

# ICPC Notebook

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## template

### hash.sh

```
# 使い方: sh hash.sh -> コピー -> Ctrl + D
# コメント・空白・改行を削除して md5 でハッシュする
g++ -dD -E -P -fpreprocessed - | tr -d '[:space:]' | md5sum | cut -c-6
```

### settings.sh

```
# CLion の設定
Settings → Build → CMake → Reload CMake Project
add_compile_options(-D_GLIBCXX_DEBUG)
# Caps Lock を Ctrl に変更
setxkbmap -option ctrl:nocaps
```

### template.hpp

md5: 136d85

```
#include <bits/stdc++.h>
using namespace std;
using ll = long long;
const ll INF = LLONG_MAX / 4;
#define rep(i, a, b) for(ll i = a; i < (b); i++)
#define all(a) begin(a), end(a)
#define sz(a) ssize(a)
bool chmin(auto& a, auto b) { return a > b ? a = b, 1 : 0; }
bool chmax(auto& a, auto b) { return a < b ? a = b, 1 : 0; }
```

```
int main() {
    cin.tie(0)->sync_with_stdio(0);
    // your code here...
}
```

## data-structure

### BIT.hpp

md5: 8133c8

```
struct BIT {
    vector<ll> a;
    BIT(ll n) : a(n + 1) {}
    void add(ll i, ll x) { // A[i] += x
        i++;
        while(i < sz(a)) {
            a[i] += x;
            i += i & -i;
        }
    }
    ll sum(ll r) {
        ll s = 0;
        while(r) {
            s += a[r];
            r -= r & -r;
        }
        return s;
    }
    ll sum(ll l, ll r) { // sum of A[l, r)
        return sum(r) - sum(l);
    }
};
```

### FastSet.hpp

md5: 2cb8c9

```
// using u64 = uint64_t;
const u64 B = 64;
struct FastSet {
    u64 n;
    vector<vector<u64>> a;
```

```
FastSet(u64 n_) : n(n_) {
    do a.emplace_back(n_ = (n_ + B - 1) / B);
    while(n_ > 1);
}
// bool operator[])(ll i) const { return a[0][i / B] >> (i % B) & 1; }
void set(ll i) {
    for(auto& v : a) {
        v[i / B] |= 1ULL << (i % B);
        i /= B;
    }
}
void reset(ll i) {
    for(auto& v : a) {
        v[i / B] &= ~(1ULL << (i % B));
        if(v[i / B]) break;
        i /= B;
    }
}
ll next(ll i) { // i を超える最小の要素
    rep(h, 0, sz(a)) {
        i++;
        if(i / B >= sz(a[h])) break;
        u64 d = a[h][i / B] >> (i % B);
        if(d) {
            i += countr_zero(d);
            while(h--) i = i * B + countr_zero(a[h][i]);
            return i;
        }
        i /= B;
    }
    return n;
}
ll prev(ll i) { // i より小さい最大の要素
    rep(h, 0, sz(a)) {
        i--;
        if(i < 0) break;
        u64 d = a[h][i / B] << (~i % B);
        if(d) {
            i -= countl_zero(d);
            while(h--) i = i * B + __lg(a[h][i]);
            return i;
        }
        i /= B;
    }
    return -1;
}
};
```

### UnionFind.md

```
struct UnionFind {
    vector<int> parents; // parents[i] := 頂点iのroot
    vector<int> sizes; // sizes[i] := 頂点iが属するグループの要素数
    UnionFind(int n){
        parents = vector<int>(n);
        for(int i=0; i<n; i++) parents.at(i) = i;
        sizes = vector<int>(n, 1);
    }
    int find(int i){
        if(parents.at(i)==i) return i; // 自身のroot == iのとき自分がroot
        return (parents.at(i) = find(parents.at(i))); // 経路圧縮
    }
    void merge(int a, int b){
        a = find(a);
        b = find(b);
        if(a!=b){
            sizes.at(a) += sizes.at(b);
            parents.at(b) = a;
        }
    }
};
```

```
bool connected(int a, int b){
    return (find(a)==find(b));
}
long long size(int i){
    return (long long)sizes.at(find(i));
}
};
```

内容	コード	計算量
宣言	UnionFind uf(N)	$O(N)$
aの根の取得	uf.find(a)	$O(\alpha(N))$
aとbを統合	uf.merge(a, b)	$O(\alpha(N))$
aとbが同じグループか判定	uf.connected(a, b)	$O(\alpha(N))$
aと同じグループの要素数	uf.size(a)	$O(\alpha(N))$

