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1 Setup & Scripts

1.1 CMake

```

1 cmake_minimum_required(VERSION 3.14)
2 project(olymp)
3
4 set(CMAKE_CXX_STANDARD 17)
5 add_compile_definitions(LOCAL)
6 #set(CMAKE_CXX_FLAGS "${CMAKE_CXX_FLAGS} -fsanitize=undefined -fno-
    ↪ sanitize-recover")
7 #sanitizers: address, leak, thread, undefined, memory
8
9 add_executable(olymp f.cpp)

```

1.2 wipe.sh

```

1 touch {a..l}.cpp
2
3 for file in ?.cpp ; do
4     cat template.cpp > $file ;
5 done

```

2 G++ builtins

- `__builtin_popcount(x)` — количество единичных бит в двоичном представлении 32-битного (знакового или беззнакового) целого числа.
- `__builtin_popcountll(x)` — то же самое для 64-битных типов.
- `__builtin_ctz(x)` — количество нулей на конце двоичного представления 32-битного целого числа. Например, для 5 вернётся 0, для $272 = 256 + 16$ — 4 и т. д. Может не работать для нуля (вообще не стоит вызывать для $x = 0$, по-моему это и упасть может).
- `__builtin_ctzll(x)` — то же самое для 64-битных типов.
- `__builtin_clz(x)` — количество нулей в начале двоичного представления 32-битного целого числа. Например, для 2^{31} или -2^{31} вернётся 0, для 1 — 31 и т. д. Тоже не надо вызывать с $x = 0$.
- `__builtin_clzll(x)` — то же самое для 64-битных типов.
- `bitset<N>._Find_first()` — номер первой позиции с единицей в битсете или его размер (то есть N), если на всех позициях нули.
- `bitset<N>._Find_next(x)` — номер первой позиции с единицей среди позиций с номерами строго больше x ; если такой нет, то N .

3 Bugs

- `powmod` :)
- Всегда чекать Куна дважды, особенно на количество итераций
- `uniform_int_distribution` от одного параметра
- `for (char c : "NEWS")`
- Порядок верхних и нижних границ в случае, когда задача двумерна $t - b \neq b - t$
- `static` с мультитестами
- `set` со своим компаратором склеивает элементы

4 Geometry

4.1 Пересечение прямых

$$AB = A - B; CD = C - D$$

$$(A \times B \cdot CD.x - C \times D \cdot AB.x : A \times B \cdot CD.y - C \times D \cdot AB.y : AB \times CD)$$

5 Numbers

- A lot of divisors

- $\leq 20 : d(12) = 6$
- $\leq 50 : d(48) = 10$
- $\leq 100 : d(60) = 12$
- $\leq 1000 : d(840) = 32$
- $\leq 10^4 : d(9240) = 64$
- $\leq 10^5 : d(83160) = 128$
- $\leq 10^6 : d(720720) = 240$
- $\leq 10^7 : d(8648640) = 448$
- $\leq 10^8 : d(91891800) = 768$
- $\leq 10^9 : d(931170240) = 1344$
- $\leq 10^{11} : d(97772875200) = 4032$
- $\leq 10^{12} : d(963761198400) = 6720$
- $\leq 10^{15} : d(866421317361600) = 26880$
- $\leq 10^{18} : d(897612484786617600) = 103680$

- Numeric integration

- simple: $F(0)$
- simpson: $\frac{F(-1)+4\cdot F(0)+F(1)}{6}$
- runge2: $\frac{F(-\sqrt{\frac{1}{3}})+F(\sqrt{\frac{1}{3}})}{2}$
- runge3: $\frac{F(-\sqrt{\frac{2}{5}})\cdot 5+F(0)\cdot 8+F(\sqrt{\frac{2}{5}})\cdot 5}{18}$

