

Given n nodes labeled from 0 to $n - 1$ and a list of undirected edges (each edge is a pair of nodes), write a function to find the number of connected components in an undirected graph.

Example 1: Given $n = 5$ and edges = $[[0, 1], [1, 2], [3, 4]]$, return 2.

Example 2: Given $n = 5$ and edges = $[[0, 1], [1, 2], [2, 3], [3, 4]]$, return 1.

Note: You can assume that no duplicate edges will appear in edges. Since all edges are undirected, $[0, 1]$ is the same as $[1, 0]$ and thus will not appear together in edges.

```
class Solution {
public:
    int countComponents(int n, vector<pair<int, int> >& edges) {
        vector<vector<int>> graph(n); // adjacency list
        vector<bool> visit(n, false); // visit state
        int res = 0;
        // create the adjacency list
        for (auto edge : edges) {
            graph[edge.first].push_back(edge.second);
            graph[edge.second].push_back(edge.first);
        }
        for (int i = 0; i < n; ++i) {
            if (!visit[i]) { // if i is not visited
                ++res; // increase the number of connected components
                dfs(graph, visit, i); // use dfs to visit all nodes in the current
                                   // conneted component
            }
        }
        return res;
    }
};
```



```

    }

    void dfs(vector<vector<int>> &graph, vector<bool> &visit, int i) {
        if (visit[i]) return;
        visit[i] = true;
        for (int j = 0; j < graph[i].size(); ++j) {
            dfs(graph, visit, graph[i][j]); // traverse all nodes connected to i
        }
    }
};

```

12.2 Graph Valid Tree (M)

Given n nodes labeled from 0 to $n - 1$ and a list of undirected edges (each edge is a pair of nodes), write a function to check whether these edges make up a valid tree.

For example:

Given $n = 5$ and edges = $[[0, 1], [0, 2], [0, 3], [1, 4]]$, return true.

Given $n = 5$ and edges = $[[0, 1], [1, 2], [2, 3], [1, 3], [1, 4]]$, return false.

Hint:

Given $n = 5$ and edges = $[[0, 1], [1, 2], [3, 4]]$, what should your return? Is this case a valid tree?

According to the definition of tree on Wikipedia: ?a tree is an undirected graph in which any two vertices are connected by exactly one path. In other words, any connected graph without simple cycles is a tree.?

Note: you can assume that no duplicate edges will appear in edges. Since all edges are undirected, $[0, 1]$ is the same as $[1, 0]$ and thus will not appear together in edges.

```

// DFS
class Solution {
public:
    bool validTree(int n, vector<pair<int, int>>& edges) {
        vector<vector<int>> graph(n, vector<int>());
        vector<bool> visit(n, false);
        for (auto edge : edges) {
            g[edge.first].push_back(edge.second);
            g[edge.second].push_back(edge.first);
        }
        if (!dfs(graph, visit, 0, -1)) return false;
        for (auto v : visit) {
            if (!v) return false;
        }
    }
}

```

```

        return true;
    }
    bool dfs(vector<vector<int>> &graph, vector<bool> &visit, int cur, int pre) {
        if (visit[cur]) return false;
        visit[cur] = true;
        for (auto g : graph[cur]) {
            if (g != pre) {
                if (!dfs(graph, visit, g, cur)) return false;
            }
        }
        return true;
    }
};

// BFS
class Solution {
public:
    bool validTree(int n, vector<pair<int, int>>& edges) {
        vector<unordered_set<int>> graph(n, unordered_set<int>());
        unordered_set<int> visit;
        queue<int> q;
        q.push(0);
        visit.insert(0);
        for (auto edge : edges) {
            graph[edge.first].insert(edge.second);
            graph[edge.second].insert(edge.first);
        }
        while (!q.empty()) {
            int t = q.front(); q.pop();
            for (auto g : graph[t]) {
                if (visit.find(g) != visit.end()) return false;
                visit.insert(g);
                q.push(g);
                graph[g].erase(t);
            }
        }
        return visit.size() == n;
    }
};

```

12.3 Copy List with Random Pointer (M)

A linked list is given such that each node contains an additional random pointer which could point to any node in the list or null.

Return a deep copy of the list.

```

"""
# Definition for a Node.
class Node(object):
    def __init__(self, val, next, random):
        self.val = val
        self.next = next
        self.random = random
"""

class Solution(object):
    def copyRandomList(self, head):
        """
        :type head: Node
        :rtype: Node
        """
        list_dict = {}
        return self.helper(head, list_dict)
    def helper(self, node, list_dict):
        if not node: return None
        # if the random node points to a node that is already in the dict,
        # then just return the node as the random node
        if node in list_dict:
            return list_dict[node]
        new_node = Node(node.val, None, None)
        list_dict[node] = new_node
        new_node.next = self.helper(node.next, list_dict)
        new_node.random = self.helper(node.random, list_dict)
        return new_node

```

12.4 Clone Graph (M)

Clone an undirected graph. Each node in the graph contains a label and a list of its neighbors.

```

"""
# Definition for a Node.
class Node(object):
    def __init__(self, val, neighbors):
        self.val = val
        self.neighbors = neighbors
"""

class Solution(object):
    def cloneGraph(self, node):
        """
        :type node: Node

```

```

        :rtype: Node
        """
        node_dict = {}
        return self.helper(node, node_dict)
def helper(self, node, node_dict):
    if not node: return None
    if node in node_dict:
        return node_dict[node]
    new_node = Node(node.val, [])
    node_dict[node] = new_node
    for n in node.neighbors:
        new_node.neighbors.append(self.helper(n, node_dict))
    return new_node

```

```

/**
 * Definition for undirected graph.
 * struct UndirectedGraphNode {
 *     int label;
 *     vector<UndirectedGraphNode *> neighbors;
 *     UndirectedGraphNode(int x) : label(x) {};
 * };
 */
class Solution {
public:
    UndirectedGraphNode *cloneGraph(UndirectedGraphNode *node) {
        // use hashtable to map label and neighbors
        unordered_map<int, UndirectedGraphNode*> umap;
        return clone(node, umap);
    }
    UndirectedGraphNode *clone(UndirectedGraphNode *node, unordered_map<int,
        UndirectedGraphNode*> &umap) {
        if (!node) return node;
        // if label is in the hashtable, return the list of neighbors
        if (umap.count(node->label)) return umap[node->label];
        // otherwise, define a new node that has label
        UndirectedGraphNode *newNode = new UndirectedGraphNode(node->label);
        // update hashtable
        umap[node->label] = newNode;
        // perform DFS
        // create a list of neighbors for the new node
        for (int i = 0; i < node->neighbors.size(); ++i) {
            (newNode->neighbors).push_back(clone(node->neighbors[i], umap));
        }
        return newNode;
    }
};

```

12.5 Course Schedule (M)

There are a total of n courses you have to take, labeled from 0 to $n - 1$. Some courses may have prerequisites, for example to take course 0 you have to first take course 1, which is expressed as a pair: $[0,1]$. Given the total number of courses and a list of prerequisite pairs, is it possible for you to finish all courses?

For example:

2, $[[1,0]]$: There are a total of 2 courses to take. To take course 1 you should have finished course 0. So it is possible.

2, $[[1,0],[0,1]]$: There are a total of 2 courses to take. To take course 1 you should have finished course 0, and to take course 0 you should also have finished course 1. So it is impossible.

Note: The input prerequisites is a graph represented by a list of edges, not adjacency matrices. Read more about how a graph is represented.

