

Team Notebook

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Data-structures

1.1 segment tree lazy

```
template <class T1, class T2, T1 merge(T1, T1),
          void pushUpdate(T2 parent, T2 &child, int, int,
                          int, int),
          void applyUpdate(T2 update, T1 &node, int, int)>
struct SegmentTreeLazy {
    int n;
    vector<T1> tree;
    vector<T2> lazy;
    vector<bool> isUpdated;

    void build(int i, int left, int right, const vector<T1>
&values) {
        if (left == right) {
            tree[i] = values[left];
            return;
        }

        int mid = (left + right) >> 1;

        build(i << 1, left, mid, values);
        build(i << 1 | 1, mid + 1, right, values);

        tree[i] = merge(tree[i << 1], tree[i << 1 | 1]);
    }

    SegmentTreeLazy(const vector<T1> &values) {
        n = values.size();
        int size = n << 2 | 3;

        tree.resize(size);
        lazy.resize(size);
        isUpdated.resize(size);

        build(1, 0, n - 1, values);
    }

    SegmentTreeLazy() {}

    void push(int i, int left, int right) {
        if (!isUpdated[i])
            return;

        applyUpdate(lazy[i], tree[i], left, right);

        if (left != right) {
            if (isUpdated[i << 1])
                pushUpdate(lazy[i], lazy[i << 1], left, right, left,
                           (left + right) / 2);
            else
                lazy[i << 1] = lazy[i];
        }
    }

    void update(int i, int left, int right, int queryLeft, int
queryRight,
               T2 &value) {
        if (left >= queryLeft and right <= queryRight) {
            if (isUpdated[i])
                pushUpdate(value, lazy[i], queryLeft, queryRight,
                           left, right);
            else
                lazy[i] = value;

            isUpdated[i] = true;
        }

        push(i, left, right);

        if (left > queryRight or right < queryLeft)
            return;

        if (left >= queryLeft and right <= queryRight)
            return;

        update(i << 1, left, (left + right) >> 1, queryLeft,
queryRight,
              value);
        update(i << 1 | 1, (left + right) / 2 + 1, right,
queryLeft,
              queryRight,
              value);

        tree[i] = merge(tree[i << 1], tree[i << 1 | 1]);
    }

    void update(int left, int right, T2 value) {
        update(1, 0, n - 1, left, right, value);
    }

    T1 query(int i, int left, int right, int queryLeft, int
queryRight) {
        push(i, left, right);

        if (queryLeft <= left and right <= queryRight)
            return tree[i];
    }
};
```

```
if (isUpdated[i << 1 | 1])
    pushUpdate(lazy[i], lazy[i << 1 | 1], left, right,
               (left + right) / 2 + 1, right);

else
    lazy[i << 1 | 1] = lazy[i];

isUpdated[i << 1] = 1;
isUpdated[i << 1 | 1] = 1;
}

isUpdated[i] = false;
}

void update(int i, int left, int right, int queryLeft, int
queryRight,
           T2 &value) {
    if (left >= queryLeft and right <= queryRight) {
        if (isUpdated[i])
            pushUpdate(value, lazy[i], queryLeft, queryRight,
                       left, right);
        else
            lazy[i] = value;

        isUpdated[i] = true;
    }

    push(i, left, right);

    if (left > queryRight or right < queryLeft)
        return;

    if (left >= queryLeft and right <= queryRight)
        return;

    update(i << 1, left, (left + right) >> 1, queryLeft,
queryRight,
          value);
    update(i << 1 | 1, (left + right) / 2 + 1, right,
queryLeft,
          queryRight,
          value);

    tree[i] = merge(tree[i << 1], tree[i << 1 | 1]);
}

void update(int left, int right, T2 value) {
    update(1, 0, n - 1, left, right, value);
}

T1 query(int i, int left, int right, int queryLeft, int
queryRight) {
    push(i, left, right);

    if (queryLeft <= left and right <= queryRight)
        return tree[i];
}
```

```
int mid = (left + right) >> 1;

if (mid < queryLeft)
    return query(i << 1 | 1, mid + 1, right, queryLeft,
queryRight);

if (mid >= queryRight)
    return query(i << 1, left, mid, queryLeft,
queryRight);

return merge(query(i << 1, left, mid, queryLeft,
queryRight),
             query(i << 1 | 1, mid + 1, right,
queryLeft,
queryRight));
}

T1 query(int left, int right) { return query(1, 0, n - 1,
left, right); }
```