6 Graphs

6.1 Weighted matroid intersection

```

1 // here we use T = __int128 to store the independent set
2 // calling expand k times to an empty set finds the maximum
3 // cost of the set with size exactly k,
4 // that is independent in blue and red matroids
5 // ver is the number of the elements in the matroid,
6 // e[i].w is the cost of the i-th element
7 // first return value is new independent set
8 // second return value is difference between
9 // new and old costs
10 // oracle(set, red) and oracle(set, blue) check whether
11 // or not the set lies in red or blue matroid respectively
12
13 auto expand = [&] (T cur_set) → pair<T, int>
14 {
```

```
15     vector<int> in(ver);
16     for (int i = 0; i < ver; i++)
17         in[i] = ((cur_set >> i) & 1);
18
19     const int red = 1;
20     const int blue = 2;
21
22     vector<vector<int>> g(ver);
23     for (int i = 0; i < ver; i++)
24     for (int j = 0; j < ver; j++)
25     {
26         T swp_mask = (cur_set ^ (T(1) << i) ^ (T(1) << j));
27         if (!in[i] && in[j])
28         {
29             if (oracle(swp_mask, red))
30                 g[i].push_back(j);
31             if (oracle(swp_mask, blue))
32                 g[j].push_back(i);
33         }
34     }
35
36     vector<int> from, to;
37     for (int i = 0; i < ver; i++) if (!in[i])
38     {
39         T add_mask = cur_set ^ (T(1) << i);
40         if (oracle(add_mask, blue))
41             from.push_back(i);
42         if (oracle(add_mask, red))
43             to.push_back(i);
44     }
45
46     auto get_cost = [&] (int x)
47     {
48         const int cost = (!in[x] ? e[x].w : -e[x].w);
49         return (ver + 1) * cost - 1;
50     };
51
52     const int inf = int(1e9);
53     vector<int> dist(ver, -inf), prev(ver, -1);
54     for (int x : from)
55         dist[x] = get_cost(x);
56
57     queue<int> q;
58
59     vector<int> used(ver);
60     for (int x : from)
61     {
62         q.push(x);
63         used[x] = 1;
64     }
```

```

65
66     while (!q.empty())
67     {
68         int cur = q.front(); used[cur] = 0; q.pop();
69
70         for (int to : g[cur])
71         {
72             int cost = get_cost(to);
73             if (dist[to] < dist[cur] + cost)
74             {
75                 dist[to] = dist[cur] + cost;
76                 prev[to] = cur;
77                 if (!used[to])
78                 {
79                     used[to] = 1;
80                     q.push(to);
81                 }
82             }
83         }
84     }
85
86     int best = -inf, where = -1;
87     for (int x : to)
88     {
89         if (dist[x] > best)
90         {
91             best = dist[x];
92             where = x;
93         }
94     }
95
96     if (best == -inf)
97         return pair<T, int>(cur_set, best);
98
99     while (where != -1)
100    {
101        cur_set ^= (T(1) << where);
102        where = prev[where];
103    }
104
105    while (best % (ver + 1))
106        best++;
107    best /= (ver + 1);
108
109    assert(oracle(cur_set, red) && oracle(cur_set, blue));
110    return pair<T, int>(cur_set, best);
111 };

```

7 Push-free segment tree

```

1 class pushfreesegetree
2 {
3     vector<modulo◇> pushed, unpushed;
4
5     modulo◇ add(int l, int r, int cl, int cr, int v, const modulo
        ↪ ◇ &x)
6     {
7         if (r ≤ cl || cr ≤ l)
8             return 0;
9         if (l ≤ cl && cr ≤ r)
10        {
11            unpushed[v] += x;
12
13            return x * (cr - cl);
14        }
15
16        int ct = (cl + cr) / 2;
17
18        auto tmp = add(l, r, cl, ct, 2 * v, x) + add(l, r, ct, cr,
            ↪ 2 * v + 1, x);
19
20        pushed[v] += tmp;
21
22        return tmp;
23    }
24
25
26    modulo◇ sum(int l, int r, int cl, int cr, int v)
27    {
28        if (r ≤ cl || cr ≤ l)
29            return 0;
30        if (l ≤ cl && cr ≤ r)
31            return pushed[v] + unpushed[v] * (cr - cl);
32
33        int ct = (cl + cr) / 2;
34
35        return sum(l, r, cl, ct, 2 * v) + unpushed[v] * (min(r, cr)
            ↪ - max(l, cl)) + sum(l, r, ct, cr, 2 * v + 1);
36    }
37
38 public:
39     pushfreesegetree(int n) : pushed(2 * up(n)), unpushed(2 * up(n))
40     {}
41
42
43     modulo◇ sum(int l, int r)
44     {
45         return sum(l, r, 0, pushed.size() / 2, 1);
46     }
47