Hints:

This problem is equivalent to finding if a cycle exists in a directed graph. If a cycle exists, no topological ordering exists and therefore it will be impossible to take all courses.

Topological Sort via DFS - A great video tutorial (21 minutes) on Coursera explaining the basic concepts of Topological Sort.

Topological sort could also be done via BFS.

```
// DFS solution
class Solution {
public:
    bool canFinish(int numCourses, vector<pair<int, int>>& prerequisites) {
        vector<vector<int> > graph(numCourses, vector<int>(0));
        vector<int> visit(numCourses, 0);
        for (auto a : prerequisites) {
            graph[a.second].push_back(a.first);
        }
        for (int i = 0; i < numCourses; ++i) {
            if (!canFinishDFS(graph, visit, i)) return false;
        }
        return true;
    }
    bool canFinishDFS(vector<vector<int> > &graph, vector<int> &visit, int i) {
        if (visit[i] == -1) return false;
        if (visit[i] == 1) return true;
        visit[i] = -1;
        for (auto a : graph[i]) {
            if (!canFinishDFS(graph, visit, a)) return false;
        }
        visit[i] = 1;
    }
};
```

```

        return true;
    }
};

// BFS solution
class Solution {
public:
    bool canFinish(int numCourses, vector<pair<int, int>>& prerequisites) {
        vector<vector<int>> > graph(numCourses, vector<int>(0));
        vector<int> in(numCourses, 0);
        for (auto a : prerequisites) {
            graph[a.second].push_back(a.first);
            ++in[a.first];
        }
        queue<int> q;
        for (int i = 0; i < numCourses; ++i) {
            if (in[i] == 0) q.push(i);
        }
        while (!q.empty()) {
            int t = q.front();
            q.pop();
            for (auto a : graph[t]) {
                --in[a];
                if (in[a] == 0) q.push(a);
            }
        }
        for (int i = 0; i < numCourses; ++i) {
            if (in[i] != 0) return false;
        }
        return true;
    }
};

```

12.6 Course Schedule II (M)

There are a total of n courses you have to take, labeled from 0 to $n - 1$. Some courses may have prerequisites, for example to take course 0 you have to first take course 1, which is expressed as a pair: $[0,1]$. Given the total number of courses and a list of prerequisite pairs, return the ordering of courses you should take to finish all courses. There may be multiple correct orders, you just need to return one of them. If it is impossible to finish all courses, return an empty array.

For example:

2, $[[1,0]]$: There are a total of 2 courses to take. To take course 1 you should have finished course 0. So the correct course order is $[0,1]$

4, [[1,0],[2,0],[3,1],[3,2]]: There are a total of 4 courses to take. To take course 3 you should have finished both courses 1 and 2. Both courses 1 and 2 should be taken after you finished course 0. So one correct course order is [0,1,2,3]. Another correct ordering is [0,2,1,3].

Note: The input prerequisites is a graph represented by a list of edges, not adjacency matrices. Read more about how a graph is represented.

```
class Solution {
public:
    vector<int> findOrder(int numCourses, vector<pair<int, int>>& prerequisites) {
        vector<int> res;
        vector<vector<int>> > graph(numCourses, vector<int>(0));
        vector<int> in(numCourses, 0);
        for (auto &a : prerequisites) {
            graph[a.second].push_back(a.first);
            ++in[a.first];
        }
        queue<int> q;
        for (int i = 0; i < numCourses; ++i) {
            if (in[i] == 0) q.push(i);
        }
        while (!q.empty()) {
            int t = q.front();
            res.push_back(t);
            q.pop();
            for (auto &a : graph[t]) {
                --in[a];
                if (in[a] == 0) q.push(a);
            }
        }
        // clear the result if a cycle exists
        if (res.size() != numCourses) res.clear();
        return res;
    }
};
```

12.7 Minimum Height Trees (M)

For a undirected graph with tree characteristics, we can choose any node as the root. The result graph is then a rooted tree. Among all possible rooted trees, those with minimum height are called minimum height trees (MHTs). Given such a graph, write a function to find all the MHTs and return a list of their root labels.

Format:

The graph contains n nodes which are labeled from 0 to $n - 1$. You will be given the number n and a list of undirected edges (each edge is a pair of labels). You can assume that no duplicate edges will appear in edges. Since all edges are undirected, $[0, 1]$ is the same as $[1, 0]$ and thus will not appear together in edges.

Example 1: Given $n = 4$, edges = $[[1, 0], [1, 2], [1, 3]]$, return $[1]$

Example 2: Given $n = 6$, edges = $[[0, 3], [1, 3], [2, 3], [4, 3], [5, 4]]$, return $[3, 4]$

Hint: How many MHTs can a graph have at most?

Note:

(1) According to the definition of tree on Wikipedia: "a tree is an undirected graph in which any two vertices are connected by exactly one path. In other words, any connected graph without simple cycles is a tree."

(2) The height of a rooted tree is the number of edges on the longest downward path between the root and a leaf.

```
// Non-recursion
class Solution {
public:
    vector<int> findMinHeightTrees(int n, vector<pair<int, int> >& edges) {
        if (n == 1) return {0};
        vector<int> res, d(n, 0);
        vector<vector<int> > g(n, vector<int>());
        queue<int> q;
        for (auto a : edges) {
            g[a.first].push_back(a.second);
            ++d[a.first];
            g[a.second].push_back(a.first);
            ++d[a.second];
        }
        for (int i = 0; i < n; ++i) {
            if (d[i] == 1) q.push(i);
        }
        while (n > 2) {
            int sz = q.size();
            for (int i = 0; i < sz; ++i) {
                int t = q.front(); q.pop();
                --n;
                for (int i : g[t]) {
                    --d[i];
                    if (d[i] == 1) q.push(i);
                }
            }
        }
        while (!q.empty()) {
```



```

        res.push_back(q.front()); q.pop();
    }
    return res;
}
};

```

12.8 Reconstruct Itinerary (M)

Given a list of airline tickets represented by pairs of departure and arrival airports [from, to], reconstruct the itinerary in order. All of the tickets belong to a man who departs from JFK. Thus, the itinerary must begin with JFK.

Note:

If there are multiple valid itineraries, you should return the itinerary that has the smallest lexical order when read as a single string. For example, the itinerary ["JFK", "LGA"] has a smaller lexical order than ["JFK", "LGB"].

All airports are represented by three capital letters (IATA code).

You may assume all tickets form at least one valid itinerary.

Example 1:

tickets = [["MUC", "LHR"], ["JFK", "MUC"], ["SFO", "SJC"], ["LHR", "SFO"]]

Return ["JFK", "MUC", "LHR", "SFO", "SJC"].

Example 2:

tickets = [["JFK", "SFO"], ["JFK", "ATL"], ["SFO", "ATL"], ["ATL", "JFK"], ["ATL", "SFO"]]

Return ["JFK", "ATL", "JFK", "SFO", "ATL", "SFO"].

Another possible reconstruction is ["JFK", "SFO", "ATL", "JFK", "ATL", "SFO"]. But it is larger in lexical order.

```

class Solution {
public:
    vector<string> findItinerary(vector<pair<string, string> > tickets) {
        vector<string> res;
        unordered_map<string, multiset<string> > m;
        for (auto a : tickets) {
            m[a.first].insert(a.second);
        }
        dfs(m, "JFK", res);
        return vector<string> (res.rbegin(), res.rend());
    }
    void dfs(unordered_map<string, multiset<string> > &m, string s,
            vector<string> &res) {
        while (m[s].size()) {
            string t = *m[s].begin();

```

```
        m[s].erase(m[s].begin());  
        dfs(m, t, res);  
    }  
    res.push_back(s);  
}  
};
```

Chapter 13

Design and Implementation

13.1 Valid Sudoku (E)

Determine if a Sudoku is valid, according to:

1. Each row must have the numbers 1-9 occurring just once.
2. Each column must have the numbers 1-9 occurring just once.
3. And the numbers 1-9 must occur just once in each of the 9 sub-boxes of the grid.