1.2 segment tree

```
template <class T, T merge(T, T)> struct SegmentTree {
    int n;
    vector<T> tree;
    SegmentTree() {}
    SegmentTree(vector<T> &values) {
        n = values.size();
        tree.resize(n << 1);
        for (int i = 0; i < n; i++)
            tree[i + n] = values[i];
        for (int i = n - 1; i > 0; i--)
            tree[i] = merge(tree[i << 1], tree[i << 1 | 1]);
    }

    void update(int position, T value) {
        position += n;
        tree[position] = value;
        for (position >= 1; position > 0; position >= 1)
            tree[position] = merge(tree[position << 1],
tree[position << 1 | 1]);
    }

    T query(int left,
            int right) // [left, right]
    {
        bool hasAnswer = false;
        T answer = T();
        for (left += n, right += n + 1; left < right; left >=
1, right >= 1) {
            if (left & 1) {
                answer = hasAnswer ? merge(answer, tree[left]) :
tree[left];
                hasAnswer = true;
                left++;
            }
            if (right & 1) {

```

```

        right--;
        answer = hasAnswer ? merge(answer, tree[right]) :
tree[right];
        hasAnswer = true;
    }
}
return answer;
};

```

1.3 ordered set

```

#include <ext/pb_ds/assoc_container.hpp>
#include <ext/pb_ds/tree_policy.hpp>
using namespace __gnu_pbds;

template <typename T>
using ordered_set =
    tree<T, null_type, less<T>, rb_tree_tag,
tree_order_statistics_node_update>;

template <typename T>
using ordered_multiset = tree<T, null_type, less_equal<T>,
rb_tree_tag,

tree_order_statistics_node_update>;

template <typename T> void erase(ordered_multiset<T>
&values, T value) {
    int rank = values.order_of_key(value);
    auto it = values.find_by_order(rank);
    values.erase(it);
}

```

1.4 merge sort tree

```

struct MergeSortTree {
    int n;
    vector<vector<int>>> tree;

    vector<int> merge(const vector<int> &left, const
vector<int> &right) {
        vector<int> result(left.size() + right.size());

        int i = 0, j = 0;

        for (int &x : result) {
            if (i == left.size())
                x = right[j++];
            else if (j == right.size())
                x = left[i++];
            else if (left[i] < right[j])
                x = left[i++];
            else
                x = right[j++];
        }
    }
};

```

```

}

return result;
}

void build(int i, int left, int right, const vector<int>
&values) {
    if (left == right) {
        tree[i] = {values[left]};
        return;
    }

    int mid = (left + right) >> 1;

    build(i << 1, left, mid, values);
    build(i << 1 | 1, mid + 1, right, values);

    tree[i] = merge(tree[i << 1], tree[i << 1 | 1]);
}

MergeSortTree(const vector<int> &values) {
    n = values.size();
    tree.resize(n << 2 | 3);
    build(1, 0, n - 1, values);
}

int query(int i, int left, int right, int queryLeft, int
queryRight, int min, int max) {
    if (left > queryRight or right < queryLeft)
        return 0;

    if (left >= queryLeft and right <= queryRight) {
        auto leftIterator = lower_bound(tree[i].begin(),
tree[i].end(), min);
        auto rightIterator = upper_bound(tree[i].begin(),
tree[i].end(), max);

        return distance(leftIterator, rightIterator);
    }

    int mid = (left + right) >> 1;

    return query(i << 1, left, mid, queryLeft, queryRight,
min, max) +
        query(i << 1 | 1, mid + 1, right, queryLeft,
queryRight, min, max);
}

int query(int left, int right, int min, int max) {
    return query(1, 0, n - 1, left, right, min, max);
}
};