```

```

48
49     void add(int l, int r, const modulo &x)
50     {
51         add(l, r, 0, pushed.size() / 2, 1, x);
52     }
53 };

```

8 Number theory

8.1 Chinese remainder theorem without overflows

```

1  // Replace T with an appropriate type!
2  using T = long long;
3
4  // Finds x, y such that ax + by = gcd(a, b).
5  T gcdext (T a, T b, T &x, T &y)
6  {
7      if (b == 0)
8      {
9          x = 1, y = 0;
10         return a;
11     }
12
13     T res = gcdext (b, a % b, y, x);
14     y -= x * (a / b);
15     return res;
16 }
17
18 // Returns true if system x = r1 (mod m1), x = r2 (mod m2) has
19 // ↪ solutions
20 // ↪ false otherwise. In first case we know exactly that x = r (mod m
21 // ↪ )
22
23 bool crt (T r1, T m1, T r2, T m2, T &r, T &m)
24 {
25     if (m2 > m1)
26     {
27         swap(r1, r2);
28         swap(m1, m2);
29     }
30
31     T g = __gcd(m1, m2);
32     if ((r2 - r1) % g != 0)
33         return false;
34
35     T c1, c2;
36     auto nrem = gcdext(m1 / g, m2 / g, c1, c2);
37     assert(nrem == 1);
38     assert(c1 * (m1 / g) + c2 * (m2 / g) == 1);
39     T a = c1;

```

```

38     a *= (r2 - r1) / g;
39     a %= (m2 / g);
40     m = m1 / g * m2;
41     r = a * m1 + r1;
42     r = r % m;
43     if (r < 0)
44         r += m;
45
46     assert(r % m1 == r1 && r % m2 == r2);
47     return true;
48 }

```

8.2 Integer points under a rational line

```

1 // integer (x, y) : 0 ≤ x < n, 0 < y ≤ (kx + b) / d
2 // (real division)
3 // In other words, sum_{x=0}^{n-1} [(kx+b)/d]
4 ll trapezoid (ll n, ll k, ll b, ll d)
5 {
6     if (k == 0)
7         return (b / d) * n;
8     if (k ≥ d || b ≥ d)
9         return (k / d) * n * (n - 1) / 2 + (b / d) * n + trapezoid(
10         ↪ n, k % d, b % d, d);
11     return trapezoid((k * n + b) / d, d, (k * n + b) % d, k);
12 }

```

9 Suffix Automaton

```

1 struct Vx{
2     static const int AL = 26;
3     int len, suf;
4     int next[AL];
5     Vx(){}
6     Vx(int l, int s):len(l), suf(s){}
7 };
8
9 struct SA{
10     static const int MAX_LEN = 1e5 + 100, MAX_V = 2 * MAX_LEN;
11     int last, vcnt;
12     Vx v[MAX_V];
13
14     SA(){
15         vcnt = 1;
16         last = newV(0, 0); // root = vertex with number 1
17     }
18     int newV(int len, int suf){
19         v[vcnt] = Vx(len, suf);
20         return vcnt++;
21     }
22 }

```



```

23  int add(char ch){
24      int p = last, c = ch - 'a';
25      last = newV(v[last].len + 1, 0);
26      while(p && !v[p].next[c]) //added p &&
27          v[p].next[c] = last, p = v[p].suf;
28      if(!p)
29          v[last].suf = 1;
30      else{
31          int q = v[p].next[c];
32          if (v[q].len == v[p].len + 1)
33              v[last].suf = q;
34          else{
35              int r = newV(v[p].len + 1, v[q].suf);
36              v[last].suf = v[q].suf = r;
37              memcpy(v[r].next, v[q].next, sizeof(v[r].next));
38              while(p && v[p].next[c] == q)
39                  v[p].next[c] = r, p = v[p].suf;
40          }
41      }
42      return last;
43  }
44  };