The Sudoku board could be partially filled, where empty cells are filled with the character '.'. A valid Sudoku board (partially filled) is not necessarily solvable. Only the filled cells need to be validated.

```
class Solution {
public:
    bool isValidSudoku(vector<vector<char>>& board) {
        bool used[9]; // count if the number in the cell is appeared

        for (int i = 0; i < 9; ++i) {

            // fill: Assigns val to all the elements in the range [first,last).
            // all set to false (not appear)
            fill(used, used + 9, false);
            // check rows
            for (int j = 0; j < 9; ++j) {
                if (!check(board[i][j], used))
                    return false;
            }

            fill(used, used + 9, false);
            // check columns
            for (int j = 0; j < 9; ++j) {
                if (!check(board[j][i], used))
                    return false;
            }
        }
    }
};
```

```

    }
}

// check 9 blocks
for (int m = 0; m < 3; ++m) {
    for (int n = 0; n < 3; ++n) {
        fill(used, used + 9, false);
        for (int i = m * 3; i < m * 3 + 3; ++i) {
            for (int j = n * 3; j < n * 3 + 3; ++j) {
                if (!check(board[i][j], used))
                    return false;
            }
        }
    }
}

return true;
}

bool check(char ch, bool used[9]) {
    if (ch == '.') return true; // continue if the current cell is .
    if (used[ch - '1']) return false; // not first time appear, return false
    return used[ch - '1'] = true; // first time appear, return true
}
};

```

13.2 Sudoku Solver (H)

Write a program to solve a Sudoku puzzle by filling the empty cells. Empty cells are indicated by the character '.'. You may assume that there will be only one unique solution.

```

class Solution {
public:
    bool solveSudoku(vector<vector<char>> &board) {
        for (int i = 0; i < 9; ++i) {
            for (int j = 0; j < 9; ++j) {
                if (board[i][j] == '.') {
                    for (int k = 0; k < 9; ++k) {
                        board[i][j] = '1' + k;
                        if (isValid(board, i, j) && solveSudoku(board))
                            return true;
                        board[i][j] = '.';
                    }
                    return false;
                }
            }
        }
    }
};

```

```

    }
}
return true;
}

bool isValid(const vector<vector<char> > &board, int x, int y) {
    int i, j;
    for (i = 0; i < 9; i++) {
        if (i != x && board[i][y] == board[x][y])
            return false;
    }
    for (j = 0; j < 9; j++) {
        if (j != y && board[x][j] == board[x][y])
            return false;
    }
    for (i = 3 * (x / 3); i < 3 * (x / 3 + 1); i++) {
        for (j = 3 * (y / 3); j < 3 * (y / 3 + 1); j++) {
            if ((i != x || j != y) && board[i][j] == board[x][y])
                return false;
        }
    }
    return true;
}
};

```

13.3 Boom Enemy (M)

Given a 2D grid, each cell is either a wall 'W', an enemy 'E' or empty '0' (the number zero), return the maximum enemies you can kill using one bomb. The bomb kills all the enemies in the same row and column from the planted point until it hits the wall since the wall is too strong to be destroyed. Note that you can only put the bomb at an empty cell.

Example:

For the given grid

0 E 0 0

E 0 W E

0 E 0 0

return 3. (Placing a bomb at (1,1) kills 3 enemies)

```

class Solution {
public:
    int maxKilledEnemies(vector<vector<char>>& grid) {
        if (grid.empty() || grid[0].empty()) return 0;
        int m = grid.size(), n = grid[0].size(), res = 0, tmp;
    }
};

```

```

vector<vector<int>> v1(m, vector<int>(n, 0)), v2 = v1, v3 = v1, v4 = v1;
// search each row
for (int i = 0; i < m; ++i) {
    for (int j = 0; j < n; ++j) { // from left to right
        if (j == 0 || grid[i][j] == 'W') tmp = 0;
        else tmp = v1[i][j-1];
        if (grid[i][j] == 'E') v1[i][j] = tmp + 1;
        else v1[i][j] = tmp;
    }
    for (int j = n - 1; j >= 0; --j) { // from right to left
        if (j == n - 1 || grid[i][j] == 'W') tmp = 0;
        else tmp = v2[i][j+1];
        if (grid[i][j] == 'E') v2[i][j] = tmp + 1;
        else v2[i][j] = tmp;
    }
}
// search each column
for (int j = 0; j < n; ++j) {
    for (int i = 0; i < m; ++i) { // from up to bottom
        if (i == 0 || grid[i][j] == 'W') tmp = 0;
        else tmp = v3[i-1][j];
        if (grid[i][j] == 'E') v3[i][j] = tmp + 1;
        else v3[i][j] = tmp;
    }
    for (int i = m - 1; i >= 0; --i) { // from bottom to up
        if (i == m - 1 || grid[i][j] == 'W') tmp = 0;
        else tmp = v4[i+1][j];
        if (grid[i][j] == 'E') v4[i][j] = tmp + 1;
        else v4[i][j] = tmp;
    }
}
// iterate all empty cell and get the max
for (int i = 0; i < m; ++i) {
    for (int j = 0; j < n; ++j) {
        if (grid[i][j] == '0') {
            res = max(res, v1[i][j] + v2[i][j] + v3[i][j] + v4[i][j]);
        }
    }
}
return res;
}
};

```

13.4 Android Unlock Patterns (M)

Given an Android 3x3 key lock screen and two integers m and n , where $1 \leq m \leq n \leq 9$, count the total number of unlock patterns of the Android lock screen, which consist of minimum of m keys and maximum n keys.

Rules for a valid pattern:

Each pattern must connect at least m keys and at most n keys.

All the keys must be distinct.

If the line connecting two consecutive keys in the pattern passes through any other keys, the other keys must have previously selected in the pattern. No jumps through non selected key is allowed.

The order of keys used matters.

```
class Solution {
public:
    int numberOfPatterns(int m, int n) {
        int res = 0;
        vector<bool> visited(10, false);
        vector<vector<int>> jumps(10, vector<int>(10, 0));
        jumps[1][3] = jumps[3][1] = 2;
        jumps[4][6] = jumps[6][4] = 5;
        jumps[7][9] = jumps[9][7] = 8;
        jumps[1][7] = jumps[7][1] = 4;
        jumps[2][8] = jumps[8][2] = 5;
        jumps[3][9] = jumps[9][3] = 6;
        jumps[1][9] = jumps[9][1] = jumps[3][7] = jumps[7][3] = 5;
        res += helper(1, 1, 0, m, n, jumps, visited) * 4;
        res += helper(2, 1, 0, m, n, jumps, visited) * 4;
        res += helper(5, 1, 0, m, n, jumps, visited);
        return res;
    }
    int helper(int num, int len, int res, int m, int n, vector<vector<int>>
        &jumps, vector<bool> &visited) {
        if (len >= m) ++res;
        ++len;
        if (len > n) return res;
        visited[num] = true;
        for (int next = 1; next <= 9; ++next) {
            int jump = jumps[num][next];
            if (!visited[next] && (jump == 0 || visited[jump])) {
                res = helper(next, len, res, m, n, jumps, visited);
            }
        }
        visited[num] = false;
        return res;
    }
};
```

```
}  
};
```

13.5 Game of Life (M)

According to the Wikipedia's article: "The Game of Life, also known simply as Life, is a cellular automaton devised by the British mathematician John Horton Conway in 1970." Given a board with m by n cells, each cell has an initial state live (1) or dead (0). Each cell interacts with its eight neighbors (horizontal, vertical, diagonal) using the following four rules (taken from the above Wikipedia article):

Any live cell with fewer than two live neighbors dies, as if caused by under-population.
Any live cell with two or three live neighbors lives on to the next generation.
Any live cell with more than three live neighbors dies, as if by over-population.
Any dead cell with exactly three live neighbors becomes a live cell, as if by reproduction.

