**Basic**

```
#include <bits/stdc++.h>
using namespace std;
using ll = long long;
const int mx_sz  = (int) 2e6+3;
void idea() {

}
int main() {
    ios::sync_with_stdio(0); cin.tie(0); cout.tie(0);
    int T = 1;
    // cin >> T;
    for(int C = 1; C <= T; C++) {
        // cout << "Case " << C << ": " << '\n';
        idea();
    }
    return 0;
}
```

**Elementary Things**

```
// freopen("input.txt", "r", stdin); freopen("output.txt", "w", stdout);
#define PI 3.14159265358979323846
#define toLowerCase(s) transform(s.begin(), s.end(), s.begin(), ::tolower);
#define toUpperCase(s) transform(s.begin(), s.end(), s.begin(), ::toupper);

int dx[] = {+1, -1, 0, 0, +1, +1, -1, -1};
int dy[] = {0, 0, -1, +1, +1, -1, +1, -1};

bool check_power_of_two(ll n){ return !(n & (n - 1)); }
bool check_perfect_square(ll n){ if (n < 0) return false; ll root = sqrt(n); return (root *
root == n); }
bool check_fibonacci(int n) { return check_perfect_square(5*n*n + 4) or
check_perfect_square(5*n*n - 4); }
bool check_parity(ll n) { return __builtin_parityll(n); } // returns 1 if the number has odd
parity
```

**Bit Manipulation**

```
int check_kth_bit_on_or_off(int x, int k) {
    return (x >> k) & 1;
}
int turn_on_kth_bit(int x, int k) {
    return (x | (1 << k));
```

**Prims Algorithm**

```
#include <bits/stdc++.h>
using namespace std;
const int N = 1e5 + 5;
vector<pair<int, int>> mat[N];
bool vis[N];
class cmp {
public:
    bool operator()(pair<int, int> a, pair<int, int> b) {
        return a.second > b.second;
    }
};
int prims(int src) {
    priority_queue<pair<int, int>, vector<pair<int, int>>, cmp> pq;
    pq.push({src, 0});
    int totalCost = 0;
    while (!pq.empty()) {
        pair<int, int> current = pq.top();
        int pnode = current.first;
        int pcost = current.second;
        pq.pop();
        if (!vis[pnode]) {
            totalCost += pcost;
            vis[pnode] = true;

            for (pair<int, int> child : mat[pnode]) {
                int cnode = child.first;
                int ccost = child.second;
                if (!vis[cnode]) {
                    pq.push({cnode, ccost});
                }
            }
        }
    }
    return totalCost;
}
int main() {
    int n, e; cin >> n >> e;
    // Reading edges
    for (int i = 0; i < e; i++) {
```

```
}
int turn_off_kth_bit(int x, int k) {
   return (x & (~(1 << k)));
}
int toggle_kth_bit(int x, int k) {
   return (x ^ (1 << k));
}
void print_on_and_off_bits(int x) {
   for (int k = 0; k <= 31; k++) {
      if (check_kth_bit_on_or_off(x, k)) {
         cout << 1 << " ";
      }
      else {
         cout << 0 << " ";
      }
   }
   cout << '\n';
}
void grey_code_sequence() {
   for (int i = 0; i < (1 << n); i++) {
      for (int k = 0; k < n; k++) {
         if ((i >> k) & 1) cout << 1 << ' ';
         else cout << 0 << ' ';
      }
      cout << '\n';
   }
}
```

**Standard Sieve: Sieve of Eratosthenes**

```
#include <bits/stdc++.h>
using namespace std;
const int N = 1e8 + 3;
vector<bool> is_prime(N + 1, true);
vector<long long> saved_primes;

void standard_sieve() {
   is_prime[0] = is_prime[1] = false;
   for (int i = 3; i * i < N; i += 2)
      if (is_prime[i])
         for (int j = i * i; j < N; j += i + i)
            is_prime[j] = false;
      int a, b, c; cin >> a >> b >> c;
      mat[a].push_back({b, c});
      mat[b].push_back({a, c});
   }
   memset(vis, false, sizeof(vis));
   int totalCost = prims(1);
   // Output total cost of MST
   cout << "Total cost of MST: " << totalCost << endl;
   return 0;
}
```

**Kruskal's Algorithm**

```
#include <bits/stdc++.h>
using namespace std;
const int N = 1e5 + 5;
int par[N], level[N];

class Edge {
public:
   int u, v, w;
   Edge(int x, int y, int z) : u(x), v(y), w(z) {}
};

int dsu_find(int node) {
   if (par[node] == -1) return node;
   return par[node] = dsu_find(par[node]);
}
void dsu_union_by_rank(int a, int b) {
   int leaderA = dsu_find(a), leaderB = dsu_find(b);
   if (leaderA != leaderB) {
      if (level[leaderA] < level[leaderB]) par[leaderA] = leaderB;
      else if (level[leaderA] > level[leaderB]) par[leaderB] = leaderA;
      else {
         par[leaderB] = leaderA;
         level[leaderA]++;
      }
   }
}
bool cmp(Edge &e1, Edge &e2) {
   return e1.w < e2.w;
}
```

```
    saved_primes.push_back(2);
    for (int i = 3; i < N; i += 2)
        if (is_prime[i]) saved_primes.push_back(i);
}
int main() {
    standard_sieve();
    cout << saved_primes.size() << '\n' << saved_primes.back() << '\n';
    return 0;
}
```

**Linear Sieve**

```
#include <bits/stdc++.h>
using namespace std;
const int N = 1e8 + 3;
vector<int> spf(N + 1, 0);
vector<long long> saved_primes;

void linear_sieve() {
    for (int i = 2; i <= N; i += 2) {
        if (spf[i] == 0) {
            spf[i] = 2;
            if (i == 2) saved_primes.push_back(2);
        }
    }
    for (int i = 3; i <= N; i += 2) {
        if (spf[i] == 0) {
            spf[i] = i;
            saved_primes.push_back(i);
        }
        for (int j = 0; j < saved_primes.size() && saved_primes[j] <= spf[i] && i * saved_primes[j] <= N; j++)
            spf[i * saved_primes[j]] = saved_primes[j];
    }
}

int main() {
    linear_sieve();
    cout << saved_primes.size() << '\n' << saved_primes.back() << '\n';
    return 0;
}
```

**Segmented Sieve**

```
int main() {
    int n, e;
    cin >> n >> e;
    vector<Edge> edges;
    for (int i = 0; i < e; i++) {
        int a, b, c;
        cin >> a >> b >> c;
        edges.push_back(Edge(a, b, c));
    }
    sort(edges.begin(), edges.end(), cmp);
    memset(par, -1, sizeof(par));
    memset(level, 0, sizeof(level));
    int totalCost = 0;
    for (Edge ed : edges) {
        int leaderA = dsu_find(ed.u), leaderB = dsu_find(ed.v);
        if (leaderA != leaderB) {
            dsu_union_by_rank(ed.u, ed.v);
            totalCost += ed.w;
            cout << ed.u << " " << ed.v << " " << ed.w << endl;
        }
    }
    cout << "Total cost of MST: " << totalCost << endl;
    return 0;
}
```

**Dynamic Programming**

**Problem Statement**: A frog is on Stone 1 and needs to reach Stone N. From Stone `i`, it can jump to Stone `i+1` or `i+2`, incurring a cost of `|h[i] - h[j]|` for each jump. Find the minimum cost for the frog to reach Stone N.

```
#include <bits/stdc++.h>
using namespace std;
typedef long long ll;
void solve() {
    int N;
    cin >> N;
    vector<int> h(N + 1);
    for (int i = 1; i <= N; i++) cin >> h[i];
    vector<ll> dp(N + 1, LLONG_MAX);
    dp[N] = 0;
    for (int i = N - 1; i >= 1; i--) {
        if (i + 1 <= N) dp[i] = min(dp[i], abs(h[i] - h[i + 1]) + dp[i + 1]);
```

```
#include <bits/stdc++.h>
using namespace std;
#define MAXSIEVE 100000001
#define MAXSIEVEHALF (MAXSIEVE >> 1)
#define MAXSQRT 5000
#define isprime(n) ((is_prime[n >> 4] & (1 << ((n >> 1) & 7))) && ((n & 1) || (n == 2)))
char is_prime[MAXSIEVE / 16 + 2];
vector<int> Yarin_primes;
void Yarin() {
    memset(is_prime, (1 << 8) - 1, sizeof(is_prime));
    is_prime[0] = 0xFE;
    for (int i = 1; i < MAXSQRT; i++) if (is_prime[i >> 3] & (1 << (i & 7)))
        for (int j = 2 * i * (i + 1); j < MAXSIEVEHALF; j += (i << 1) + 1)
            is_prime[j >> 3] &= ~(1 << (j & 7));
}
void nPrime() {
    for (int i = 2; i < MAXSIEVE; i++) if (isprime(i)) Yarin_primes.push_back(i);
}
int main() {
    Yarin(); nPrime();
    cout << "Number of primes found: " << Yarin_primes.size() << '\n';
    if (!Yarin_primes.empty()) cout << "Last prime: " << Yarin_primes.back() << '\n';
    for (int prime : Yarin_primes) cout << prime << " ";
    cout << '\n';
    return 0;
}
```