```

10 Smth added at last moment

10.1 Dominator Tree

```

1  struct dom_tree {
2      vvi g, rg, tree, bucket;
3      vi sdom, par, dom, dsu, label, in, order, tin, tout;
4      int T = 0, root = 0, n = 0;
5
6      void dfs_tm (int x) {
7          in[x] = T;
8          order[T] = x;
9          label[T] = T, sdom[T] = T, dsu[T] = T, dom[T] = T;
10         T++;
11         for (int to : g[x]) {
12             if (in[to] == -1) {
13                 dfs_tm(to);
14                 par[in[to]] = in[x];
15             }
16             rg[in[to]].pb(in[x]);
17         }
18     }
19
20     void dfs_tree (int v, int p) {
21         tin[v] = T++;
22         for (int dest : tree[v]) {
23             if (dest != p) {

```

```
24     dfs_tree(dest, v);
25     }
26 }
27 tout[v] = T;
28 }
29
30 dom_tree (const vvi &g_, int root_) {
31     g = g_;
32     n = sz(g);
33     assert(0 ≤ root && root < n);
34     in.assign(n, -1);
35     rg.resize(n);
36     order = sdom = par = dom = dsu = label = vi(n);
37     root = root_;
38     bucket.resize(n);
39     tree.resize(n);
40
41     dfs_tm(root);
42
43     for (int i = n - 1; i ≥ 0; i--) {
44         for (int j : rg[i])
45             sdom[i] = min(sdom[i], sdom[find(j)]);
46         if (i > 0)
47             bucket[sdom[i]].pb(i);
48
49         for (int w : bucket[i]) {
50             int v = find(w);
51             dom[w] = (sdom[v] == sdom[w] ? sdom[w] : v);
52         }
53
54         if (i > 0)
55             unite(par[i], i);
56     }
57
58     for (int i = 1; i < n; i++) {
59         if (dom[i] ≠ sdom[i])
60             dom[i] = dom[dom[i]];
61         tree[order[i]].pb(order[dom[i]]);
62         tree[order[dom[i]]].pb(order[i]);
63     }
64
65     T = 0;
66     tin = tout = vi(n);
67     dfs_tree(root, -1);
68 }
69
70 void unite (int u, int v) {
71     dsu[v] = u;
72 }
73
```

```

74  int find (int u, int x = 0) {
75      if (u == dsu[u])
76          return (x ? -1 : u);
77      int v = find(dsu[u], x + 1);
78      if (v == -1)
79          return u;
80      if (sdom[label[dsu[u]]] < sdom[label[u]])
81          label[u] = label[dsu[u]];
82      dsu[u] = v;
83      return (x ? v : label[u]);
84  }
85
86  bool dominated_by (int v, int by_what) {
87      return tin[by_what] ≤ tin[v] && tout[v] ≤ tout[by_what];
88  }
89  };

```

10.2 Suffix Array

```

1  namespace suff_arr {
2
3  const int MAXN = 2e5 + 10;
4
5  string s;
6  int n;
7  int p[MAXN];
8  int lcp[MAXN];
9  int pos[MAXN];
10 int c[MAXN];
11
12 void print() {
13     #ifndef LOCAL
14         return;
15     #endif
16     eprintf("p:\n");
17     for(i, sz(s)) {
18         eprintf("i=%d -- %d: %s, lcp=%d, c=%d\n", i, p[i], s.substr
           ↪ (p[i], sz(s) - p[i]).data(), lcp[i], c[p[i]]);
19     }
20     eprintf("\n");
21 }
22
23 void build(const string& s_) {
24     static int cnt[MAXN];
25     static int np[MAXN];
26     static int nc[MAXN];
27
28     s = s_;
29     n = sz(s);
30
31     memset (cnt, 0, sizeof cnt);