Write a function to compute the next state (after one update) of the board given its current state.

Follow up:

Could you solve it in-place? Remember that the board needs to be updated at the same time: You cannot update some cells first and then use their updated values to update other cells.

In this question, we represent the board using a 2D array. In principle, the board is infinite, which would cause problems when the active area encroaches the border of the array. How would you address these problems?

```
/** [2nd bit, 1st bit] = [next state, current state]  
 * 00 dead (next) <- dead (current)  
 * 01 dead (next) <- live (current)  
 * 10 live (next) <- dead (current)  
 * 11 live (next) <- live (current)  
 *  
 * 1. In the beginning, every cell is either 00 or 01.  
 * 2. Notice that 1st state is independent of 2nd state.  
 * 3. Imagine all cells are instantly changing from the 1st to the 2nd state, at  
 *    the same time.  
 * 4. Let's count # of neighbors from 1st state and set 2nd state bit.  
 * 5. Since every 2nd state is by default dead, no need to consider transition  
 *    01 -> 00.  
 * 6. In the end, delete every cell's 1st state by doing >> 1.  
 *  
 * For each cell's 1st bit, check the 8 pixels around itself, and set the cell's  
 * 2nd bit.
```



```

    Transition 01 -> 11: when board == 1 and (lives == 2 || lives == 3).
    Transition 00 -> 10: when board == 0 and lives == 3.
    * To get the current state, simply do board[i][j] & 1
    * To get the next state, simply do board[i][j] >> 1
    */
class Solution {
public:
    void gameOfLife(vector<vector<int>>& board) {
        if (board.empty() || board.size() == 0) return;
        int m = board.size(), n = board[0].size();
        for (int i = 0; i < m; ++i) {
            for (int j = 0; j < n; ++j) {
                int lives = getLives(board, i, j, m, n); // get current live
                numbers
                if (board[i][j] == 1 && (lives == 2 || lives == 3)) {
                    board[i][j] = 3; // 01 -> 11
                }

                if (board[i][j] == 0 && lives == 3) {
                    board[i][j] = 2; // 00 -> 10
                }
            }
        }
        // update board based on the 2nd bit
        for (int i = 0; i < m; ++i) {
            for (int j = 0; j < n; ++j) {
                board[i][j] >>= 1; // get the 2nd bit
            }
        }
    }
    int getLives(vector<vector<int>>& board, int i, int j, int m, int n) {
        int lives = 0;
        for (int p = max(i-1, 0); p <= min(i+1, m-1); ++p) {
            for (int q = max(j-1, 0); q <= min(j+1, n-1); ++q) {
                lives += board[p][q] & 1; // add the 1st bit
            }
        }
        lives -= board[i][j] & 1; // remove (i,j) itself
        return lives;
    }
};

```

13.6 Peeking Iterator (M)

Given an Iterator class interface with methods: `next()` and `hasNext()`, design and implement a `PeekingIterator` that support the `peek()` operation – it essentially `peek()` at the element

that will be returned by the next call to next().

Here is an example. Assume that the iterator is initialized to the beginning of the list: [1, 2, 3].

Call next() gets you 1, the first element in the list.

Now you call peek() and it returns 2, the next element. Calling next() after that still return 2.

You call next() the final time and it returns 3, the last element. Calling hasNext() after that should return false.

Hint:

Think of "looking ahead". You want to cache the next element.

Is one variable sufficient? Why or why not?

Test your design with call order of peek() before next() vs next() before peek().

For a clean implementation, check out Google's guava library source code.

Follow up: How would you extend your design to be generic and work with all types, not just integer?

```
// Below is the interface for Iterator, which is already defined for you.
// **DO NOT** modify the interface for Iterator.
class Iterator {
    struct Data;
    Data* data;
public:
    Iterator(const vector<int>& nums);
    Iterator(const Iterator& iter);
    virtual ~Iterator();
    // Returns the next element in the iteration.
    int next();
    // Returns true if the iteration has more elements.
    bool hasNext() const;
};

class PeekingIterator : public Iterator {
public:
    PeekingIterator(const vector<int>& nums) : Iterator(nums) {
        // Initialize any member here.
        // **DO NOT** save a copy of nums and manipulate it directly.
        // You should only use the Iterator interface methods.
        flag = false; // use flag to indict if next is saved in value
    }

    // Returns the next element in the iteration without advancing the iterator.
    int peek() {
```

```

        if (!flag) {
            value = Iterator::next();
            flag = true;
        }
        return value;
    }

    // hasNext() and next() should behave the same as in the Iterator interface.
    // Override them if needed.
    int next() {
        if (!flag) {
            return Iterator::next();
        } else {
            flag = false;
            return value;
        }
    }

    bool hasNext() const {
        if (flag || Iterator::hasNext()) return true;
        else return false;
    }

private:
    bool flag;
    int value;
};

```

13.7 LRU Cache (H)

Design and implement a data structure for Least Recently Used (LRU) cache. It should support the following operations: get and set.

get(key) - Get the value (will always be positive) of the key if the key exists in the cache, otherwise return -1.

set(key, value) - Set or insert the value if the key is not already present. When the cache reached its capacity, it should invalidate the least recently used item before inserting a new item.

```

class LRUCache(object):

    def __init__(self, capacity):
        """
        :type capacity: int
        """

```

```

self.capacity = capacity
self.cache = {} # dict for cache key and value mappings
self.queue = [] # queue of cache keys

def get(self, key):
    """
    :type key: int
    :rtype: int
    """
    # if key is in the cache
    # update its current position to the end of queue
    # the LRU is stored at the beginning of queue
    if key in self.cache:
        self.queue.remove(key)
        self.queue.insert(0, key)
        return self.cache[key]
    else:
        return -1

def put(self, key, value):
    """
    :type key: int
    :type value: int
    :rtype: None
    """
    if not key or not value:
        return None
    # remove the current key from the queue, update later
    if key in self.cache:
        self.queue.remove(key)
    # if key is not in cache and the capacity is full
    # pop LRU from queue and delete it from cache
    elif len(self.queue) == self.capacity:
        lru = self.queue.pop()
        del self.cache[lru]
    # update both cache and queue
    self.cache[key] = value
    self.queue.insert(0, key)

# Your LRUCache object will be instantiated and called as such:
# obj = LRUCache(capacity)
# param_1 = obj.get(key)
# obj.put(key,value)

```

```

class LRUCache{
public:

```

```

LRUCache(int capacity) {
    cap = capacity;
}

int get(int key) {
    auto it = m.find(key);
    if (it == m.end()) return -1;
    // void splice (iterator position, list& x, iterator i)
    // transfers only the element pointed by i from x into the container,
    // inserting it at position.
    l.splice(l.begin(), l, it->second);
    return it->second->second;
}

void set(int key, int value) {
    auto it = m.find(key);
    // if the current key and value exist in list, remove it
    if (it != m.end()) l.erase(it->second);
    // insert the new pair to the top of list
    l.push_front(make_pair(key, value));
    m[key] = l.begin();
    // if capacity is exceeded, remove the bottom one
    if (m.size() > cap) {
        int k = l.rbegin()->first;
        l.pop_back();
        m.erase(k);
    }
}

private:
    int cap;
    list<pair<int, int> > l;
    unordered_map<int, list<pair<int, int> >::iterator> m;
};

```

13.8 Design Tic-Tac-Toe (M)

Design a Tic-tac-toe game that is played between two players on a $n \times n$ grid.