**All divisor of a number**

```
vector<long long> all_divisors(long long n) {
    vector<long long> divisor;
    for (long long i = 1; i * i <= n; i++) {
        if (n % i == 0) {
            divisor.push_back(i);
            if (i * i != n) divisor.push_back(n / i);
        }
    }
    return divisor;
}
```

**Divisor List and Divisor Count of a number**

```
const int MAX_LIMIT = 1e7 + 3;
// Store lists of divisors for all numbers from 1 to MAX_LIMIT
        if (i + 2 <= N) dp[i] = min(dp[i], abs(h[i] - h[i + 2]) + dp[i + 2]);
    }
    cout << dp[1] << '\n';
}
int main() {
    ios::sync_with_stdio(0); cin.tie(0);
    solve(); return 0;
}
```

**Problem Statement**: There are N stones, numbered 1, 2, ..., N. For each i ($1 \le i \le N$), the height of Stone i is h[i]. A frog starts on Stone 1 and can jump to one of the next K stones: Stone i+1, i+2, ..., i+K. The cost of jumping from Stone i to Stone j is |h[i] - h[j]|. Find the minimum cost for the frog to reach Stone N.

```
#include <bits/stdc++.h>
using namespace std;
typedef long long ll;
void solve() {
    int N, K; cin >> N >> K;
    vector<int> h(N + 1);
    for (int i = 1; i <= N; i++) cin >> h[i];
    vector<ll> dp(N + 1, LLONG_MAX);
    dp[N] = 0;
    for (int i = N - 1; i >= 1; i--) {
        for (int j = 1; j <= K && i + j <= N; j++) {
            dp[i] = min(dp[i], abs(h[i] - h[i + j]) + dp[i + j]);
        }
    }
    cout << dp[1] << '\n';
}
int main() {
    ios::sync_with_stdio(0); cin.tie(0);
    solve(); return 0;
}
```

**Problem Statement**: Taro's vacation consists of N days. On each day, he can choose one of three activities:
1. Swim in the sea, gaining a[i] points of happiness.
2. Catch bugs in the mountains, gaining b[i] points of happiness.
3. Do homework at home, gaining c[i] points of happiness.

Taro cannot repeat the same activity on consecutive days. Find the maximum total happiness Taro can gain during the vacation.
Constraints: $1 \le N \le 10^5$ and $1 \le a[i], b[i], c[i] \le 10^4$

```
vector<vector<int>> divisorLists(MAX_LIMIT);
// Count of divisors for all numbers from 1 to MAX_LIMIT
vector<int> divisorCounts(MAX_LIMIT, 0);
void computeDivisors() {
    for (int num = 1; num < MAX_LIMIT; num++) {
        for (int multiple = num; multiple < MAX_LIMIT; multiple += num){
            divisorLists[multiple].push_back(num);
            divisorCounts[multiple]++;
        }
    } // (O(N log N))
}
```

**Single Query Prime Factors**

```
#include <bits/stdc++.h>
using namespace std;
vector<unsigned long long> Factorization(unsigned long long n) {
    vector<unsigned long long> Factors;
    for (unsigned long long ii = 2; ii * ii <= n; ii++) {
        if (n % ii == 0) Factors.push_back(ii);
        while (n % ii == 0) n /= ii;
    }
    if (n > 1) Factors.push_back(n);
    return Factors;
}
void idea() {
    unsigned long long n = (1ULL << 63) - 1 + (1ULL << 63);
    for (auto i : Factorization(n)) cout << i << ' ';
    cout << '\n';
}
int main() {
    ios::sync_with_stdio(0); cin.tie(0); cout.tie(0);
    for (int T = 1; T <= 1; T++) idea();
    return 0;
}
```

**Multiple Query Prime Factors**

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

const int N = 1e8 + 3;
vector<bool> is_prime(N + 1, true);
vector<long long> saved_primes;
```

```
#include <bits/stdc++.h>
using namespace std;
typedef long long ll;
void solve() {
    ll N; cin >> N;
    vector<ll> a(N + 1), b(N + 1), c(N + 1);
    for (ll i = 1; i <= N; i++) {
        cin >> a[i] >> b[i] >> c[i];
    }
    vector<ll> dp1(N + 1, 0), dp2(N + 1, 0), dp3(N + 1, 0);
    dp1[1] = a[1]; dp2[1] = b[1]; dp3[1] = c[1];
    for (ll i = 2; i <= N; i++) {
        dp1[i] = max(dp2[i - 1] + a[i], dp3[i - 1] + a[i]);
        dp2[i] = max(dp1[i - 1] + b[i], dp3[i - 1] + b[i]);
        dp3[i] = max(dp1[i - 1] + c[i], dp2[i - 1] + c[i]);
    }
    cout << max({dp1[N], dp2[N], dp3[N]}) << '\n';
}
int main() {
    ios::sync_with_stdio(0); cin.tie(0);
    solve(); return 0;
}
```

**Problem Statement**: There are N items, numbered 1, 2, ..., N. For each i (1 ≤ i ≤ N), Item i has a weight w[i] and a value v[i]. Taro wants to choose a subset of items and carry them in a knapsack with a capacity W. The total weight of the items chosen should not exceed W. The task is to find the maximum possible sum of values of the items that Taro can take home.
Constraints: 1 ≤ N ≤ 100, 1 ≤ W ≤ 10^5, 1 ≤ w[i] ≤ W, 1 ≤ v[i] ≤ 10^9

```
#include <bits/stdc++.h>
using namespace std;
typedef long long ll;
const int MAX_N = 105;
const int MAX_W = 100005;
ll dp[MAX_N][MAX_W];  // dp[i][w] represents the max value for the first i items with total weight <= w
void solve() {
    int n, W; cin >> n >> W;
    vector<int> weight(n + 1), value(n + 1);
    for (int i = 1; i <= n; i++) { cin >> weight[i] >> value[i]; }
```

```
void standard_sieve() { // TC: O(N log log N)
    is_prime[0] = is_prime[1] = false;
    for (int i = 3; i * i < N; i += 2) if (is_prime[i])
        for (int j = i * i; j < N; j += i + i) is_prime[j] = false;
    saved_primes.push_back(2);
    for (int i = 3; i < N; i += 2) if (is_prime[i]) saved_primes.push_back(i);
}

vector<unsigned long long> Prime_Factorization(unsigned long long n) {
    vector<unsigned long long> prime_factors;
    for (size_t i = 0; i < saved_primes.size() && saved_primes[i] * saved_primes[i] <=
n; i++) {
        if (n % saved_primes[i] == 0) {
            prime_factors.push_back(saved_primes[i]);
            while (n % saved_primes[i] == 0) n /= saved_primes[i];
        }
    }
    if (n > 1) prime_factors.push_back(n);
    return prime_factors;
}

int main() {
    standard_sieve();

    cout << "Number of primes found: " << saved_primes.size() << '\n'
         << "Last prime: " << saved_primes.back() << '\n';

    unsigned long long n = (1ULL << 63) - 1 + (1ULL << 63);
    vector<unsigned long long> factors = Prime_Factorization(n);

    cout << "Prime factors of " << n << ": ";
    for (auto factor : factors) cout << factor << ' ';
    cout << '\n';

    return 0;
}
```

**Modular Arithmatic**

```
ll Modular_Exponentiation(ll base, ll exp, ll mod) {
    // Initialize dp table with 0 (base case: 0 items, 0 weight)
    for (int i = 0; i <= n; i++) {
        for (int w = 0; w <= W; w++) { dp[i][w] = 0; }
    }
    // Fill the dp table using bottom-up approach
    for (int i = 1; i <= n; i++) {
        for (int w = 0; w <= W; w++) {
            // If we do not take the current item
            dp[i][w] = dp[i-1][w];
            // If we take the current item, check if the weight fits
            if (w >= weight[i]) {
                dp[i][w] = max(dp[i][w], dp[i-1][w - weight[i]] + value[i]);
            }
        }
    }
    // The answer is in dp[n][W] which is the max value with the full capacity
    cout << dp[n][W] << '\n';
}
int main() {
    ios::sync_with_stdio(0); cin.tie(0); cout.tie(0);
    solve(); return 0;
}
```

**Problem Statement**: There are N items, numbered 1, 2, ..., N. For each i ($1 \le i \le N$), Item i has a weight w[i] and a value v[i]. Taro wants to choose some of the N items and carry them in a knapsack with a capacity W. The total weight of the items chosen should not exceed W. The task is to find the maximum possible sum of values of the items that Taro can take home.
Constraints: $1 \le N \le 100$, $1 \le W \le 10^9$, $1 \le w[i] \le W$, $1 \le v[i] \le 10^3$