```

```
32     for (char ch : s) {
33         ++cnt[int(ch)];
34     }
35     forn(i, 256) {
36         cnt[i + 1] += cnt[i];
37     }
38     forn(i, sz(s)) {
39         p[--cnt[int(s[i])]] = i;
40     }
41
42     int cls = 1;
43     c[p[0]] = cls - 1;
44     for (int i = 1; i < n; ++i) {
45         if (s[p[i]] ≠ s[p[i - 1]]) {
46             ++cls;
47         }
48         c[p[i]] = cls - 1;
49     }
50
51     for (int len = 1; len ≤ n; len *= 2) {
52         memset(cnt, 0, sizeof(int) * cls);
53         forn(i, n) {
54             ++cnt[c[i]];
55         }
56         forn(i, cls - 1) {
57             cnt[i + 1] += cnt[i];
58         }
59         ford(i, n) {
60             const int j = p[i];
61             int j2 = (j - len + n) % n;
62             np[--cnt[c[j2]]] = j2;
63         }
64         memcpy(p, np, sizeof(int) * n);
65
66         cls = 1;
67         nc[p[0]] = cls - 1;
68         for (int i = 1; i < n; ++i) {
69             if (c[p[i]] ≠ c[p[i - 1]] || c[(p[i] + len) % n] ≠ c
70                 ↪ [(p[i - 1] + len) % n]) {
71                 ++cls;
72             }
73             nc[p[i]] = cls - 1;
74         }
75         memcpy(c, nc, sizeof(int) * n);
76
77         forn(i, n) {
78             pos[p[i]] = i;
79         }
80     }
```

```

81     int pref = 0;
82     for(i, n) {
83         int pi = pos[i];
84         if (pi == n - 1) {
85             continue;
86         }
87         int j = p[pi + 1];
88         while (i + pref < n && j + pref < n && s[i + pref] == s[j +
            ↪ pref]) {
89             ++pref;
90         }
91         lcp[pi] = pref;
92         pref = max(0, pref - 1);
93     }
94
95     //     print();
96 }
97
98 };

```

10.3 Fast LCS

```

1 // assumes that strings consist of lowercase latin letters
2 const int M = ((int)1e5 + 64) / 32 * 32;
3 // maximum value of m
4 using bs = bitset<M>;
5 using uint = unsigned int;
6 const ll bnd = (1LL << 32);
7
8 // WARNING: invokes undefined behaviour of modifying ans through
    ↪ pointer to another data type (uint)
9 // seems to work, but be wary
10 bs sum (const bs &bl, const bs &br)
11 {
12     const int steps = M / 32;
13     const uint* l = (uint*)&bl;
14     const uint* r = (uint*)&br;
15
16     bs ans;
17     uint* res = (uint*)&ans;
18
19     int carry = 0;
20     for (i, steps)
21     {
22         ll cur = ll(*l++) + ll(*r++) + carry;
23         carry = (cur ≥ bnd);
24         cur = (cur ≥ bnd ? cur - bnd : cur);
25         *res++ = uint(cur);
26     }
27
28     return ans;

```

```

29 }
30
31 int fast_lcs (const string &s, const string &t)
32 {
33     const int m = sz(t);
34     const int let = 26;
35
36     vector<bs> has(let);
37     vector<bs> rev = has;
38
39     forn (i, m)
40     {
41         const int pos = t[i] - 'a';
42         has[pos].set(i);
43         forn (j, let) if (j  $\neq$  pos)
44             rev[j].set(i);
45     }
46
47     bs row;
48     forn (i, m)
49         row.set(i);
50
51     int cnt = 0;
52     for (char ch : s)
53     {
54         const int pos = ch - 'a';
55
56         bs next = sum(row, row & has[pos]) | (row & rev[pos]);
57         cnt += next[m];
58         next[m] = 0;
59
60         row = next;
61     }
62
63     return cnt;
64 }

```

10.4 Fast Subset Convolution

```

1 // algorithm itself starts here
2 void mobius (int* a, int n, int sign)
3 {
4     forn (i, n)
5     {
6         int free = ((1 << n) - 1) ^ (1 << i);
7         for (int mask = free; mask > 0; mask = ((mask - 1) & free))
8             (sign == +1 ? add : sub)(a[mask ^ (1 << i)], a[mask]);
9         add(a[1 << i], a[0]);
10    }
11 }
12