```

2 Math

2.1 128bits

```

#if defined(__LP64__) || defined(_WIN64)
using int128 = __int128;
using uint128 = __uint128_t;
#else
using int128 = ll;
using uint128 = ull;
#endif

template <typename T>
typename enable_if<is_same<T, int128>::value || is_same<T,
uint128>::value,
                istream &>::type
operator>>(istream &is, T &value) {
    string input;
    is >> input;

    value = 0;

    for (char character : input)
        if (isdigit(character))
            value = 10 * value + character - '0';

    if (input[0] == '-')
        value *= -1;

    return is;
}

template <typename T>
typename enable_if<is_same<T, int128>::value || is_same<T,
uint128>::value,
                ostream &>::type
operator<<(ostream &os, T value) {
    string output;

    bool isNegative = value < 0;

    if (isNegative) {
        value *= -1;
        output += '-';
    }

    do {
        output += value % 10 + '0';
        value /= 10;
    } while (value > 0);

    reverse(output.begin() + isNegative, output.end());
}

```

```
    return os << output;
}
```

2.2 gcd lcm

```
#define gcd __gcd

template <typename T>
typename enable_if<is_integral<T>::value, T>::type lcm(T a,
T b) {
    return a / gcd(a, b) * b;
}
```

2.3 system mod 2

```
struct Mod2System {
    vector<vector<int>>> matrix;
    int rows, columns, variables;
    vector<int> pivotPosition, freeColumns;

    Mod2System(vector<vector<int>>> matrixToSolve) {
        matrix = matrixToSolve;
        rows = matrix.size();
        columns = (rows > 0 ? matrix[0].size() : 0);
        variables = columns - 1;

        pivotPosition = vector<int>(rows, -1);

        int pivotRow = 0;
        for (int pivotColumn = 0; pivotColumn < variables &&
pivotRow < rows;
            pivotColumn++) {
            int pivotIndex = pivotRow;

            while (pivotIndex < rows && matrix[pivotIndex]
[pivotColumn] == 0)
                pivotIndex++;

            if (pivotIndex == rows)
                continue;

            swap(matrix[pivotRow], matrix[pivotIndex]);
            pivotPosition[pivotRow] = pivotColumn;

            for (int i = 0; i < rows; i++)
                if (i != pivotRow && (matrix[i][pivotColumn] & 1))
                    for (int j = pivotColumn; j < columns; j++)
                        matrix[i][j] = matrix[i][j] ^ matrix[pivotRow]
[j];

            pivotRow++;
        }

        vector<bool> isPivot(variables);
    }
}
```

```
for (int position : pivotPosition)
    if (position != -1)
        isPivot[position] = true;

for (int j = 0; j < variables; j++)
    if (!isPivot[j])
        freeColumns.push_back(j);
}

vector<int> findOneSolution() {
    vector<int> solution(variables);

    if (freeColumns.empty())
        return solution;

    solution[freeColumns[0]] = 1;

    for (int i = 0; i < rows; i++) {
        if (pivotPosition[i] == -1)
            continue;

        int position = pivotPosition[i];
        solution[position] = matrix[i][freeColumns[0]];
    }

    return solution;
}

vector<vector<int>>> findSolutions(int maxSolutions = 1e5)
{
    if (freeColumns.empty())
        return {vector<int>(variables)};

    vector<vector<int>>> solutions;

    for (int freeColumn : freeColumns) {
        vector<int> solution(variables);
        solution[freeColumn] = 1;

        for (int i = 0; i < rows; i++) {
            if (pivotPosition[i] == -1)
                continue;

            int pivotCol = pivotPosition[i];
            solution[pivotCol] = matrix[i][freeColumn];
        }

        solutions.push_back(solution);

        if (solutions.size() == maxSolutions)
            break;
    }

    return solutions;
}
```

```
bool isTrivial(vector<int> &solution) {
    return count(solution.begin(), solution.end(), 1) == 0;
}

bool onlyHasTrivialSolution() {
    if (freeColumns.empty())
        return true;

    vector<int> solution = findOneSolution();

    return isTrivial(solution);
}
};
```