$\alpha(N)$ はアッカーマンの逆関数

## math

### BinaryGCD.hpp

md5: f3ab31

```
u64 ctz(u64 x) { return countr_zero(x); }
u64 binary_gcd(u64 x, u64 y) {
    if(!x || !y) return x | y;
    u64 n = ctz(x), m = ctz(y);
    x >>= n, y >>= m;
    while(x != y) {
        if(x > y) x = (x - y) >> ctz(x - y);
        else y = (y - x) >> ctz(y - x);
    }
    return x << min(n, m);
}
};
```

### ExtGCD.hpp

md5: c3fa9b

```
// returns gcd(a, b) and assign x, y to integers
// s.t. ax + by = gcd(a, b) and |x| + |y| is minimized
ll extgcd(ll a, ll b, ll& x, ll& y) {
    // assert(a >= 0 && b >= 0);
    if(!b) return x = 1, y = 0, a;
    ll d = extgcd(b, a % b, y, x);
    y -= a / b * x;
    return d;
}
};
```

## modint

### BarrettReduction.hpp

md5: 2ca7f3

```
// using u64 = uint64_t;
struct Barrett { // mod < 2^32
    u64 m, im;
    Barrett(u64 mod) : m(mod), im((-1ULL / m + 1) {})
    // input: a * b < 2^64, output: a * b % mod
    u64 mul(u64 a, u64 b) const {
        a *= b;
        u64 x = ((__uint128_t)a * im) >> 64;
        a -= x * m;
        if((ll)a < 0) a += m;
        return a;
    }
};
};
```

### modint.hpp

md5: 81b530

```
const ll mod = 998244353;
struct mm {
    ll x;
    mm(ll x_ = 0) : x(x_ % mod) {
        if(x < 0) x += mod;
    }
    friend mm operator+(mm a, mm b) { return a.x + b.x; }
    friend mm operator-(mm a, mm b) { return a.x - b.x; }
    friend mm operator*(mm a, mm b) { return a.x * b.x; }
    friend mm operator/(mm a, mm b) { return a * b.inv(); }
    // 4 行コピペ Alt + Shift + クリックで複数カーソル
    friend mm& operator+=(mm& a, mm b) { return a = a.x + b.x; }
    friend mm& operator-=(mm& a, mm b) { return a = a.x - b.x; }
    friend mm& operator*=(mm& a, mm b) { return a = a.x * b.x; }
    friend mm& operator/=(mm& a, mm b) { return a = a * b.inv(); }
    mm inv() const { return pow(mod - 2); }
    mm pow(ll b) const {
        mm a = *this, c = 1;
        while(b) {
            if(b & 1) c *= a;
            a *= a;
            b >>= 1;
        }
        return c;
    }
};
};
```

## FPS

### FFT.hpp

md5: 3138c7

```
// {998244353, 3}, {1811939329, 13}, {2013265921, 31}
mm g = 3; // 原始根
void fft(vector<mm>& a) {
    ll n = sz(a), lg = __lg(n);
    assert((1 << lg) == n);
    vector<mm> b(n);
    rep(l, 1, lg + 1) {
        ll w = n >> l;
        mm s = 1, r = g.pow(mod >> l);
        for(ll u = 0; u < n / 2; u += w) {
            rep(d, 0, w) {
                mm x = a[u << 1 | d], y = a[u << 1 | w | d] * s;
                b[u | d] = x + y;
                b[n >> 1 | u | d] = x - y;
            }
            s *= r;
        }
        swap(a, b);
    }
}
vector<mm> conv(vector<mm> a, vector<mm> b) {
    if(a.empty() || b.empty()) return {};;
    size_t s = sz(a) + sz(b) - 1, n = bit_ceil(s);
    // if(min(sz(a), sz(b)) <= 60) 愚直に掛け算
    a.resize(n);
    b.resize(n);
    fft(a);
    fft(b);
    mm inv = mm(n).inv();
    rep(i, 0, n) a[i] *= b[i] * inv;
    reverse(1 + all(a));
    fft(a);
    a.resize(s);
    return a;
}
};
```