```

```

13 // maximum number of bits allowed
14 const int B = 20;
15
16 vi fast_conv (vi a, vi b)
17 {
18     assert(!a.empty());
19     const int bits = __builtin_ctz(sz(a));
20     assert(sz(a) == (1 << bits) && sz(a) == sz(b));
21
22     static int trans_a[B + 1][1 << B];
23     static int trans_b[B + 1][1 << B];
24     static int trans_res[B + 1][1 << B];
25
26     for (cnt, bits + 1)
27     {
28         for (auto cur : {trans_a, trans_b, trans_res})
29             fill(cur[cnt], cur[cnt] + (1 << bits), 0);
30     }
31
32     for (mask, 1 << bits)
33     {
34         const int cnt = __builtin_popcount(mask);
35         trans_a[cnt][mask] = a[mask];
36         trans_b[cnt][mask] = b[mask];
37     }
38
39     for (cnt, bits + 1)
40     {
41         mobius(trans_a[cnt], bits, +1);
42         mobius(trans_b[cnt], bits, +1);
43     }
44
45     // Not really a valid ranked mobius transform! But algorithm
46     ↪ works anyway
47
48     for (i, bits + 1) for (j, bits - i + 1) for (mask, 1 << bits
49     ↪ )
50         add(trans_res[i + j][mask], mult(trans_a[i][mask], trans_b[
51     ↪ j][mask]));
52
53     for (cnt, bits + 1)
54         mobius(trans_res[cnt], bits, -1);
55
56     for (mask, 1 << bits)
57     {
58         const int cnt = __builtin_popcount(mask);
59         a[mask] = trans_res[cnt][mask];
60     }
61
62     return a;

```

60 }

11 Karatsuba

```

1 // functon Karatsuba (and stupid as well) computes  $c += a * b$ , not
  ↪  $c = a * b$ 
2
3 using hvect = vector<modulo◇>::iterator;
4 using hcvect = vector<modulo◇>::const_iterator;
5
6
7 void add(hcvect abegin, hcvect aend, hvect ans)
8 {
9     for (auto it = abegin; it ≠ aend; ++it, ++ans)
10         *ans += *it;
11 }
12
13
14 void sub(hcvect abegin, hcvect aend, hvect ans)
15 {
16     for (auto it = abegin; it ≠ aend; ++it, ++ans)
17         *ans -= *it;
18 }
19
20
21 void stupid(int siz, hcvect abegin, hcvect bbegin, hvect ans)
22 {
23     for (auto a = abegin; a ≠ abegin + siz; ++a, ans -= (siz - 1))
24         for (auto b = bbegin; b ≠ bbegin + siz; ++b, ++ans)
25             *ans += *a * *b;
26 }
27
28
29 void Karatsuba(size_t siz, hcvect abegin, hcvect bbegin, hvect ans,
  ↪ hvect small, hvect big, hvect sum)
30 {
31     assert((siz & (siz - 1)) = 0);
32
33     if (siz ≤ 32)
34     {
35         stupid(siz, abegin, bbegin, ans);
36
37         return;
38     }
39
40     auto amid = abegin + siz / 2, aend = abegin + siz;
41     auto bmid = bbegin + siz / 2, bend = bbegin + siz;
42     auto smid = sum + siz / 2, send = sum + siz;
43
44     fill(small, small + siz, 0);

```



```
45     Karatsuba(siz / 2, abegin, bbegin, small, small + siz, big +
        ↪ siz, sum);
46     fill(big, big + siz, 0);
47     Karatsuba(siz / 2, amid, bmid, big, small + siz, big + siz, sum
        ↪ );
48
49     copy(abegin, amid, sum);
50     add(amid, aend, sum);
51     copy(bbegin, bmid, sum + siz / 2);
52     add(bmid, bend, sum + siz / 2);
53
54     Karatsuba(siz / 2, sum, smid, ans + siz / 2, small + siz, big +
        ↪ siz, send);
55
56     add(small, small + siz, ans);
57     sub(small, small + siz, ans + siz / 2);
58     add(big, big + siz, ans + siz);
59     sub(big, big + siz, ans + siz / 2);
60 }
61
62
63 void mult(vector<modulo◇> a, vector<modulo◇> b, vector<modulo◇>
        ↪ &c)
64 {
65     a.resize(up(max(a.size(), b.size())), 0);
66     b.resize(a.size(), 0);
67
68     c.assign(a.size() * 2, 0);
69
70     auto small = c;
71     auto big = c;
72     auto sum = c;
73
74     Karatsuba(a.size(), a.begin(), b.begin(), c.begin(), small.
        ↪ begin(), big.begin(), sum.begin());
75 }
```