2.4 sieve

```
struct Sieve {
    vector<int> primes, smallestFactor;

    Sieve(int n) {
        smallestFactor.resize(n + 1);

        for (ll i = 2; i <= n; i++) {
            if (smallestFactor[i] == 0) {
                smallestFactor[i] = i;
                primes.push_back(i);
            }

            for (ll prime : primes) {
                if (prime * i > n || prime > smallestFactor[i])
                    break;

                smallestFactor[prime * i] = prime;
            }
        }

        bool getIsPrime(int n) { return smallestFactor[n] == n; }

        map<int, int> factorize(int n) {
            map<int, int> factors;

            while (n > 1) {
                int factor = smallestFactor[n];

                factors[factor]++;
                n /= factor;
            }

            return factors;
        }
    };
};
```

2.5 gauss mod 2

```
vector<vector<int>>
solveHomogeneousSystemMod2(vector<vector<int>> &A,
                             int
maxSolutions = 1e5) {
    int rows = A.size(), columns = A[0].size();

    int variables = columns - 1;

    vector<int> pivotPosition(rows, -1);

    int pivotRow = 0;

    for (int pivotColumn = 0; pivotColumn < variables &&
        pivotRow < rows;
        pivotColumn++) {
        int pivotIndex = pivotRow;

        while (pivotIndex < rows && A[pivotIndex][pivotColumn]
            == 0)
            pivotIndex++;

        if (pivotIndex == rows)
            continue;

        swap(A[pivotRow], A[pivotIndex]);

        pivotPosition[pivotRow] = pivotColumn;

        for (int i = 0; i < rows; i++)
            if (i != pivotRow && A[i][pivotColumn] & 1)
                for (int j = pivotColumn; j < columns; j++)
                    A[i][j] = A[i][j] ^ A[pivotRow][j];

        pivotRow++;
    }

    vector<bool> isPivot(variables);

    for (int position : pivotPosition) {
        if (position == -1)
            continue;

        isPivot[position] = true;
    }

    vector<int> freeColumns;

    for (int j = 0; j < variables; j++)
        if (!isPivot[j])
            freeColumns.push_back(j);

    if (freeColumns.empty())
```

```
        return {vector<int>(variables)};

    vector<vector<int>> solutions;

    for (int freeColumn : freeColumns) {
        vector<int> solution(variables);

        solution[freeColumn] = 1;

        for (int i = 0; i < rows; i++) {
            if (pivotPosition[i] == -1)
                continue;

            int positionColumn = pivotPosition[i];
            solution[positionColumn] = A[i][freeColumn];
        }

        solutions.push_back(solution);

        if (solutions.size() == maxSolutions)
            break;
    }

    return solutions;
}
```

3 Algorithms

3.1 ternary search

```
template <typename T = double>
typename enable_if<is_floating_point<T>::value>
ternarySearch(function<T(T)> calculate, T left, T right,
    bool searchMin = true,
                T epsilon = 1e-9) { // [left, right]
    while (right - left > epsilon) {
        T midA = left + (right - left) / 3, midB = right -
            (right - left) / 3;

        T valueA = calculate(midA), valueB = calculate(midB);

        if (searchMin)
            valueA *= -1, valueB *= -1;

        if (valueA < valueB)
            left = midA;
        else
            right = midB;
    }

    return calculate(left);
}

template <typename T = int>
```

```
typename enable_if<is_integral<T>::value>
ternarySearch(function<T(T)> calculate, T left, T right,
    bool searchMin = true,
                T epsilon = 5) { // [left, right]
    while (right - left > epsilon) {
        T midA = left + (right - left) / 3, midB = right -
            (right - left) / 3;

        T valueA = calculate(midA), valueB = calculate(midB);

        if (searchMin)
            valueA *= -1, valueB *= -1;

        if (valueA < valueB)
            left = midA;
        else
            right = midB;
    }

    T answer = calculate(left);

    for (T i = left + 1; i <= right; i++) {
        T value = calculate(i);

        if (searchMin)
            answer = min(answer, value);
        else
            answer = max(answer, value);
    }

    return answer;
}
```