```
#include <bits/stdc++.h>
using namespace std;
typedef long long ll;
const int MAX_N = 100; // Maximum number of items
const int MAX_W = 100000; // Maximum weight for dp array (since weight can be up
to W)
void solve() {
    int n, W; cin >> n >> W;
    vector<int> weight(n + 1), value(n + 1);
    for (int i = 1; i <= n; i++) { cin >> weight[i] >> value[i]; }
    vector<ll> dp(W + 1, 0); // DP array to store maximum value for each weight capacity
```

```
    ll res = 1LL;
    base %= mod;
    while (exp) {
        if (exp % 2) res = res * base % mod;
        base = base * base % mod;
        exp /= 2;
    }
    return res;
}
ll Modular_Addition(ll x, ll y, ll mod) {
    return ((x % mod + y % mod) % mod + mod) % mod;
}
ll Modular_Subtraction(ll x, ll y, ll mod) {
    return ((x % mod - y % mod) % mod + mod) % mod;
}
ll Modular_Multiplication(ll x, ll y, ll mod) {
    return ((x % mod * y % mod) % mod + mod) % mod;
}
ll Modular_Inverse(ll x, ll mod) {
    return Modular_Exponentiation(x, mod - 2, mod);
}
```

**Combinatorics**

```
// nPr % MOD calculation
ll nPr(ll n, ll r, ll mod) { // O(log(MOD))
    if (r > n) return -1;
    ll numerator = fact[n] % mod;
    ll denominator = fact[n - r] % mod;
    numerator = (numerator * Modular_Exponentiation(denominator, mod - 2, mod)) %
mod;
    return numerator;
}
// nCr % MOD calculation
ll nCr(ll n, ll r, ll mod) { // O(log(MOD))
    if (r == 0) return 1;
    if (r > n) return -1;
    ll numerator = fact[n] % mod;
    ll denominator = (fact[n - r] * fact[r]) % mod;
    numerator = (numerator * Modular_Exponentiation(denominator, mod - 2, mod)) %
mod;
    return numerator;
    // Process each item
    for (int i = 1; i <= n; i++) {
        for (int w = W; w >= weight[i]; w--) { // Traverse from W down to weight[i] to
prevent overwriting results
            dp[w] = max(dp[w], dp[w - weight[i]] + value[i]);
        }
    }
    // The answer is the maximum value that can be obtained with any weight ≤ W
    cout << dp[W] << '\n';
}
int main() {
    ios::sync_with_stdio(0); cin.tie(0); cout.tie(0);
    solve(); return 0;
}
```

**Longest Increasing Subsequence**

```
#include <bits/stdc++.h>
using namespace std;
vector<long long> LIS_Path(vector<long long>& seq) {
    long long n = seq.size();
    vector<long long> sub, subIndex, path(n, -1);
    for (long long i = 0; i < n; ++i) {
        if (sub.empty() || sub.back() < seq[i]) {
            path[i] = sub.empty() ? -1 : subIndex.back();
            sub.push_back(seq[i]);
            subIndex.push_back(i);
        } else {
            long long idx = lower_bound(sub.begin(), sub.end(), seq[i]) - sub.begin();
            path[i] = (idx == 0) ? -1 : subIndex[idx - 1];
            sub[idx] = seq[i];
            subIndex[idx] = i;
        }
    }
    vector<long long> result;
    for (long long t = subIndex.back(); t != -1; t = path[t])
        result.push_back(seq[t]);
    reverse(result.begin(), result.end());
    return result;
}
int main() {
    vector<long long> v = {1, 3, 5, 4, 6, 2, 8};
```

```
}
// Precompute factorials up to n % mod
void cal_fact(ll n, ll mod) {
    fact.resize(n + 1);
    fact[0] = 1;
    for (ll i = 1; i <= n; i++) {
        fact[i] = (fact[i - 1] * i) % mod;
    }
}
```

**BigInteger**

```
#include <bits/stdc++.h>
#define debug(x) cout << #x << " = "; cout << x << '\n';
using namespace std;
typedef long long ll;
const int ARRAY_SIZE = (int)2e6 + 3;

// BigInt class for large integer support
class BigInt{
    string digits;
public:
    // Constructors
    BigInt(unsigned long long n = 0);
    BigInt(string &);
    BigInt(const char *);
    BigInt(BigInt &);
    BigInt(const BigInt &);

    // Helper Functions
    friend void divide_by_2(BigInt &a);
    friend bool Null(const BigInt &);
    friend int Length(const BigInt &);
    int operator[](const int) const;
    // Operators
    BigInt &operator=(const BigInt &);
    BigInt &operator++();
    BigInt operator++(int temp);
    BigInt &operator--();
    BigInt operator--(int temp);
    friend BigInt &operator+=(BigInt &, const BigInt &);
    friend BigInt operator+(const BigInt &, const BigInt &);
    vector<long long> lis = LIS_Path(v);
    for (long long i : lis) cout << i << ' ';
}
```

**Longest Common Subsequence**

```
#include <bits/stdc++.h>
using namespace std;
int LCS(string& s1, string& s2) {
    int len1 = s1.length();
    int len2 = s2.length();
    vector<int> dp(len2 + 1, 0);
    for (int i = 1; i <= len1; i++) {
        int prevDiagonal = 0;
        for (int j = 1; j <= len2; j++) {
            int temp = dp[j];
            if (s1[i - 1] == s2[j - 1]) { dp[j] = prevDiagonal + 1; }
            else { dp[j] = max(dp[j], dp[j - 1]); }
            prevDiagonal = temp;
        }
    }
    return dp[len2];
}
int main() {
    string s1 = "AGGTAB"; string s2 = "GXTXAYB";
    int lcsLength = LCS(s1, s2);
    cout << "Length of Longest Common Subsequence: " << lcsLength << '\n';
    return 0;
}
```

**Longest Common Substring**

```
#include <bits/stdc++.h>
using namespace std;
int LongestCommonSubstring(string& s1, string& s2) {
    int len1 = s1.length(); int len2 = s2.length();
    vector<int> dp(len2 + 1, 0);
    int maxLength = 0;
    for (int i = 1; i <= len1; i++) {
        int prevDiagonal = 0;
        for (int j = 1; j <= len2; j++) {
            int temp = dp[j];
            if (s1[i - 1] == s2[j - 1]) {
                dp[j] = prevDiagonal + 1;
```

```
    friend BigInt operator-(const BigInt &, const BigInt &);
    friend BigInt &operator-=(BigInt &, const BigInt &);
    friend bool operator==(const BigInt &, const BigInt &);
    friend bool operator!=(const BigInt &, const BigInt &);
    friend bool operator>(const BigInt &, const BigInt &);
    friend bool operator>=(const BigInt &, const BigInt &);
    friend bool operator<(const BigInt &, const BigInt &);
    friend bool operator<=(const BigInt &, const BigInt &);
    friend BigInt &operator*=(BigInt &, const BigInt &);
    friend BigInt operator*(const BigInt &, const BigInt &);
    friend BigInt &operator/=(BigInt &, const BigInt &);
    friend BigInt operator/(const BigInt &, const BigInt &);
    friend BigInt operator%(const BigInt &, const BigInt &);
    friend BigInt &operator%=(BigInt &, const BigInt &);
    friend BigInt &operator^=(BigInt &, const BigInt &);
    friend BigInt operator^(BigInt &, const BigInt &);
    // Additional Functions
    friend BigInt sqrt(BigInt &a);
    friend BigInt NthCatalan(int n);
    friend BigInt NthFibonacci(int n);
    friend BigInt Factorial(int n);
    // I/O
    friend ostream &operator<<(ostream &, const BigInt &);
    friend istream &operator>>(istream &, BigInt &);
};

// Constructor: BigInt from string
BigInt::BigInt(string &s) {
    digits = ""; int n = s.size();
    for (int i = n - 1; i >= 0; i--) {
        if (!isdigit(s[i])) throw("ERROR");
        digits.push_back(s[i] - '0');
    }
}
// Constructor: BigInt from unsigned long long
BigInt::BigInt(unsigned long long nr) {
    do { digits.push_back(nr % 10); nr /= 10; } while (nr);
}

// Constructor: BigInt from char*
```

```
                maxLength = max(maxLength, dp[j]);
            } else { dp[j] = 0; }
            prevDiagonal = temp;
        }
    }
    return maxLength;
}
int main() {
    string s1 = "ABABC";
    string s2 = "BABCAB";
    int lcsLength = LongestCommonSubstring(s1, s2);
    cout << "Length of Longest Common Substring: " << lcsLength << '\n';
    return 0;
}
```

**BFS Graph Traversal**

```
#include <bits/stdc++.h>
using namespace std;
const int mx = 2e5 + 5;
vector<int> v[mx];
bool vis[mx];
void bfs(int src) {
    queue<int> q;
    q.push(src);
    vis[src] = true;
    while (!q.empty()) {
        int par = q.front();
        q.pop();
        cout << par << endl;
        for (int child : v[par]) {
            if (!vis[child]) {
                q.push(child);
                vis[child] = true;
            }
        }
    }
}
int main() {
    int n, e; cin >> n >> e;
    while (e--) {
        int a, b; cin >> a >> b;
```