### FFT\_fast.hpp

md5: c8c567

```
// modint を u32 にして加減算を真面目にやると速い
mm g = 3; // 原始根
void fft(vector<mm>& a) {
    ll n = sz(a), lg = __lg(n);
    static auto z = [] {
        vector<mm> z(30);
        mm s = 1;
        rep(i, 2, 32) {
            z[i - 2] = s * g.pow(mod >> i);
            s *= g.inv().pow(mod >> i);
        }
        return z;
    }();
    rep(l, 0, lg) {
        ll w = 1 << (lg - l - 1);
        mm s = 1;
        rep(k, 0, 1 << l) {
            ll o = k << (lg - l);
            rep(i, o, o + w) {
                mm x = a[i], y = a[i + w] * s;
                a[i] = x + y;
                a[i + w] = x - y;
            }
            s *= z[countr_zero<uint64_t>(~k)];
        }
    }
}
// コピペ
void ifft(vector<mm>& a) {
    ll n = sz(a), lg = __lg(n);
    static auto z = [] {
        vector<mm> z(30);
        mm s = 1;
        rep(i, 2, 32) { // g を逆数に
            z[i - 2] = s * g.inv().pow(mod >> i);
            s *= g.pow(mod >> i);
        }
        return z;
    }();
    for(ll l = lg; l--;) { // 逆順に
        ll w = 1 << (lg - l - 1);
        mm s = 1;
        rep(k, 0, 1 << l) {
            ll o = k << (lg - l);
            rep(i, o, o + w) {
                mm x = a[i], y = a[i + w]; // *s を下に移動
                a[i] = x + y;
                a[i + w] = (x - y) * s;
            }
            s *= z[countr_zero<uint64_t>(~k)];
        }
    }
}
vector<mm> conv(vector<mm> a, vector<mm> b) {
    if(a.empty() || b.empty()) return {};;
    size_t s = sz(a) + sz(b) - 1, n = bit_ceil(s);
    // if(min(sz(a), sz(b)) <= 60) 愚直に掛け算
    a.resize(n);
    b.resize(n);
    fft(a);
    fft(b);
    mm inv = mm(n).inv();
    rep(i, 0, n) a[i] *= b[i] * inv;
    ifft(a);
    a.resize(s);
    return a;
}
};
```

## graph

## graph/tree

## flow

## 燃やす埋める.md

変形前の制約	変形後の制約
$x$ が 0 のとき $z$ 失う	$(x,T,z)$
$x$ が 0 のとき $z$ 得る	無条件で $z$ 得る; $(S,x,z)$
$x$ が 1 のとき $z$ 失う	$(S,x,z)$
$x$ が 1 のとき $z$ 得る	無条件で $z$ 得る; $(x,T,z)$
$x,y,\dots$ がすべて 0 のとき $z$ 得る	無条件で $z$ 得る; $(S,w,z),(w,x,\infty),(w,y,\infty)$
$x,y,\dots$ がすべて 1 のとき $z$ 得る	無条件で $z$ 得る; $(w,T,z),(x,w,\infty),(y,w,\infty)$

## string

KMP.hpp	md5: 886c63
<pre>// kmp[i] := max{ l ≤ i   s[:l] == s[(i+1)-l:i+1] } // abacaba -&gt; 0010123 auto KMP(string s) {     vector&lt;ll&gt; p(sz(s));     rep(i, 1, sz(s)) {         ll g = p[i - 1];         while(g &amp;&amp; s[i] != s[g]) g = p[g - 1];         p[i] = g + (s[i] == s[g]);     }     return p; }</pre>	

## Manacher.md

<pre>vector&lt;long long&gt; manacher(const string &amp;s){     int i = 0, j = 0;     vector&lt;long long&gt; r(s.size(), 0);     while(i&lt;s.size()){         while(i-j&gt;=0 &amp;&amp; i+j&lt;s.size() &amp;&amp; s[i-j]==s[i+j]) j++;         r[i] = j;         int k = 1;         while(i-k&gt;=0 &amp;&amp; k+r[i-k]&lt;j) r[i+k] = r[i-k], k++;         i += k; j -= k;     }     return r; }</pre>		
---	--	--

内容	コード	計算量
i文字目を中心とする最長の回文半径を記録した配列の取得	r = manacher(S)	$O( S )$

偶数長の回文を判定する場合はダミーを交互に挿入する。(例: abba → #a#b#b#a#)