3.2 prefix sum

```
template <typename T> struct PrefixSum {
    static_assert(is_arithmetic<T>::value);

    vector<T> prefix;

    PrefixSum(vector<T> &values) {
        int n = values.size();
        prefix.resize(n);

        prefix[0] = values[0];

        for (int i = 1; i < n; i++)
            prefix[i] = prefix[i - 1] + values[i];
    }

    T query(int left, int right) // [left, right]
    {
        return prefix[right] - (left > 0 ? prefix[left - 1] :
            0);
    }
}
```



```

    if (visited[edge.to] || edge.flow == edge.capacity)
        continue;

    dfs(edge.to);
}
};

dfs(source);

vector<pii> minCutEdges;

for (Edge &edge : edges) {
    if (edge.capacity == 0 || edge.flow != edge.capacity)
        continue;

    if (visited[edge.from] && !visited[edge.to])
        minCutEdges.emplace_back(edge.from, edge.to);
}

return {maxFlow, minCutEdges};
};
};

```

4.2 dsu

```

struct DisjointUnionSet {
    int n;
    vector<int> parent, size;

    DisjointUnionSet(int n) : n(n) {
        parent.resize(n);
        size.resize(n);

        for (int i = 0; i < n; i++) {
            parent[i] = i;
            size[i] = 1;
        }
    }

    int Find(int u) {
        if (parent[u] == u)
            return u;

        return parent[u] = Find(parent[u]);
    }

    int Size(int u) { return size[Find(u)]; }
    void Union(int u, int v) {
        u = Find(u);
        v = Find(v);

        if (u == v)
            return;

        if (size[u] < size[v])
            swap(u, v);
    }
}

```

```

parent[v] = u;
size[u] += size[v];
}

bool areConnected(int u, int v) { return Find(u) == Find(v); }
};

```

4.3 heavylightdecomposition

```

template <class ST, class T, T merge(T a, T b)> struct
HeavyLightDecomposition {
    vector<vector<int>> tree;
    vector<int> parent, depth, heavy, head, position, size;
    int currentPosition;
    ST segmentTree;

    HeavyLightDecomposition() {}
    HeavyLightDecomposition(vector<vector<int>> &tree) :
tree(tree) {
    int n = tree.size();

    parent.resize(n);
    depth.resize(n);
    heavy.assign(n, -1);
    head.resize(n);
    position.resize(n);
    size.resize(n);
    currentPosition = 0;

    dfs(0);
    decompose(0, 0);
}

int dfs(int node) {
    size[node] = 1;
    int maxSubtreeSize = 0;

    for (int child : tree[node]) {
        if (child == parent[node])
            continue;

        parent[child] = node;
        depth[child] = depth[node] + 1;

        int subtreeSize = dfs(child);
        size[node] += subtreeSize;

        if (subtreeSize <= maxSubtreeSize)
            continue;

        maxSubtreeSize = subtreeSize;
        heavy[node] = child;
    }
}

```

```

return size[node];
}

void decompose(int node, int nodeHead) {
    head[node] = nodeHead;
    position[node] = currentPosition++;

    if (heavy[node] != -1)
        decompose(heavy[node], nodeHead);

    for (int child : tree[node])
        if (child != parent[node] && child != heavy[node])
            decompose(child, child);
}

int query(int a, int b) {
    T answer;
    bool hasValue = false;

    while (head[a] != head[b]) {
        if (depth[head[a]] > depth[head[b]])
            swap(a, b);

        T current = segmentTree.query(position[head[b]],
position[b]);

        answer = hasValue ? merge(answer, current) : current;
        hasValue = true;

        b = parent[head[b]];
    }

    if (depth[a] > depth[b])
        swap(a, b);

    T last = segmentTree.query(position[a], position[b]);

    return hasValue ? merge(answer, last) : last;
}

vector<T> sorted(vector<T> &values) {
    int n = values.size();

    vector<T> result(n);

    for (int i = 0; i < n; i++)
        result[position[i]] = values[i];

    return result;
}

void update(int node, T value)
{ segmentTree.update(position[node], value); }

// void update(int subtree, T value) {

```

```
// segmentTree.update(position[subtree],
position[subtree] + size[subtree] -
// 1,
//                               value);
// }
};
```