```
BigInt::BigInt(const char *s) {
    digits = "";
    for (int i = strlen(s) - 1; i >= 0; i--) {
        if (!isdigit(s[i])) throw("ERROR");
        digits.push_back(s[i] - '0');
    }
}
// Copy constructor
BigInt::BigInt(BigInt &a) { digits = a.digits; }
BigInt::BigInt(const BigInt &a) { digits = a.digits; }

// Helper Functions
bool Null(const BigInt &a) {
    return (a.digits.size() == 1 && a.digits[0] == 0);
}

int Length(const BigInt &a) { return a.digits.size(); }

int BigInt::operator[](const int index) const {
    if (digits.size() <= index || index < 0) throw("ERROR");
    return digits[index];
}

// Comparison operators
bool operator==(const BigInt &a, const BigInt &b) { return a.digits == b.digits; }
bool operator!=(const BigInt &a, const BigInt &b) { return !(a == b); }
bool operator<(const BigInt &a, const BigInt &b) {
    int n = Length(a), m = Length(b);
    if (n != m) return n < m;
    while (n--) if (a.digits[n] != b.digits[n]) return a.digits[n] < b.digits[n];
    return false;
}
bool operator>(const BigInt &a, const BigInt &b) { return b < a; }
bool operator>=(const BigInt &a, const BigInt &b) { return !(a < b); }
bool operator<=(const BigInt &a, const BigInt &b) { return !(a > b); }
// Assignment operator
BigInt &BigInt::operator=(const BigInt &a) { digits = a.digits; return *this; }
// Increment/Decrement
BigInt &BigInt::operator++() {
    int i, n = digits.size();
```

```
        v[a].push_back(b); v[b].push_back(a);
    }
    int src; cin >> src;
    memset(vis, false, sizeof(vis));
    bfs(src);
    return 0;
}
```

**BFS Graph Levels**

```
#include <bits/stdc++.h>
using namespace std;
const int mx = 2e5 + 5;
vector<int> adj[mx];
bool visited[mx];
int level[mx];
void bfs(int src) {
    queue<int> q;
    q.push(src);
    visited[src] = true;
    level[src] = 0;
    while (!q.empty()) {
        int par = q.front();
        q.pop();
        for (int child : adj[par])
            if (!visited[child]) {
                q.push(child);
                visited[child] = true;
                level[child] = level[par] + 1;
            }
    }
}
int main() {
    ios::sync_with_stdio(false);
    cin.tie(NULL);
    int n, e; cin >> n >> e;
    for (int i = 0; i < e; i++) {
        int a, b; cin >> a >> b;
        adj[a].push_back(b);
        adj[b].push_back(a);
    }
    int src; cin >> src;
```

```
    for (i = 0; i < n && digits[i] == 9; i++) digits[i] = 0;
    if (i == n) digits.push_back(1);
    else digits[i]++;
    return *this;
}
BigInt BigInt::operator++(int temp) { BigInt aux; aux = *this; ++(*this); return aux; }
BigInt &BigInt::operator--() {
    if (digits[0] == 0 && digits.size() == 1) throw("UNDERFLOW");
    int i, n = digits.size();
    for (i = 0; digits[i] == 0 && i < n; i++) digits[i] = 9;
    digits[i]--;
    if (n > 1 && digits[n - 1] == 0) digits.pop_back();
    return *this;
}
BigInt BigInt::operator--(int temp) { BigInt aux; aux = *this; --(*this); return aux; }
// Addition and Subtraction
BigInt &operator+=(BigInt &a, const BigInt &b) {
    int t = 0, s, i;
    int n = Length(a), m = Length(b);
    if (m > n) a.digits.append(m - n, 0);
    n = Length(a);
    for (i = 0; i < n; i++) {
        s = (i < m ? (a.digits[i] + b.digits[i]) : a.digits[i]) + t;
        t = s / 10;
        a.digits[i] = s % 10;
    }
    if (t) a.digits.push_back(t);
    return a;
}

BigInt operator+(const BigInt &a, const BigInt &b) { BigInt temp; temp = a; temp +=
b; return temp; }

BigInt &operator-=(BigInt &a, const BigInt &b) {
    if (a < b) throw("UNDERFLOW");
    int n = Length(a), m = Length(b), t = 0, s, i;
    for (i = 0; i < n; i++) {
        s = a.digits[i] - (i < m ? b.digits[i] : 0) + t;
        if (s < 0) s += 10, t = -1;
        else t = 0;
    memset(visited, false, sizeof(visited));
    memset(level, -1, sizeof(level));
    bfs(src);
    for (int i = 0; i < n; i++) cout << "Node: " << i << ", Level: " << level[i] << '\n';
    return 0;
}
```

**BFS Cycle Detection**

```
#include <bits/stdc++.h>
using namespace std;
const int N = 1e5 + 5;
bool vis[N];
vector<int> adj[N];
int parentArray[N];
bool ans;
void bfs(int s) {
    queue<int> q;
    q.push(s);
    vis[s] = true;
    while (!q.empty()) {
        int parent = q.front(); q.pop();
        for (int child : adj[parent]) {
            if (vis[child] == true && parentArray[parent] != child) { ans = true; }
            if (vis[child] == false) {
                vis[child] = true;
                parentArray[child] = parent;
                q.push(child);
            }
        }
    }
}
int main() {
    int n, e; cin >> n >> e;
    while (e--) {
        int a, b; cin >> a >> b;
        adj[a].push_back(b); adj[b].push_back(a);
    }
    memset(vis, false, sizeof(vis));
    memset(parentArray, -1, sizeof(parentArray));
    ans = false;
    for (int i = 0; i < n; i++) {
```

```
        a.digits[i] = s;
    }
    while (n > 1 && a.digits[n - 1] == 0) a.digits.pop_back(), n--;
    return a;
}

BigInt operator-(const BigInt &a, const BigInt &b) { BigInt temp; temp = a; temp -= b;
return temp; }
// Multiplication
BigInt &operator*=(BigInt &a, const BigInt &b) {
    if (Null(a) || Null(b)) { a = BigInt(); return a; }
    int n = a.digits.size(), m = b.digits.size();
    vector<int> v(n + m, 0);
    for (int i = 0; i < n; i++)
        for (int j = 0; j < m; j++) v[i + j] += (a.digits[i]) * (b.digits[j]);
    n += m;
    a.digits.resize(v.size());
    for (int s, i = 0, t = 0; i < n; i++) {
        s = t + v[i]; v[i] = s % 10; t = s / 10; a.digits[i] = v[i];
    }
    for (int i = n - 1; i >= 1 && !v[i]; i--) a.digits.pop_back();
    return a;
}
BigInt operator*(const BigInt &a, const BigInt &b) { BigInt temp; temp = a; temp *=
b; return temp; }
// Division and Modulo
BigInt &operator/=(BigInt &a, const BigInt &b) {
    if (Null(b)) throw("Arithmetic Error: Division By 0");
    if (a < b) { a = BigInt(); return a; }
    if (a == b) { a = BigInt(1); return a; }
    int i, lgcat = 0, cc;
    int n = Length(a), m = Length(b);
    vector<int> cat(n, 0);
    BigInt t;
    for (i = n - 1; t * 10 + a.digits[i] < b; i--) { t *= 10; t += a.digits[i]; }
    for (; i >= 0; i--) {
        t = t * 10 + a.digits[i];
        for (cc = 9; cc * b > t; cc--);
        t -= cc * b;
        cat[lgcat++] = cc;
        if (!vis[i]) { bfs(i); }
    }
    if (ans) { cout << "Cycle found"; } else { cout << "Cycle not found";}
    return 0;
}
```

**BFS Shortest Path**

```
#include <bits/stdc++.h>
using namespace std;
const int mx = 2e5 + 5;
vector<int> adj[mx];
bool visited[mx];
void bfs(int src, int des) {
    queue<pair<int, int>> q;
    q.push({src, 0});
    visited[src] = true;
    bool found = false;
    while (!q.empty()) {
        pair<int, int> parent = q.front();
        q.pop();
        int node = parent.first;
        int level = parent.second;
        if (node == des) {
            cout << "Shortest path length: " << level << '\n';
            found = true;
            break;
        }
        for (int child : adj[node]) {
            if (!visited[child]) {
                q.push({child, level + 1});
                visited[child] = true;
            }
        }
    }
    if (!found) { cout << "Destination not reachable" << '\n'; }
}
int main() {
    ios::sync_with_stdio(false);
    cin.tie(NULL);
    int n, e; cin >> n >> e;
    for (int i = 0; i < e; i++) {
```