You may assume the following rules:

A move is guaranteed to be valid and is placed on an empty block.

Once a winning condition is reached, no more moves is allowed.

A player who succeeds in placing n of their marks in a horizontal, vertical, or diagonal row wins the game.

Example:

Given $n = 3$, assume that player 1 is "X" and player 2 is "O" in the board.

`TicTacToe toe = new TicTacToe(3);`

`toe.move(0, 0, 1);` -> Returns 0 (no one wins)

—X— — —

— — — // Player 1 makes a move at (0, 0).

— — — —

`toe.move(0, 2, 2);` -> Returns 0 (no one wins)

—X— —O—

— — — // Player 2 makes a move at (0, 2).

— — — —

`toe.move(2, 2, 1);` -> Returns 0 (no one wins)

—X— —O—

— — — // Player 1 makes a move at (2, 2).

— — —X—

`toe.move(1, 1, 2);` -> Returns 0 (no one wins)

—X— —O—

— —O— // Player 2 makes a move at (1, 1).

— — —X—

`toe.move(2, 0, 1);` -> Returns 0 (no one wins)

—X— —O—

— —O— // Player 1 makes a move at (2, 0).

—X— —X—

`toe.move(1, 0, 2);` -> Returns 0 (no one wins)

—X— —O—

—O—O— // Player 2 makes a move at (1, 0).

—X— —X—

`toe.move(2, 1, 1);` -> Returns 1 (player 1 wins)

—X— —O—

—O—O— // Player 1 makes a move at (2, 1).

—X—X—X—

Follow up:

Could you do better than $O(n^2)$ per `move()` operation?

Hint:

Could you trade extra space such that `move()` operation can be done in $O(1)$? You need two arrays: `int rows[n]`, `int cols[n]`, plus two variables: `diagonal`, `antidiagonal`.

```

class TicTacToe {
public:
    /** Initialize your data structure here. */
    TicTacToe(int n) {
        board.resize(n, vector<int>(n, 0));
    }

    int move(int row, int col, int player) {
        board[row][col] = player;
        int i = 0, j = 0, N = board.size();
        // check row
        for (i = 0; i < N; ++i) {
            if (board[i][0] != 0) {
                for (j = 1; j < N; ++j) {
                    if (board[i][j] != board[i][j - 1]) break;
                }
                if (j == N) return board[i][0];
            }
        }
        // check column
        for (j = 0; j < N; ++j) {
            if (board[0][j] != 0) {
                for (i = 1; i < N; ++i) {
                    if (board[i][j] != board[i - 1][j]) break;
                }
                if (i == N) return board[0][j];
            }
        }
        // check diagonal
        if (board[0][0] != 0) {
            for (i = 1; i < N; ++i) {
                if (board[i][i] != board[i - 1][i - 1]) break;
            }
            if (i == N) return board[0][0];
        }
        // check antidiagonal
        if (board[N - 1][0] != 0) {
            for (i = 1; i < N; ++i) {
                if (board[N - i - 1][i] != board[N - i][i - 1]) break;
            }
            if (i == N) return board[N - 1][0];
        }
        return 0;
    }

private:

```

```
vector<vector<int>>> board;
};
```

13.9 Design Snake Game (M)

Design a Snake game that is played on a device with screen size = width x height. Play the game online if you are not familiar with the game. The snake is initially positioned at the top left corner (0,0) with length = 1 unit. You are given a list of food's positions in row-column order. When a snake eats the food, its length and the game's score both increase by 1. Each food appears one by one on the screen. For example, the second food will not appear until the first food was eaten by the snake. When a food does appear on the screen, it is guaranteed that it will not appear on a block occupied by the snake.

Example:

Given width = 3, height = 2, and food = [[1,2],[0,1]].

Snake snake = new Snake(width, height, food);

Initially the snake appears at position (0,0) and the food at (1,2).

```
—S— — —
— — —F—
```

snake.move("R"); -> Returns 0

```
— —S— —
— — —F—
```

snake.move("D"); -> Returns 0

```
— — — —
— —S—F—
```

snake.move("R"); -> Returns 1 (Snake eats the first food and right after that, the second food appears at (0,1))

```
— —F— —
— —S—S—
```

snake.move("U"); -> Returns 1

```
— —F—S—
— — —S—
```

snake.move("L"); -> Returns 2 (Snake eats the second food)

```
— —S—S—
— — —S—
```

snake.move("U"); -> Returns -1 (Game over because snake collides with border)

```

class SnakeGame {
public:
    /** Initialize your data structure here.
        @param width - screen width
        @param height - screen height
        @param food - A list of food positions
        E.g food = [[1,1], [1,0]] means the first food is positioned at [1,1],
        the second is at [1,0]. */
    SnakeGame(int width, int height, vector<pair<int, int>> food) {
        this->width = width;
        this->height = height;
        this->food = food;
        score = 0;
        pos.push_back({0, 0});
    }

    /** Moves the snake.
        @param direction - 'U' = Up, 'L' = Left, 'R' = Right, 'D' = Down
        @return The game's score after the move. Return -1 if game over.
        Game over when snake crosses the screen boundary or bites its body. */
    int move(string direction) {
        auto head = pos.front(), tail = pos.back();
        pos.pop_back();
        if (direction == "U") --head.first;
        else if (direction == "L") --head.second;
        else if (direction == "R") ++head.second;
        else if (direction == "D") ++head.first;
        if (count(pos.begin(), pos.end(), head) || head.first < 0 || head.first
            >= height || head.second < 0 || head.second >= width) {
            return -1;
        }
        pos.insert(pos.begin(), head);
        if (!food.empty() && head == food.front()) {
            food.erase(food.begin());
            pos.push_back(tail);
            ++score;
        }
        return score;
    }
};

private:
    int width, height, score;
    vector<pair<int, int>> food, pos;
};

```

13.10 Design Phone Directory (M)

Design a Phone Directory which supports the following operations:

get: Provide a number which is not assigned to anyone.

check: Check if a number is available or not.

release: Recycle or release a number.