5 Strings

5.1 rolling hash

```
struct RollingHash {
    static const ll BASE = 31;
    static const ll MOD1 = 1e9 + 9, MOD2 = 1e9 + 7, MOD3 =
(119LL << 23) | 1;
    const vector<ll> MODS = {MOD1, MOD2, MOD3};

    vector<vector<ll>> prefixes, powers;
    int n;

    RollingHash(const string &text) {
        n = text.size();
        prefixes.assign(3, vector<ll>(n + 2));
        powers.assign(3, vector<ll>(n + 2, 1));

        for (int j = 0; j < 3; j++)
            for (int i = 1; i <= n + 1; i++)
                powers[j][i] = (powers[j][i - 1] * BASE) % MODS[j];

        for (int j = 0; j < 3; j++) {
            for (int i = 0; i < n; i++)
                prefixes[j][i + 1] = (prefixes[j][i] * BASE +
text[i]) % MODS[j];

            prefixes[j][n + 1] = (prefixes[j][n] * BASE) %
MODS[j];
        }
    }

    tuple<int, int, int> query(int left, int right) {
        vector<int> result(3);

        for (int i = 0; i < 3; i++) {
            ll hash = (prefixes[i][right + 1] -
prefixes[i][left] * powers[i][right - left
+ 1] + MODS[i]) %
MODS[i];

            if (hash < 0)
                hash += MODS[i];

            result[i] = hash;
        }
    }
};
```

```
return {result[0], result[1], result[2]};
}
};
```

6 General

6.1 template

```
#include <bits/stdc++.h>
using namespace std;

using ll = long long;
using ull = unsigned long long;
using ld = long double;
using pii = pair<int, int>;
using pll = pair<ll, ll>;

const ll MOD = 1e9 + 7;
const ll FFT_MOD = 119 << 23 | 1;
const ld PI = acos(-1);

void solve() {}

int main() {
    ios::sync_with_stdio(0);
    cin.tie(0);

    // freopen("input.txt", "r", stdin);
    // freopen("output.txt", "w", stdout);

    int t = 1;
    // cin >> t;

    while (t--)
        solve();
}
```

6.2 complete template

```
#include <bits/stdc++.h>
using namespace std;

#include <ext/pb_ds/assoc_container.hpp>
#include <ext/pb_ds/tree_policy.hpp>
using namespace __gnu_pbds;

template <typename T>
using ordered_set =
    tree<T, null_type, less<T>, rb_tree_tag,
tree_order_statistics_node_update>;

template <typename T>
using ordered_multiset = tree<T, null_type, less_equal<T>,
rb_tree_tag,
```

```
tree_order_statistics_node_update>;
```

```
template <typename T> void erase(ordered_multiset<T>
&values, T value) {
    int rank = values.order_of_key(value);
    auto it = values.find_by_order(rank);
    values.erase(it);
}
```

```
using ll = long long;
using ull = unsigned long long;
using ld = long double;
using pii = pair<int, int>;
using pll = pair<ll, ll>;
#define gcd __gcd
```

```
#if defined(__LP64__) || defined(_WIN64)
using int128 = __int128;
using uint128 = __uint128_t;
#else
using int128 = ll;
using uint128 = ull;
#endif
```

```
template <typename T>
typename enable_if<is_same<T, int128>::value || is_same<T,
uint128>::value,
                    istream &>::type
operator>>(istream &is, T &value) {
    string input;
    is >> input;

    value = 0;

    for (char character : input)
        if (isdigit(character))
            value = 10 * value + character - '0';

    if (input[0] == '-')
        value *= -1;

    return is;
}
```

```
template <typename T>
typename enable_if<is_same<T, int128>::value || is_same<T,
uint128>::value,
                    ostream &>::type
operator<<(ostream &os, T value) {
    string output;

    bool isNegative = value < 0;

    if (isNegative) {
```



```
    value *= -1;
    output += '-';
}

do {
    output += value % 10 + '0';
    value /= 10;
} while (value > 0);

reverse(output.begin() + isNegative, output.end());

return os << output;
}

template <typename T>
typename enable_if<is_integral<T>::value, T>::type lcm(T a,
T b) {
    return a / gcd(a, b) * b;
}

const ll MOD = 1e9 + 7;
const ll FFT_MOD = 119 << 23 | 1;
const ld PI = acos(-1);

void solve() {}

int main() {
    ios::sync_with_stdio(0);
    cin.tie(0);

    // freopen("input.txt", "r", stdin);
    // freopen("output.txt", "w", stdout);

    int t = 1;
    // cin >> t;

    while (t--)
        solve();
}
```