```
    }
    a.digits.resize(cat.size());
    for (i = 0; i < lgcat; i++) a.digits[i] = cat[lgcat - i - 1];
    a.digits.resize(lgcat);
    return a;
}
BigInt operator/(const BigInt &a, const BigInt &b) { BigInt temp; temp = a; temp /= b;
return temp; }
BigInt &operator%=(BigInt &a, const BigInt &b) {
    if (Null(b)) throw("Arithmetic Error: Division By 0");
    if (a < b) { return a; }
    if (a == b) { a = BigInt(); return a; }
    int i, lgcat = 0, cc;
    int n = Length(a), m = Length(b);
    vector<int> cat(n, 0);
    BigInt t;
    for (i = n - 1; t * 10 + a.digits[i] < b; i--) { t *= 10; t += a.digits[i]; }
    for (; i >= 0; i--) {
        t = t * 10 + a.digits[i];
        for (cc = 9; cc * b > t; cc--);
        t -= cc * b;
        cat[lgcat++] = cc;
    }
    a = t; return a;
}
BigInt operator%(const BigInt &a, const BigInt &b) { BigInt temp; temp = a; temp %=
b; return temp; }

// Power operator
BigInt &operator^=(BigInt &a, const BigInt &b) {
    BigInt Exponent, Base(a); Exponent = b; a = 1;
    while (!Null(Exponent)) {
        if (Exponent[0] & 1) a *= Base;
        Base *= Base;
        divide_by_2(Exponent);
    }
    return a;
}
BigInt operator^(BigInt &a, BigInt &b) { BigInt temp(a); temp ^= b; return temp; }
// Helper function for dividing BigInt by 2
```

```
        int a, b; cin >> a >> b;
        adj[a].push_back(b); adj[b].push_back(a);
    }
    int src, des; cin >> src >> des;
    memset(visited, false, sizeof(visited));
    bfs(src, des);
    return 0;
}
```

**BFS Shortest Path with Path Printing**

```
#include <bits/stdc++.h>
using namespace std;
const int mx = 2e5 + 5;
vector<int> adj[mx];
bool visited[mx];
int level[mx];
int parent[mx];
void bfs(int src) {
    queue<int> q;
    q.push(src);
    visited[src] = true;
    level[src] = 0;
    parent[src] = -1;
    while (!q.empty()) {
        int par = q.front();
        q.pop();
        for (int child : adj[par]) {
            if (!visited[child]) {
                q.push(child);
                visited[child] = true;
                level[child] = level[par] + 1;
                parent[child] = par;
            }
        }
    }
}
int main() {
    ios::sync_with_stdio(false);
    cin.tie(NULL);
    int n, e; cin >> n >> e;
    for (int i = 0; i < e; i++) {
```

```
void divide_by_2(BigInt &a) {
    int add = 0;
    for (int i = a.digits.size() - 1; i >= 0; i--) {
        int digit = (a.digits[i] >> 1) + add;
        add = ((a.digits[i] & 1) * 5);
        a.digits[i] = digit;
    }
    while (a.digits.size() > 1 && !a.digits.back()) a.digits.pop_back();
}
// Square root function for BigInt
BigInt sqrt(BigInt &a) {
    BigInt left(1), right(a), v(1), mid, prod; divide_by_2(right);
    while (left <= right) {
        mid += left; mid += right; divide_by_2(mid); prod = (mid * mid);
        if (prod <= a) { v = mid; ++mid; left = mid; }
        else { --mid; right = mid; }
        mid = BigInt();
    }
    return v;
}
// Catalan number
BigInt NthCatalan(int n) {
    BigInt a(1), b;
    for (int i = 2; i <= n; i++) a *= i;
    b = a;
    for (int i = n + 1; i <= 2 * n; i++) b *= i;
    a *= a; a *= (n + 1); b /= a;
    return b;
}
// Fibonacci sequence
BigInt NthFibonacci(int n) {
    BigInt a(1), b(1), c;
    if (!n) return c;
    n--;
    while (n--) { c = a + b; b = a; a = c; }
    return b;
}
// Factorial of n
BigInt Factorial(int n) {
    BigInt f(1);
```

```
        int a, b; cin >> a >> b;
        adj[a].push_back(b); adj[b].push_back(a);
    }
    int src, des; cin >> src >> des;
    memset(visited, false, sizeof(visited));
    memset(level, -1, sizeof(level));
    memset(parent, -1, sizeof(parent));
    bfs(src);
    if (level[des] == -1) {
        cout << "Destination not reachable" << '\n';
    } else {
        vector<int> path;
        int x = des;
        while (x != -1) {
            path.push_back(x);
            x = parent[x];
        }
        reverse(path.begin(), path.end());
        cout << "Shortest path length: " << level[des] << '\n';
        cout << "Path: ";
        for (int val : path) { cout << val << " "; }
        cout << '\n';
    }
    return 0;
}
```

**BFS Grid Shortest Distance**

```
#include <bits/stdc++.h>
using namespace std;
const int MAX = 20;
bool visited[MAX][MAX];
int level[MAX][MAX];
vector<pair<int, int>> directions = {{0, 1}, {0, -1}, {-1, 0}, {1, 0}};
int row, col;
char grid[MAX][MAX];
bool isValid(int i, int j) {
    return (i >= 0 and i < row and j >= 0 and j < col);
}
void bfs(int startX, int startY) {
    queue<pair<int, int>> q;
    q.push({startX, startY});
```

```
    for (int i = 2; i <= n; i++) f *= i;
    return f;
}
// Input stream for BigInt
istream &operator>>(istream &in, BigInt &a) {
    string s; in >> s; a.digits.clear();
    for (int i = s.size() - 1; i >= 0; i--) {
        if (!isdigit(s[i])) throw("INVALID NUMBER");
        a.digits.push_back(s[i] - '0');
    }
    return in;
}

// Output stream for BigInt
ostream &operator<<(ostream &out, const BigInt &a) {
    for (int i = a.digits.size() - 1; i >= 0; i--) out << (short)a.digits[i];
    return out;
}
// Main function with test cases
void idea() {
    // take input
    BigInt first_num, Second_num;
    cin >> first_num >> Second_num;

    // check equality
    if (first_num == Second_num) cout << "Equal" << '\n';
    else cout << "Not Equal" << '\n';

    // comparison
    if (first_num > Second_num) cout << "Greater" << '\n';
    else cout << "Smaller" << '\n';

    // printing
    cout << first_num << ' ' << Second_num << '\n';

    // vector input
    vector <BigInt> vec = {first_num, Second_num};
    for (auto val : vec) { cout << val << ' '; cout << '\n'; }

    BigInt Fib = NthFibonacci(6); // 6th Fibonacci is 8
```

```
    visited[startX][startY] = true;
    level[startX][startY] = 0;
    while (!q.empty()) {
        auto [x, y] = q.front();
        q.pop();
        for (auto [dx, dy] : directions) {
            int newX = x + dx;
            int newY = y + dy;
            if (isValid(newX, newY) and !visited[newX][newY]) {
                q.push({newX, newY});
                visited[newX][newY] = true;
                level[newX][newY] = level[x][y] + 1;
            }
        }
    }
}
int main() {
    ios::sync_with_stdio(false);
    cin.tie(NULL);
    cin >> row >> col;
    for (int i = 0; i < row; i++) {
        for (int j = 0; j < col; j++) {
            cin >> grid[i][j];
        }
    }
    int startX, startY; cin >> startX >> startY;
    memset(visited, false, sizeof(visited));
    memset(level, -1, sizeof(level));
    bfs(startX, startY);
    cout << "Distance to (2, 3): " << level[2][3] << '\n';
    return 0;
}
```

**DFS Graph Traversal**

```
#include <bits/stdc++.h>
using namespace std;
const int MAX = 20;
char grid[MAX][MAX];
bool visited[MAX][MAX];
vector<pair<int, int>> directions = {{0, 1}, {0, -1}, {-1, 0}, {1, 0}};
int n, m;
```

```
    BigInt Cat = NthCatalan(10); // 10th Catalan is 16796
    BigInt Fact = Factorial(5); // Factorial of 5 is 120
    cout << Fib << ' ' << Cat << ' ' << Fact << '\n';
}

int main() {
    ios::sync_with_stdio(0); cin.tie(0); cout.tie(0);
    int T = 1;
    // cin >> T;
    for (int C = 1; C <= T; C++) {
        // cout << "Case " << C << ": " << '\n';
        idea();
    }
    return 0;
}
```

**Binary Search**

```
#include <bits/stdc++.h>
using namespace std;
int main() {
    ios::sync_with_stdio(false); cin.tie(NULL);
    int n, key; cin >> n >> key;
    vector<int> a(n);
    for (int i = 0; i < n; i++) cin >> a[i];
    int l = 0, r = n - 1, idx = -1;
    while (l <= r) {
        int mid = l + (r - l) / 2;
        if (a[mid] == key) { idx = mid; break; }
        if (a[mid] < key) l = mid + 1;
        else r = mid - 1;
    }
    cout << (idx == -1 ? "Element not found" : "Element found at index " + to_string(idx))
<< '\n';
    return 0;
}
```

**Maximize the Median**

```
#include <bits/stdc++.h>
using namespace std;
int main() {
    ios::sync_with_stdio(false); cin.tie(NULL);
    int n, k; cin >> n >> k;
```