## RollingHash.md

<pre>struct RollingHash{      using ll = long long;      const ll mod = (1ll&lt;&lt;61)-1;     ll n, rnd;     vector&lt;ll&gt; hs, pw;     RollingHash(string s): n(s.size()), hs(n+1), pw(n+1, 1) {         // rnd = rand()%mod;         rnd = 93842743347298748;         for(int i=0; i&lt;n; i++){             pw[i+1] = mul(pw[i], rnd);             hs[i+1] = add(mul(hs[i], rnd), s[i]);         }     };     ll add(ll a, ll b){         return (a+b)%mod;     }     ll mul(ll a, ll b){         auto c = (__uint128_t)a*b;         return add(c&gt;&gt;61, c&amp;mod);     }     ll get(ll l, ll r){         return add(hs[r], mod - mul(hs[l], pw[r-l]));     } };</pre>		
---	--	--

内容	コード	計算量
宣言	RollingHash rh(s)	$O(s.size())$
$[l,r)$ のハッシュ値の取得	rh.get(l, r)	$O(1)$

## SuffixArray.hpp

<pre>// returns pair{sa, lcp} // sa 長さ n<span> </span>: s[sa[0]:] &lt; s[sa[1]:] &lt; ... &lt; s[sa[n-1]:] // lcp 長さ n-1<span> </span>: lcp[i] = LCP(s[sa[i]:], s[sa[i+1]:]) auto SA(string s) {     ll n = sz(s) + 1, lim = 256;     // assert(lim &gt; ranges::max(s));     vector&lt;ll&gt; sa(n), lcp(n), x(all(s) + 1), y(n), ws(max(n, lim)), rk(n);     iota(all(sa), 0);     for(ll j = 0, p = 0; p &lt; n; j = max(1LL, j * 2), lim = p) {         p = j;         iota(all(y), n - j);         rep(i, 0, n) if(sa[i] &gt;= j) y[p++] = sa[i] - j;         fill(all(ws), 0);         rep(i, 0, n) ws[x[i]]++;         rep(i, 1, lim) ws[i] += ws[i - 1];         for(ll i = n; i--;) sa[--ws[x[y[i]]]] = y[i];         swap(x, y);         p = 1;         x[sa[0]] = 0;         rep(i, 1, n) {             ll a = sa[i - 1], b = sa[i];             x[b] = (y[a] == y[b] &amp;&amp; y[a + j] == y[b + j]) ? p - 1<span> </span>: p++;         }     }</pre>		
---	--	--

<pre>} rep(i, 1, n) rk[sa[i]] = i; for(ll i = 0, k = 0; i &lt; n - 1; lcp[rk[i++]] = k) {     if(k) k--;     while(s[i + k] == s[sa[rk[i] - 1] + k]) k++; } sa.erase(begin(sa)); lcp.erase(begin(lcp)); return pair{sa, lcp}; }</pre>		
---	--	--

## Zalgorithm.hpp

<pre>// Z[i] := LCP(s, s[i:]) // abacaba -&gt; 7010301 auto Z(string s) {     ll n = sz(s), l = -1, r = -1;     vector&lt;ll&gt; z(n, n);     rep(i, 1, n) {         ll&amp; x = z[i] = i &lt; r ? min(r - i, z[i - l])<span> </span>: 0;         while(i + x &lt; n &amp;&amp; s[i + x] == s[x]) x++;         if(i + x &gt; r) l = i, r = i + x;     }     return z; }</pre>		
---	--	--

## algorithm

## geometry

## memo

## Primes.md

素数の個数									
$n$	10 <sup>2</sup>	10 <sup>3</sup>	10 <sup>4</sup>	10 <sup>5</sup>	10 <sup>6</sup>	10 <sup>7</sup>	10 <sup>8</sup>	10 <sup>9</sup>	10 <sup>10</sup>
$\pi(n)$	25	168	1229	9592	78498	664579	5.76e+6	5.08e+7	4.55e+8

高度合成数

$\leq n$	$10^3$	$10^4$	$10^5$	$10^6$	$10^7$	$10^8$	$10^9$
$x$	840	7560	83160	720720	8648640	73513440	735134400
$d^0(x)$	32	64	128	240	448	768	1344

$\leq n$	$10^{10}$	$10^{11}$	$10^{12}$	$10^{13}$	$10^{14}$	$10^{15}$	$10^{16}$	$10^{17}$	$10^{18}$
$d^0(x)$	2304	4032	6720	10752	17280	26880	41472	64512	103680

素数階乗										
$n$	2	3	5	7	11	13	17	19	23	29
$n\#$	2	6	30	210	2310	30030	510510	9.70e+6	2.23e+8	6.47e+9

階乗									
4!	5!	6!	7!	8!	9!	10!	11!	12!	13!
24	120	720	5040	40320	362880	3.63e+6	3.99e+7	4.79e+8	6.23e+9