Example:

```
// Init a phone directory containing a total of 3 numbers: 0, 1, and 2.
```

```
PhoneDirectory directory = new PhoneDirectory(3);
```

```
// It can return any available phone number. Here we assume it returns 0.
```

```
directory.get();
```

```
// Assume it returns 1.
```

```
directory.get();
```

```
// The number 2 is available, so return true.
```

```
directory.check(2);
```

```
// It returns 2, the only number that is left.
```

```
directory.get();
```

```
// The number 2 is no longer available, so return false.
```

```
directory.check(2);
```

```
// Release number 2 back to the pool.
```

```
directory.release(2);
```

```
// Number 2 is available again, return true.
```

```
directory.check(2);
```

```
class PhoneDirectory {
public:
    /** Initialize your data structure here
        @param maxNumbers - The maximum numbers that can be stored in the phone
        directory. */
    PhoneDirectory(int maxNumbers) {
        max_num = maxNumbers;
        next = idx = 0;
        recycle.resize(max_num);
        flag.resize(max_num, 1);
    }

    /** Provide a number which is not assigned to anyone.
```

```

    @return - Return an available number. Return -1 if none is available. */
int get() {
    if (next == max_num && idx <= 0) return -1;
    if (idx > 0) {
        int t = recycle[--idx];
        flag[t] = 0;
        return t;
    }
    flag[next] = false;
    return next++;
}

/** Check if a number is available or not. */
bool check(int number) {
    return number >= 0 && number < max_num && flag[number];
}

/** Recycle or release a number. */
void release(int number) {
    if (number >= 0 && number < max_num && !flag[number]) {
        recycle[idx++] = number;
        flag[number] = 1;
    }
}
private:
    int max_num, next, idx;
    vector<int> recycle, flag;
};

```

13.11 Design Twitter (M)

Design a simplified version of Twitter where users can post tweets, follow/unfollow another user and is able to see the 10 most recent tweets in the user's news feed. Your design should support the following methods:

postTweet(userId, tweetId): Compose a new tweet.

getNewsFeed(userId): Retrieve the 10 most recent tweet ids in the user's news feed. Each item in the news feed must be posted by users who the user followed or by the user herself. Tweets must be ordered from most recent to least recent.

follow(followerId, followeeId): Follower follows a followee.

unfollow(followerId, followeeId): Follower unfollows a followee.

Example:

```
Twitter twitter = new Twitter();
```

```
// User 1 posts a new tweet (id = 5).
```

```

twitter.postTweet(1, 5);

// User 1's news feed should return a list with 1 tweet id -> [5].
twitter.getNewsFeed(1);

// User 1 follows user 2.
twitter.follow(1, 2);

// User 2 posts a new tweet (id = 6).
twitter.postTweet(2, 6);

// User 1's news feed should return a list with 2 tweet ids -> [6, 5].
// Tweet id 6 should precede tweet id 5 because it is posted after tweet id 5.
twitter.getNewsFeed(1);

// User 1 unfollows user 2.
twitter.unfollow(1, 2);

// User 1's news feed should return a list with 1 tweet id -> [5],
// since user 1 is no longer following user 2.
twitter.getNewsFeed(1);

```

```

class Twitter {
public:
    /** Initialize your data structure here. */
    Twitter() {
        cnt = 0;
    }

    /** Compose a new tweet. */
    void postTweet(int userId, int tweetId) {
        follow(userId, userId);
        tweets[userId].insert({cnt++, tweetId});
    }

    /** Retrieve the 10 most recent tweet ids in the user's news feed. Each item
        in the news feed must be posted by users who the user followed or by the
        user herself. Tweets must be ordered from most recent to least recent. */
    vector<int> getNewsFeed(int userId) {
        vector<int> res;
        map<int, int> top10;
        for (auto it = friends[userId].begin(); it != friends[userId].end();
            ++it) {
            int t = *it;
            for (auto a = tweets[t].begin(); a != tweets[t].end(); ++a) {

```

```

        if (top10.size() > 0 && top10.begin()->first > a->first &&
            top10.size() > 10) break;
        top10.insert({a->first, a->second});
        if (top10.size() > 10) top10.erase(top10.begin());
    }
}

for (auto it = top10.rbegin(); it != top10.rend(); ++it) {
    res.push_back(it->second);
}
return res;
}

/** Follower follows a followee. If the operation is invalid, it should be a
    no-op. */
void follow(int followerId, int followeeId) {
    friends[followerId].insert(followeeId);
}

/** Follower unfollows a followee. If the operation is invalid, it should be
    a no-op. */
void unfollow(int followerId, int followeeId) {
    if (followerId != followeeId) {
        friends[followerId].erase(followeeId);
    }
}

private:
    int cnt;
    unordered_map<int, set<int>> friends;
    unordered_map<int, map<int, int>> tweets;
};

/**
 * Your Twitter object will be instantiated and called as such:
 * Twitter obj = new Twitter();
 * obj.postTweet(userId,tweetId);
 * vector<int> param_2 = obj.getNewsFeed(userId);
 * obj.follow(followerId,followeeId);
 * obj.unfollow(followerId,followeeId);
 */

```

13.12 Insert Delete GetRandom O(1) (H)

Design a data structure that supports all following operations in average O(1) time.

insert(val): Inserts an item val to the set if not already present.

remove(val): Removes an item val from the set if present.

getRandom: Returns a random element from current set of elements. Each element must have the same probability of being returned.

Example:

```
// Init an empty set.
RandomizedSet randomSet = new RandomizedSet();

// Inserts 1 to the set. Returns true as 1 was inserted successfully.
randomSet.insert(1);

// Returns false as 2 does not exist in the set.
randomSet.remove(2);

// Inserts 2 to the set, returns true. Set now contains [1,2].
randomSet.insert(2);

// getRandom should return either 1 or 2 randomly.
randomSet.getRandom();

// Removes 1 from the set, returns true. Set now contains [2].
randomSet.remove(1);

// 2 was already in the set, so return false.
randomSet.insert(2);

// Since 1 is the only number in the set, getRandom always return 1.
randomSet.getRandom();
```

```
class RandomizedSet(object):

    def __init__(self):
        """
        Initialize your data structure here.
        """
        self.nums = []
        self.map = {} # val: idx

    def insert(self, val):
        """
        Inserts a value to the set. Returns true if the set did not already
        contain the specified element.
        :type val: int
        :rtype: bool
        """
        if val not in self.map:
```

```

        self.nums.append(val) # O(1)
        self.map[val] = len(self.nums) - 1 # O(1)
        return True
    return False

def remove(self, val):
    """
    Removes a value from the set. Returns true if the set contained the
    specified element.
    :type val: int
    :rtype: bool
    """
    if val in self.map:
        # get the idx of val and the last val in nums
        idx, last = self.map[val], self.nums[-1]
        # overwrite nums[idx] by the last val,
        # so the last val can be popped from the list with O(1)
        self.nums[idx] = last
        self.nums.pop()
        # update the map between the original last val and the new idx
        # then delete val from map
        self.map[last] = idx
        del self.map[val]
        return True
    return False

def getRandom(self):
    """
    Get a random element from the set.
    :rtype: int
    """
    return self.nums[random.randint(0, len(self.nums)-1)]

# Your RandomizedSet object will be instantiated and called as such:
# obj = RandomizedSet()
# param_1 = obj.insert(val)
# param_2 = obj.remove(val)
# param_3 = obj.getRandom()

```

```

class RandomizedSet {
public:
    /** Initialize your data structure here. */
    RandomizedSet() {}

    /** Inserts a value to the set. Returns true if the set did not already

```

```

        contain the specified element. */
bool insert(int val) {
    if (m.count(val)) return false;
    nums.push_back(val);
    m[val] = nums.size()-1; // index is the last index of nums
    return true;
}

/** Removes a value from the set. Returns true if the set contained the
    specified element. */
// switch val and last in nums, then remove the end of nums
bool remove(int val) {
    if (!m.count(val)) return false;
    int last = nums.back(); // save the last element of nums
    m[last] = m[val]; // update the index of last to the index of val
    nums[m[val]] = last; // overwrite val in nums by last
    nums.pop_back(); // remove the end in nums
    m.erase(val); // remove val in m
    return true;
}

/** Get a random element from the set. */
int getRandom() {
    return nums[rand() % nums.size()];
}
private:
    vector<int> nums;
    unordered_map<int, int> m;
};

/**
 * Your RandomizedSet object will be instantiated and called as such:
 * RandomizedSet obj = new RandomizedSet();
 * bool param_1 = obj.insert(val);
 * bool param_2 = obj.remove(val);
 * int param_3 = obj.getRandom();
 */

```

13.13 Insert Delete GetRandom O(1) - Duplicates allowed ? (H)

Design a data structure that supports all following operations in average O(1) time.