```
bool isValid(int row, int col) {
    return (row >= 0 && row < n && col >= 0 && col < m);
}
void dfs(int row, int col) {
    cout << "Visited cell: (" << row << ", " << col << ")\n";
    visited[row][col] = true;
    for (auto [dRow, dCol] : directions) {
        int newRow = row + dRow;
        int newCol = col + dCol;
        if (isValid(newRow, newCol) && !visited[newRow][newCol]) {
            dfs(newRow, newCol);
        }
    }
}
int main() {
    ios::sync_with_stdio(false); cin.tie(NULL);
    cin >> n >> m;
    for (int i = 0; i < n; ++i) {
        for (int j = 0; j < m; ++j) { cin >> grid[i][j]; }
    }
    int startRow, startCol; cin >> startRow >> startCol;
    memset(visited, false, sizeof(visited));
    dfs(startRow, startCol);
    return 0;
}
```

**DFS Cycle Detection**

```
#include <bits/stdc++.h>
using namespace std;
const int N = 1e5 + 5;
bool vis[N];
bool pathVisit[N];
vector<int> adj[N];
bool ans;
void dfs(int parent) {
    vis[parent] = true;
    pathVisit[parent] = true;
    for (int child : adj[parent]) {
        if (pathVisit[child]) { ans = true; }
        if (!vis[child]) { dfs(child); }
    }
```

```
    vector<int> a(n);
    for (int &x : a) cin >> x;
    sort(a.begin(), a.end());
    auto ok = [&](long long mid) {
        long long cnt = 0;
        for (int i = n / 2; i < n; i++) {
            cnt += max(0LL, mid - a[i]);
        }
        return cnt <= k;
    };

    long long l = 1, r = 2e9, ans = 0;
    while (l <= r) {
        long long mid = l + (r - l) / 2;
        if (ok(mid)) {
            ans = mid;
            l = mid + 1;
        } else {
            r = mid - 1;
        }
    }
    cout << ans << '\n';
    return 0;
}
```

**Policy Based Data Structure**

```
// count_elements_less_or_equal
#include <bits/stdc++.h>
#include <ext/pb_ds/assoc_container.hpp>
#include <ext/pb_ds/tree_policy.hpp>
using namespace std;
using namespace __gnu_pbds;
template <typename T> using pbds = tree<T, null_type, less_equal<T>, rb_tree_tag,
tree_order_statistics_node_update>;

int main() {
    ios::sync_with_stdio(false); cin.tie(NULL);
    int n, q;
    cin >> n >> m;
    pbds<int> p;
    for (int i = 1; i <= n; i++) {
```

```
    pathVisit[parent] = false;
}
int main() {
    int n, e;
    cin >> n >> e;
    while (e--) {
        int a, b; cin >> a >> b;
        adj[a].push_back(b);
        // Uncomment the following line for an undirected graph
        // adj[b].push_back(a);
    }
    memset(vis, false, sizeof(vis));
    memset(pathVisit, false, sizeof(pathVisit));
    ans = false;
    for (int i = 0; i < n; i++) {
        if (!vis[i]) { dfs(i); }
    }
    if (ans) cout << "Cycle detected";
    else cout << "Cycle not detected";
    return 0;
}
```

**DFS Connected Components**

```
#include <bits/stdc++.h>
using namespace std;
const int N = 1e5 + 5;
vector<int> adj[N];
bool visited[N];
void dfs(int src) {
    cout << "Visited node: " << src << '\n';
    visited[src] = true;
    for (int child : adj[src]) {
        if (!visited[child]) {
            dfs(child);
        }
    }
}
int main() {
    ios::sync_with_stdio(false);
    cin.tie(NULL);
    int n, e; cin >> n >> e;
```

```
        int x;
        cin >> x;
        p.insert(x);
    }
    for (int i = 1; i <= q; i++) {
        int x;
        cin >> x;
        cout << p.order_of_key(x + 1) << " ";
    }
    cout << '\n';
    return 0;
}
```

**Sliding Window Median**

```
#include <bits/stdc++.h>
#include <ext/pb_ds/assoc_container.hpp>
#include <ext/pb_ds/tree_policy.hpp>
using namespace __gnu_pbds;
using namespace std;
template <typename T>
using pbds = tree<T, null_type, less<T>, rb_tree_tag,
tree_order_statistics_node_update>;
int main() {
    ios::sync_with_stdio(false); cin.tie(NULL);
    int n, k;
    cin >> n >> k;
    vector<int> a(n);
    for (int &x : a) cin >> x;
    int l = 0;
    pbds<pair<int, int>> p;
    for (int r = 0; r < n; r++) {
        p.insert({a[r], r});
        if (r - l + 1 == k) {
            int pos = (k - 1) / 2;
            auto it = p.find_by_order(pos);
            cout << it->first << " ";
            p.erase({a[l], l});
            l++;
        }
    }
    cout << '\n';
    for (int i = 0; i < e; i++) {
        int a, b; cin >> a >> b;
        adj[a].push_back(b);
        adj[b].push_back(a);
    }
    memset(visited, false, sizeof(visited));
    int componentCount = 0;
    for (int i = 0; i < n; i++) {
        if (!visited[i]) {
            cout << "Starting DFS at component: " << componentCount + 1 << " starting
from node " << i << '\n';
            dfs(i);
            componentCount++;
        }
    }
    cout << "Number of components: " << componentCount << '\n';
    return 0;
}
```

**Dijkstra**

```
#include <bits/stdc++.h>
using namespace std;
const int N = 100;
vector<pair<int, int>> v[N];
int dis[N];
class cmp {
public:
    bool operator()(pair<int, int> a, pair<int, int> b) {
        return a.second > b.second;
    }
};
void dijkstra(int src) {
    priority_queue<pair<int, int>, vector<pair<int, int>>, cmp> pq;
    pq.push({src, 0});
    dis[src] = 0;
    while (!pq.empty()) {
        pair<int, int> parent = pq.top();
        pq.pop();
        int node = parent.first;
        int cost = parent.second;
        for (pair<int, int> child : v[node]) {
```

```
    return 0;
}
```

**Segment Tree**

```
#include <bits/stdc++.h>
using namespace std;
typedef long long ll;
const ll N = 2e5 + 5;
ll arr[N];  // Input array
ll segTree[4 * N];  // Segment Tree
ll lazy[4 * N];  // Lazy propagation array
// Propagate the pending updates to child nodes
void propagate(int node, int start, int end) {
    if (lazy[node] != 0) {
        segTree[node] += lazy[node] * (end - start + 1);  // Apply the pending update to
this node
        if (start != end) {  // Not a leaf node
            lazy[2 * node] += lazy[node];  // Mark left child for lazy propagation
            lazy[2 * node + 1] += lazy[node];  // Mark right child for lazy propagation
        }
        lazy[node] = 0;  // Clear the lazy value
    }
}
// Build the segment tree
void build(int node, int start, int end) {
    if (start == end) {
        segTree[node] = arr[start];  // Leaf node stores the actual value
    } else {
        int mid = (start + end) / 2;
        build(2 * node, start, mid);  // Left child
        build(2 * node + 1, mid + 1, end);  // Right child
        segTree[node] = segTree[2 * node] + segTree[2 * node + 1];  // Merge the results
    }
}
// Range query: get the sum of elements in the range [L, R]
ll query(int node, int start, int end, int L, int R) {
    propagate(node, start, end);  // Ensure any pending updates are applied
    if (start > R || end < L) {  // No overlap
        return 0;  // For sum queries, return 0 for no overlap
    }
    if (start >= L && end <= R) {  // Total overlap
            int childNode = child.first;
            int childCost = child.second;
            if (cost + childCost < dis[childNode]) {
                dis[childNode] = cost + childCost;
                pq.push({childNode, dis[childNode]});
            }
        }
    }
}
int main() {
    int n, e; cin >> n >> e;
    while (e--) {
        int a, b, c; cin >> a >> b >> c;
        v[a].push_back({b, c});
        v[b].push_back({a, c});
    }
    for (int i = 0; i < n; i++) { dis[i] = INT_MAX; }
    dijkstra(0);
    for (int i = 0; i < n; i++) {
        cout << i << " -> " << dis[i] << endl;
    }
    return 0;
}
```

**Adhoc**

```
ll All_Possible_Substring_Sum(string s) {
    int n = (int)s.size();
    vector<ll> digit_sum(n);
    digit_sum[0] = s[0] - '0';
    ll totalSum = digit_sum[0];
    for (int i = 1; i < n; i++) {
        int cur_val = s[i] - '0';
        digit_sum[i] = (i + 1) * cur_val + 10 * digit_sum[i - 1];
        totalSum += digit_sum[i];
    }
    return totalSum; // TC: O(N)
}
void GenerateAndPrintAllSubstrings(string s) {
    int n = s.size();
    for (int i = 0; i < n; i++) {
        string currentSubstring;
```

```
        return segTree[node];
    }
    // Partial overlap
    int mid = (start + end) / 2;
    ll leftQuery = query(2 * node, start, mid, L, R);
    ll rightQuery = query(2 * node + 1, mid + 1, end, L, R);
    return leftQuery + rightQuery;  // Merge the results
}
// Point update: update the value at index 'idx' by 'val'
void update(int node, int start, int end, int idx, ll val) {
    propagate(node, start, end);  // Ensure any pending updates are applied
    if (start == end) {
        segTree[node] += val;  // Point update
    } else {
        int mid = (start + end) / 2;
        if (idx <= mid) {
            update(2 * node, start, mid, idx, val);  // Update left child
        } else {
            update(2 * node + 1, mid + 1, end, idx, val);  // Update right child
        }
        segTree[node] = segTree[2 * node] + segTree[2 * node + 1];  // Recalculate the
sum for this node
    }
}
// Range update: add 'val' to all elements in the range [L, R]
void rangeUpdate(int node, int start, int end, int L, int R, ll val) {
    propagate(node, start, end);  // Ensure any pending updates are applied
    if (start > R || end < L) {  // No overlap
        return;
    }
    if (start >= L && end <= R) {  // Total overlap
        segTree[node] += val * (end - start + 1);  // Apply the update
        if (start != end) {  // Not a leaf node
            lazy[2 * node] += val;  // Mark left child for lazy propagation
            lazy[2 * node + 1] += val;  // Mark right child for lazy propagation
        }
        return;
    }
    // Partial overlap
    int mid = (start + end) / 2;
```

```
        for (int j = i; j < n; j++) {
            currentSubstring += s[j];
            cout << currentSubstring << '\n';
        }
    } // TC: O(N x N)
}
```

**Maximum Sum Subarray in fixed length**

```
ll maximumSumSubarray(int k, vector<int>& a, int n) {
    int l = 0, r = 0;
    long long sum = 0, ans = 0;
    while (r < n) {
        sum += a[r];
        if ((r - l + 1) == k) {
            ans = max(ans, sum);
            sum -= a[l];
            l++;
        }
        r++;
    }
    return ans;
}
```

**Kadane's Algo**

```
ll maximum_subarray_sum(vector <ll> &v) {
    int n = v.size();
    ll maxSum = v[0], currentSum = v[0];
    for (int i = 1; i < n; i++) {
        currentSum = max(currentSum + v[i], v[i]);
        maxSum = max(maxSum, currentSum);
    }
    return maxSum; // TC: O(N)
}
```

**String**

```
void String_Permutations(string s) { // TC: O(n x n!)
    sort(s.begin(), s.end());
    do { cout << s << '\n'; } while (next_permutation(s.begin(), s.end()));
}
ll longestSubstringWithKUniqueChars(string s, ll k) {
    ll start = 0; ll end = 0; ll maxLength = -1; ll uniqueCount = 0;
    vector<ll> charFrequency(26, 0);
    while (end < s.size()) {
```

```
    rangeUpdate(2 * node, start, mid, L, R, val);
    rangeUpdate(2 * node + 1, mid + 1, end, L, R, val);
    segTree[node] = segTree[2 * node] + segTree[2 * node + 1];  // Recalculate the sum
for this node
}
void solve() {
    ll n, q;
    cin >> n;
    for (ll i = 1; i <= n; i++) {
        cin >> arr[i];
    }
    build(1, 1, n);  // Build the segment tree
    cin >> q;
    while (q--) {
        int type;
        cin >> type;
        if (type == 1) {  // Query operation: Sum in range [L, R]
            int L, R; cin >> L >> R;
            cout << query(1, 1, n, L, R) << '\n';
        } else if (type == 2) {  // Point update: Update arr[idx] by value
            int idx, val; cin >> idx >> val;
            update(1, 1, n, idx, val);
        } else if (type == 3) {  // Range update: Add value to range [L, R]
            int L, R, val; cin >> L >> R >> val;
            rangeUpdate(1, 1, n, L, R, val);
        }
    }
}
int main() {
    ios::sync_with_stdio(0); cin.tie(0); cout.tie(0);
    solve(); return 0;
}
```

**Debugger**

```
#include <bits/stdc++.h>
using namespace std;
#define bug(x) debug(x, #x)
// Pair Input
template <typename X, typename Y>
istream &operator>>(istream &cin, pair<X, Y> &a) {
    return cin >> a.first >> a.second;
        if (charFrequency[s[end] - 'a']++ == 0) { uniqueCount++; }
        while (uniqueCount > k) {
            if (--charFrequency[s[start] - 'a'] == 0) { uniqueCount--; }
            start++;
        }
        if (uniqueCount == k) { maxLength = max(maxLength, end - start + 1); }
        end++;
    }
    return maxLength; // O(N)
}
bool is_subsequence(string& s1, string& s2) {
    int n = s1.length(), m = s2.length();
    int i = 0, j = 0;
    while (i < n && j < m) { if (s1[i] == s2[j]) i++; j++; }
    return i == n; // TC: O(len(s2))
}
bool is_substring(string child, string mother) {
    if (mother.find(child) != string::npos) return true;
    return false; // TC: O(N)
}
```

**KMP**

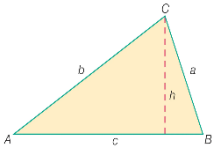
```
vector<int> constructTempArray(string pattern) {
    vector<int> lps(pattern.size());
    int index = 0;
    for (int i = 1; i < (int)pattern.size();) {
        if (pattern[i] == pattern[index]) {
            lps[i] = index + 1; ++index; ++i;
        } else {
            if (index != 0) { index = lps[index - 1] } else { lps[i] = index; ++i; }
        }
    }
    return lps;
}
bool KMPMultipleTimes(string text, string pattern) {
    vector<int> lps = constructTempArray(pattern);
    int j = 0, i = 0;
    while (i < (int)text.size()) {
        if (text[i] == pattern[j]) { ++i; ++j; }
        else {
            if (j != 0) j = lps[j - 1];
```

```
}
// Pair Output
template <typename X, typename Y>
ostream &operator<<(ostream &cout, const pair<X, Y> &a) {
    return cout << a.first << ' ' << a.second;
}
// Vector of Pairs Input
template <typename X, typename Y>
istream &operator>>(istream &cin, vector<pair<X, Y>> &vec) {
    for (auto &x : vec) cin >> x; return cin;
}
// Vector of Pairs Output
template <typename X, typename Y>
ostream &operator<<(ostream &cout, const vector<pair<X, Y>> &vec) {
    for (const auto &x : vec) cout << x << '\n';
    return cout;
}
// Tuple Input
template <typename X, typename Y, typename Z>
istream &operator>>(istream &cin, tuple<X, Y, Z> &a) {
    return cin >> get<0>(a) >> get<1>(a) >> get<2>(a);
}
// Tuple Output
template <typename X, typename Y, typename Z>
ostream &operator<<(ostream &cout, const tuple<X, Y, Z> &a) {
    return cout << '(' << get<0>(a) << ", " << get<1>(a) << ", " << get<2>(a) << ')';
}
// Vector of Tuples Input
template <typename X, typename Y, typename Z>
istream &operator>>(istream &cin, vector<tuple<X, Y, Z>> &vec) {
    for (auto &t : vec) cin >> t; return cin;
}
// Vector of Tuples Output
template <typename X, typename Y, typename Z>
ostream &operator<<(ostream &cout, const vector<tuple<X, Y, Z>> &vec) {
    for (const auto &t : vec) cout << t << '\n'; return cout;
}
// Vector Input
template <typename X>
istream &operator>>(istream &cin, vector<X> &a) {
```