Note: Duplicate elements are allowed.

insert(val): Inserts an item val to the collection.

remove(val): Removes an item val from the collection if present.

getRandom: Returns a random element from current collection of elements. The probability of each element being returned is linearly related to the number of same value the collection contains.

Example:

```
// Init an empty collection.
```

```
RandomizedCollection collection = new RandomizedCollection();
```

```
// Inserts 1 to the collection. Returns true as the collection did not contain 1.
```

```
collection.insert(1);
```

```
// Inserts another 1 to the collection. Returns false as the collection contained 1. Collection now contains [1,1].
```

```
collection.insert(1);
```

```
// Inserts 2 to the collection, returns true. Collection now contains [1,1,2].
```

```
collection.insert(2);
```

```
// getRandom should return 1 with the probability 2/3, and returns 2 with the probability 1/3.
```

```
collection.getRandom();
```

```
// Removes 1 from the collection, returns true. Collection now contains [1,2].
```

```
collection.remove(1);
```

```
// getRandom should return 1 and 2 both equally likely.
```

```
collection.getRandom();
```

```
class RandomizedCollection {
public:
    /** Initialize your data structure here. */
    RandomizedCollection() {}

    /** Inserts a value to the collection. Returns true if the collection did not
        already contain the specified element. */
    bool insert(int val) {
        m[val].push_back(nums.size());
        nums.push_back(val);
        return m[val].size() == 1;
    }

    /** Removes a value from the collection. Returns true if the collection
        contained the specified element. */
    bool remove(int val) {
        if (!m.count(val)) return false;
```

```

        int last = nums.back(), pos = m[val].back();
        m[last].back() = m[val].back();
        if (m[val].size() > 1) m[val].pop_back();
        else m.erase(val);
        nums.pop_back();
        nums[pos] = last;
        return true;
    }

    /** Get a random element from the collection. */
    int getRandom() {
        return nums[rand() % nums.size()];
    }

private:
    vector<int> nums;
    unordered_map<int, vector<int>> m;
};

/**
 * Your RandomizedCollection object will be instantiated and called as such:
 * RandomizedCollection obj = new RandomizedCollection();
 * bool param_1 = obj.insert(val);
 * bool param_2 = obj.remove(val);
 * int param_3 = obj.getRandom();
 */

```

13.14 Basic Calculator (H)

Implement a basic calculator to evaluate a simple expression string. The expression string may contain open (and closing parentheses), the plus + or minus sign -, non-negative integers and empty spaces . You may assume that the given expression is always valid.

Some examples:

"1 + 1" = 2

"2 - 1 + 2" = 3

"(1 + (4 + 5 + 2) - 3) + (6 + 8)" = 23

Note: Do not use the eval built-in library function.

```

class Solution {
public:
    int calculate(string s) {
        int res = 0;
    }
}

```

```

vector<int> sign(2, 1); // use sign to decide add or minus
for (int i = 0; i < s.size(); ++i) {
    char c = s[i];
    if (c >= '0') {
        int num = 0;
        while (i < s.size() && s[i] >= '0') {
            num = 10 * num + s[i++] - '0'; // get the value
        }
        res += sign.back() * num;
        sign.pop_back();
        --i;
    }
    else if (c == ')') sign.pop_back();
    else if (c != ' ') sign.push_back(sign.back() * (c == '-' ? -1 : 1));
}
return res;
}
};

```

13.15 Basic Calculator II (M)

Implement a basic calculator to evaluate a simple expression string. The expression string contains only non-negative integers, +, -, *, / operators and empty spaces . The integer division should truncate toward zero. You may assume that the given expression is always valid.

Some examples:

"3 + 2 * 2" = 7

"3/2" = 1

"3 + 5/2" = 5

Note: Do not use the eval built-in library function.

```

class Solution {
public:
    int calculate(string s) {
        int res = 0, d = 0;
        char sign = '+';
        stack<int> nums;
        for (int i = 0; i < s.size(); ++i) {
            if (s[i] >= '0') {
                d = d * 10 + s[i] - '0';
            }
            if ((s[i] < '0' && s[i] != ' ') || i == s.size() - 1) {
                if (sign == '+') nums.push(d);
            }
        }
    }
};

```

```

        if (sign == '-') nums.push(-d);
        if (sign == '*' || sign == '/') {
            int tmp = sign == '*' ? nums.top() * d : nums.top() / d;
            nums.pop();
            nums.push(tmp);
        }
        sign = s[i];
        d = 0;
    }
}
while (!nums.empty()) {
    res += nums.top();
    nums.pop();
}
return res;
}
};

```

13.16 Expression Add Operators (H)

Given a string that contains only digits 0-9 and a target value, return all possibilities to add binary operators (not unary) +, -, or * between the digits so they evaluate to the target value.

Examples:

```

"123", 6 -> ["1+2+3", "1*2*3"]
"232", 8 -> ["2*3+2", "2+3*2"]
"105", 5 -> ["1*0+5", "10-5"]
"00", 0 -> ["0+0", "0-0", "0*0"]
"3456237490", 9191 -> []

```

```

class Solution {
public:
    vector<string> addOperators(string num, int target) {
        vector<string> res;
        addOperatorsDFS(num, target, 0, 0, "", res);
        return res;
    }
    void addOperatorsDFS(string num, int target, long long diff, long long
        curNum, string out, vector<string> &res) {
        if (num.size() == 0 && curNum == target) {
            res.push_back(out);
        }
        for (int i = 1; i <= num.size(); ++i) {
            string cur = num.substr(0, i);

```

```

        if (cur.size() > 1 && cur[0] == '0') return;
        string next = num.substr(i);
        if (out.size() > 0) {
            addOperatorsDFS(next, target, stoll(cur), curNum + stoll(cur), out
                + "+" + cur, res);
            addOperatorsDFS(next, target, -stoll(cur), curNum - stoll(cur),
                out + "-" + cur, res);
            addOperatorsDFS(next, target, diff * stoll(cur), (curNum - diff) +
                diff * stoll(cur), out + "*" + cur, res);
        } else {
            addOperatorsDFS(next, target, stoll(cur), stoll(cur), cur, res);
        }
    }
}
};

```

13.17 Implement Trie (Prefix Tree) (M)

Implement a trie with insert, search, and startsWith methods.