```
            else i++;
        }
        if (j == (int)pattern.size()) { return true; }
    }
    return false; // O(N + M)
}
int main() {
    string text = "ababcabcabababd";
    string pattern = "ababd";
    if (KMPMultipleTimes(text, pattern)) { cout << "Pattern found in the text.\n"; }
    else { cout << "Pattern not found in the text.\n"; }
    return 0;
}
// (graph revise kora) Bellman ford + seg tree
```

**Geometry**

Triangle:

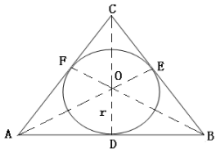



Area = 0.5 x base x height

$= \sqrt{s(s-a)(s-b)(s-c)}$ This is Heron's formula

= 0.5 ab sin C = 0.5 bc sin A = 0.5 ac sin B

Perimeter, 2S = a + b + c Semi perimeter, S = $\frac{a+b+c}{2}$



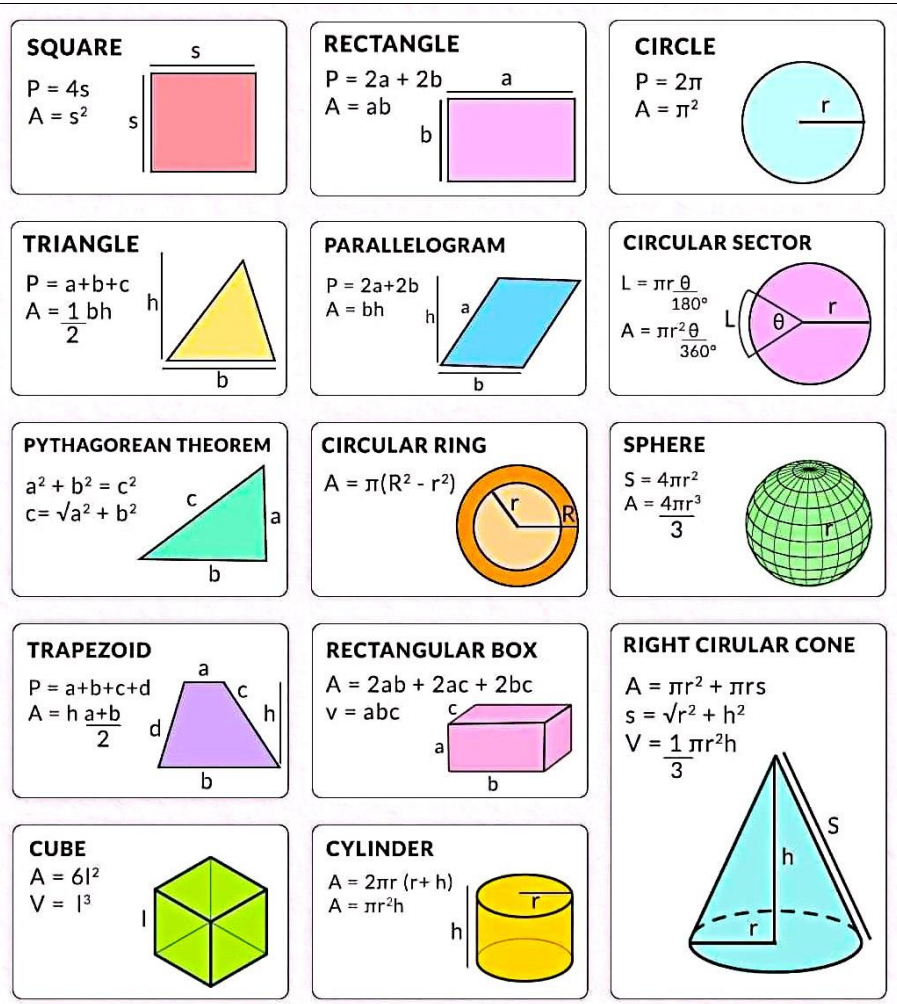

Triangle Area = S . r

= r . $\frac{a+b+c}{2}$

= 0.5 ar + 0.5 br + 0.5 cr

Radius, r = $\frac{Area}{S}$

```
    for (auto &x : a) cin >> x; return cin;
}
// Vector Output
template <typename X>
ostream &operator<<(ostream &cout, const vector<X> &a) {
    int n = a.size();
    if (n == 0) return cout; cout << a[0];
    for (int i = 1; i < n; i++) cout << ' ' << a[i]; return cout;
}
// Matrix (Nested Vector) Input
template <typename X>
istream &operator>>(istream &cin, vector<vector<X>> &mat) {
    for (auto &row : mat) { for (auto &elem : row) { cin >> elem;  } } return cin;
}
// Matrix (Nested Vector) Output
template <typename X>
ostream &operator<<(ostream &cout, const vector<vector<X>> &mat) {
    for (const auto &row : mat) {
        for (const auto &elem : row) { cout << elem << ' '; } cout << '\n';
    } return cout;
}
// Map Input
template <typename X, typename Y>
istream &operator>>(istream &cin, map<X, Y> &m) {
    size_t n; cin >> n;
    for (size_t i = 0; i < n; ++i) {
        X key; Y value; cin >> key >> value;
        m[key] = value;
    } return cin;
}
// Map Output
template <typename X, typename Y>
ostream &operator<<(ostream &cout, const map<X, Y> &m) {
    for (const auto &[x, y] : m) cout << x << ' ' << y << '\n';  return cout;
}
// Set Input
template <typename X>
istream &operator>>(istream &cin, set<X> &s) {
    size_t n; cin >> n;
    for (size_t i = 0; i < n; ++i) { X value; cin >> value; s.insert(value); } return cin;
```



```
}
// Set Output
template <typename X>
ostream &operator<<(ostream &cout, const set<X> &s) {
    for (const auto &x : s) cout << x << ' '; return cout;
}
// Stack Input
template <typename X>
istream &operator>>(istream &cin, stack<X> &s) {
    size_t n; cin >> n;
    for (size_t i = 0; i < n; ++i) {
        X value; cin >> value; s.push(value);
    } return cin;
}
// Stack Output
template <typename X>
ostream &operator<<(ostream &cout, stack<X> s) {
    while (!s.empty()) { cout << s.top() << ' '; s.pop(); } return cout;
}
// Queue Input
template <typename X>
istream &operator>>(istream &cin, queue<X> &q) {
    size_t n; cin >> n;
    for (size_t i = 0; i < n; ++i) { X value; cin >> value; q.push(value); } return cin;
}
// Queue Output
template <typename X>
ostream &operator<<(ostream &cout, queue<X> q) {
    while (!q.empty()) { cout << q.front() << ' '; q.pop(); } return cout;
}
// Deque Input
template <typename X>
istream &operator>>(istream &cin, deque<X> &dq) {
    for (auto &x : dq) cin >> x; return cin;
}
// Deque Output
template <typename X>
ostream &operator<<(ostream &cout, const deque<X> &dq) {
    for (const auto &x : dq) cout << x << ' '; return cout;
}
```

**Stress Testing Code:**

```
// Bash Script for Stress Testing: (checker.sh)

/*-------------------------------------------

for((i = 1; ; ++i)); do
    echo $i
    ./gen $i > in.txt
    diff -w <(./a < in.txt) <(./b < in.txt) || break
done

-------------------------------------------*/



// Random Integer Number Generator:

#using ll = long long

mt19937_64 rng(chrono::steady_clock::now().time_since_epoch().count());

inline ll gen_random(ll l, ll r) {
    return uniform_int_distribution<ll>(l, r)(rng);
}


// Random Real Number Generator:

mt19937_64 rng(chrono::steady_clock::now().time_since_epoch().count());

inline double gen_random(double l, double r) {
    return uniform_real_distribution<double>(l, r)(rng);
}
```

```
// Priority Queue Input
template <typename X>
istream &operator>>(istream &cin, priority_queue<X> &pq) {
    size_t n; cin >> n;
    for (size_t i = 0; i < n; ++i) {
        X value; cin >> value; pq.push(value);
    } return cin;
}
// Priority Queue Output
template <typename X>
ostream &operator<<(ostream &cout, priority_queue<X> pq) {
    while (!pq.empty()) { cout << pq.top() << ' '; pq.pop(); } return cout;
}
// Debugger: Finding Bug
template <typename X>
void debug(const X &x, const string &name) { cout << name << " = " << x << '\n'; }
void Run_Time() {
    auto start = chrono::high_resolution_clock::now();
    auto end = chrono::high_resolution_clock::now();
    chrono::duration<double> elapsed = end - start;
    cout << "Code Execution Time: " << elapsed.count() << " seconds.\n";
}
int main() {
    int num = 42;
    double pi = 3.14159;
    string msg = "Hello, World!";
    vector <int> vec = {1, 2, 3, 4, 5};
    bug(num);   // Output: num = 42
    bug(pi);    // Output: pi = 3.14159
    bug(msg);   // Output: msg = Hello, World!
    bug(vec);   // Output: vec = 1 2 3 4 5
    return 0;
}
```

**Environment Setup:**

```
{
    "C_Cpp.default.cppStandard": "c++23",
    "C_Cpp.default.cStandard": "c11",
    "terminal.integrated.defaultProfile.windows": "Command Prompt",
    "code-runner.runInTerminal": false,
    "code-runner.saveAllFilesBeforeRun": true,
    "code-runner.terminalRoot": "/",
    "code-runner.executorMap": {
        "c": "cd $dir && gcc $fileName -o $fileNameWithoutExt.exe && $dir$fileNameWithoutExt.exe <input.txt> output.txt",
        "cpp": "cd $dir && g++ $fileName -o $fileNameWithoutExt.exe && $dir$fileNameWithoutExt.exe <input.txt> output.txt",
        // "cpp": "cd $dir && g++ $fileName -o $fileNameWithoutExt.exe && $dir$fileNameWithoutExt.exe",
    },
    "extensions.ignoreRecommendations": true,
    "terminal.integrated.enableMultiLinePasteWarning": false,
    "settingsSync.ignoredExtensions": [
        "formulahendry.code-runner"
    ],
    "code-runner.defaultLanguage": "cpp",
    "editor.largeFileOptimizations": false,
    "editor.fontSize": 17,
    "files.autoSave": "afterDelay",
    "editor.minimap.enabled": false,
    "workbench.iconTheme": "material-icon-theme",
    "workbench.colorTheme": "GitHub Light",
    "[cpp]": {
        "editor.defaultFormatter": "ms-vscode.cpptools"
    }
}
```