Note: You may assume that all inputs are consist of lowercase letters a-z.

```

class TrieNode(object):

    def __init__(self):
        self.isEnd = False
        self.children = {} # hash between char and TrieNode

class Trie(object):

    def __init__(self):
        """
        Initialize your data structure here.
        """
        self.root = TrieNode()

    def insert(self, word):
        """
        Inserts a word into the trie.
        :type word: str
        :rtype: None
        """
        node = self.root

```

```

# for each char in word, either update node.children or move node to it's
    TrieNode
for c in word:
    if not c in node.children:
        node.children[c] = TrieNode()
    node = node.children[c]
node.isEnd = True

def search(self, word):
    """
    Returns if the word is in the trie.
    :type word: str
    :rtype: bool
    """
    node = self.root
    # check all chars in word by traversaling all node childrens
    for c in word:
        if c in node.children:
            node = node.children[c]
        else:
            return False
    return node.isEnd

def startsWith(self, prefix):
    """
    Returns if there is any word in the trie that starts with the given
    prefix.
    :type prefix: str
    :rtype: bool
    """
    node = self.root
    # check all chars in prefix by traversaling all node childrens
    for c in prefix:
        if c in node.children:
            node = node.children[c]
        else:
            return False
    return True

# Your Trie object will be instantiated and called as such:
# obj = Trie()
# obj.insert(word)
# param_2 = obj.search(word)
# param_3 = obj.startsWith(prefix)

```

```

class TrieNode {
public:
    // Initialize your data structure here.
    TrieNode *child[26];
    bool isWord;
    TrieNode() : isWord(false){
        for (auto &a : child) a = NULL;
    }
};

class Trie {
public:
    Trie() {
        root = new TrieNode();
    }

    // Inserts a word into the trie.
    void insert(string s) {
        TrieNode *p = root;
        for (auto &a : s) {
            int i = a - 'a';
            if (!p->child[i]) p->child[i] = new TrieNode();
            p = p->child[i];
        }
        p->isWord = true;
    }

    // Returns if the word is in the trie.
    bool search(string key) {
        TrieNode *p = root;
        for (auto &a : key) {
            int i = a - 'a';
            if (!p->child[i]) return false;
            p = p->child[i];
        }
        return p->isWord;
    }

    // Returns if there is any word in the trie
    // that starts with the given prefix.
    bool startsWith(string prefix) {
        TrieNode *p = root;
        for (auto &a : prefix) {
            int i = a - 'a';
            if (!p->child[i]) return false;
            p = p->child[i];
        }
    }
};

```

```

        return true;
    }

private:
    TrieNode* root;
};

// Your Trie object will be instantiated and called as such:
// Trie trie;
// trie.insert("somestring");
// trie.search("key");

```

13.18 Add and Search Word - Data structure design (M)

Design a data structure that supports the following two operations:

void addWord(word)

bool search(word)

search(word) can search a literal word or a regular expression string containing only letters a-z or .. A . means it can represent any one letter.

For example:

addWord("bad")

addWord("dad")

addWord("mad")

search("pad") -> false

search("bad") -> true

search(".ad") -> true

search("b..") -> true

Note:

You may assume that all words are consist of lowercase letters a-z.

You should be familiar with how a Trie works. If not, please work on this problem: Implement Trie (Prefix Tree) first.

```

class TrieNode(object):

    def __init__(self):
        self.isEnd = False
        self.children = {}

class WordDictionary(object):

```



```

def __init__(self):
    """
    Initialize your data structure here.
    """
    self.root = TrieNode()

def addWord(self, word):
    """
    Adds a word into the data structure.
    :type word: str
    :rtype: None
    """
    node = self.root
    for c in word:
        if not c in node.children:
            node.children[c] = TrieNode()
        node = node.children[c]
    node.isEnd = True

def search(self, word):
    """
    Returns if the word is in the data structure. A word could contain the
    dot character '.' to represent any one letter.
    :type word: str
    :rtype: bool
    """
    return self.searchFrom(self.root, word)

def searchFrom(self, node, word):
    for i in range(len(word)):
        c = word[i]
        # for dot symbol, check if the substring after dot is in Trie
        if c == '.':
            for k in node.children:
                if self.searchFrom(node.children[k], word[i+1:]):
                    return True
            return False
        elif c not in node.children:
            return False
        node = node.children[c]
    return node.isEnd

```

Your WordDictionary object will be instantiated and called as such:

```
# obj = WordDictionary()
# obj.addWord(word)
# param_2 = obj.search(word)
```

```
class WordDictionary {
public:
    struct TrieNode {
    public:
        TrieNode *child[26];
        bool isWord;
        TrieNode() : isWord(false) {
            for (auto &a : child) a = NULL;
        }
    };

    WordDictionary() {
        root = new TrieNode();
    }

    // Adds a word into the data structure.
    void addWord(string word) {
        TrieNode *p = root;
        for (auto &a : word) {
            int i = a - 'a';
            if (!p->child[i]) p->child[i] = new TrieNode();
            p = p->child[i];
        }
        p->isWord = true;
    }

    // Returns if the word is in the data structure. A word could
    // contain the dot character '.' to represent any one letter.
    bool search(string word) {
        return searchWord(word, root, 0);
    }

    bool searchWord(string &word, TrieNode *p, int i) {
        if (i == word.size()) return p->isWord;
        if (word[i] == '.') {
            for (auto &a : p->child) {
                if (a && searchWord(word, a, i + 1)) return true;
            }
            return false;
        } else {
            return p->child[word[i] - 'a'] && searchWord(word, p->child[word[i] -
                'a'], i + 1);
        }
    }
}
```

```

    }

private:
    TrieNode *root;
};

// Your WordDictionary object will be instantiated and called as such:
// WordDictionary wordDictionary;
// wordDictionary.addWord("word");
// wordDictionary.search("pattern");

// Your WordDictionary object will be instantiated and called as such:
// WordDictionary wordDictionary;
// wordDictionary.addWord("word");
// wordDictionary.search("pattern");

```

13.19 Design HashSet (M)

Design a HashSet without using any built-in hash table libraries.

To be specific, your design should include these functions:

`add(value)`: Insert a value into the HashSet.

`contains(value)` : Return whether the value exists in the HashSet or not.

`remove(value)`: Remove a value in the HashSet. If the value does not exist in the HashSet, do nothing.

```

class MyHashSet(object):

    def __init__(self):
        """
        Initialize your data structure here.
        """
        self.data = [0 for i in range(1000000)]

    def add(self, key):
        """
        :type key: int
        :rtype: None
        """
        self.data[key] = 1

    def remove(self, key):
        """

```

```

        :type key: int
        :rtype: None
        """
        self.data[key] = 0

    def contains(self, key):
        """
        Returns true if this set contains the specified element
        :type key: int
        :rtype: bool
        """
        return self.data[key] == 1

# Your MyHashSet object will be instantiated and called as such:
# obj = MyHashSet()
# obj.add(key)
# obj.remove(key)
# param_3 = obj.contains(key)

```

13.20 Design HashMap (M)

Design a HashMap without using any built-in hash table libraries.

To be specific, your design should include these functions:

put(key, value) : Insert a (key, value) pair into the HashMap. If the value already exists in the HashMap, update the value.

get(key): Returns the value to which the specified key is mapped, or -1 if this map contains no mapping for the key.

remove(key) : Remove the mapping for the value key if this map contains the mapping for the key.

```

class MyHashMap(object):

    def __init__(self):
        """
        Initialize your data structure here.
        """
        self.data = [-1 for i in range(1000000)]

    def put(self, key, value):
        """
        value will always be non-negative.
        :type key: int

```

```

        :type value: int
        :rtype: None
        """
        self.data[key] = value

def get(self, key):
    """
    Returns the value to which the specified key is mapped, or -1 if this map
        contains no mapping for the key
    :type key: int
    :rtype: int
    """
    return self.data[key]

def remove(self, key):
    """
    Removes the mapping of the specified value key if this map contains a
        mapping for the key
    :type key: int
    :rtype: None
    """
    self.data[key] = -1

# Your MyHashMap object will be instantiated and called as such:
# obj = MyHashMap()
# obj.put(key,value)
# param_2 = obj.get(key)
# obj.remove(key)

```

13.21 Sparse Vector Dot Product (FB high frequency)

How to compute sparse vector dot product efficiently?

Solution:

1. HashMap: $O(M \cdot N)$
2. Binary Search: $O(M \log N)$, N is the longer vector
3. Sorting + Two pointers: $O(M + N)$