Team Notebook

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Contents

1 Data Structure

1.1 Binary Trie

```
//Binary Trie
//without deletion, comment all val change and trie.check
     condition
//Don't forget to check maxval
struct node{
    node *kiri = NULL;
    node *kanan = NULL;
    int val = 0; //Can be deleted
};

struct btrie{
    node *head = new node;
    node *cur = head;
    void insert(int x){
        for(int i = 30; i >= 0; i--){
            if((x&(1<<i)) == 0){
                if(head->kanan == NULL)head->kanan = new node;
                head = head->kanan;
            } else{
                if(head->kiri == NULL)head->kiri = new node;
                head = head->kiri;
            }
            head->val += 1; // Can be deleted
        }
        head = cur;
    }
    void del(int x){
        for(int i = 30; i >= 0; i--){
            if((x&(1<<i)) == 0){
                head = head->kanan;
            } else{
                head = head->kiri;
            }
            head->val -= 1; //Can be deleted
        }
        head = cur;
    }
    int max(int x){
        int res = 0;
        for(int i = 30; i >= 0; i--){
            if((x&(1<<i)) == 0){
                if(check(head->kiri)){
                    res += (1<<i);
                    head = head->kiri;
                } else if(check(head->kanan)){
                    head = head->kanan;
                }//Break can be placed here

            } else {
                if(check(head->kanan)){
                    head = head->kanan;
                } else if(check(head->kiri)){
                    head = head->kiri;
                    res += (1<<i);
                }//Break can be placed here
            }
        }
        head = cur;
        return (res^x);
    }
private:
    bool check(node *x){
        if(x != NULL and x->val > 0)return true; //Condition
             may be changed
        else return false;
    }
};
```

1.2 LazyPropagation

```
// Program to show segment tree to demonstrate lazy
// propagation
#include <stdio.h>
#include <math.h>
#define MAX 1000

// Ideally, we should not use global variables and large
// constant-sized arrays, we have done it here for
     simplicity.
int tree[MAX] = {0}; // To store segment tree
int lazy[MAX] = {0}; // To store pending updates

/*  si -> index of current node in segment tree
    ss and se -> Starting and ending indexes of elements for
                 which current nodes stores sum.
    us and ue -> starting and ending indexes of update query
    diff -> which we need to add in the range us to ue */
void updateRangeUtil(int si, int ss, int se, int us,
                     int ue, int diff)
{
    // If lazy value is non-zero for current node of segment
    // tree, then there are some pending updates. So we need
    // to make sure that the pending updates are done before
    // making new updates. Because this value may be used by
    // parent after recursive calls (See last line of this
    // function)
    if (lazy[si] != 0)
    {
        // Make pending updates using value stored in lazy
        // nodes
        tree[si] += (se-ss+1)*lazy[si];

        // checking if it is not leaf node because if
        // it is leaf node then we cannot go further
        if (ss != se)
        {
            // We can postpone updating children we don't
            // need their new values now.
            // Since we are not yet updating children of si,
            // we need to set lazy flags for the children
            lazy[si*2 + 1]  += lazy[si];
            lazy[si*2 + 2]  += lazy[si];
        }

        // Set the lazy value for current node as 0 as it
        // has been updated
        lazy[si] = 0;
    }

    // out of range
    if (ss>se || ss>ue || se<us)
        return ;

    // Current segment is fully in range
    if (ss>=us && se<=ue)
    {
        // Add the difference to current node
        tree[si] += (se-ss+1)*diff;

        // same logic for checking leaf node or not
        if (ss != se)
        {
            // This is where we store values in lazy nodes,
            // rather than updating the segment tree itelf
            // Since we don't need these updated values now
            // we postpone updates by storing values in lazy
                 []
            lazy[si*2 + 1]  += diff;
            lazy[si*2 + 2]  += diff;
        }
        return;
    }

    // If not completely in rang, but overlaps, recur for
    // children,
    int mid = (ss+se)/2;
    updateRangeUtil(si*2+1, ss, mid, us, ue, diff);
    updateRangeUtil(si*2+2, mid+1, se, us, ue, diff);

    // And use the result of children calls to update this
    // node
    tree[si] = tree[si*2+1] + tree[si*2+2];
}

// Function to update a range of values in segment
// tree
/*  us and eu -> starting and ending indexes of update query
    ue  -> ending index of update query
    diff -> which we need to add in the range us to ue */
void updateRange(int n, int us, int ue, int diff)
{
   updateRangeUtil(0, 0, n-1, us, ue, diff);
}


/*  A recursive function to get the sum of values in given
    range of the array. The following are parameters for
    this function.
    si --> Index of current node in the segment tree.
           Initially 0 is passed as root is always at'
           index 0
    ss & se --> Starting and ending indexes of the
                segment represented by current node,
                i.e., tree[si]
    qs & qe --> Starting and ending indexes of query
                range */
int getSumUtil(int ss, int se, int qs, int qe, int si)
{
    // If lazy flag is set for current node of segment tree,
    // then there are some pending updates. So we need to
    // make sure that the pending updates are done before
    // processing the sub sum query
    if (lazy[si] != 0)
    {
        // Make pending updates to this node. Note that this
        // node represents sum of elements in arr[ss..se] and
        // all these elements must be increased by lazy[si]
        tree[si] += (se-ss+1)*lazy[si];

        // checking if it is not leaf node because if
        // it is leaf node then we cannot go further
        if (ss != se)
        {
            // Since we are not yet updating children os si,
            // we need to set lazy values for the children
            lazy[si*2+1] += lazy[si];
            lazy[si*2+2] += lazy[si];
        }

        // unset the lazy value for current node as it has
        // been updated
        lazy[si] = 0;
    }

    // Out of range
    if (ss>se || ss>qe || se<qs)
        return 0;

    // At this point we are sure that pending lazy updates
    // are done for current node. So we can return value
    // (same as it was for query in our previous post)

    // If this segment lies in range
    if (ss>=qs && se<=qe)
        return tree[si];

    // If a part of this segment overlaps with the given
    // range
    int mid = (ss + se)/2;
    return getSumUtil(ss, mid, qs, qe, 2*si+1) +
           getSumUtil(mid+1, se, qs, qe, 2*si+2);
}

// Return sum of elements in range from index qs (quey
// start) to qe (query end). It mainly uses getSumUtil()
int getSum(int n, int qs, int qe)
{
    // Check for erroneous input values
    if (qs < 0 || qe > n-1 || qs > qe)
    {
        printf("Invalid Input");
        return -1;
    }

    return getSumUtil(0, n-1, qs, qe, 0);
}

// A recursive function that constructs Segment Tree for
//  array[ss..se]. si is index of current node in segment
// tree st.
void constructSTUtil(int arr[], int ss, int se, int si)
{
    // out of range as ss can never be greater than se
    if (ss > se)
        return ;

    // If there is one element in array, store it in
    // current node of segment tree and return
    if (ss == se)
    {
        tree[si] = arr[ss];
        return;
    }

    // If there are more than one elements, then recur
    // for left and right subtrees and store the sum
    // of values in this node
    int mid = (ss + se)/2;
    constructSTUtil(arr, ss, mid, si*2+1);
    constructSTUtil(arr, mid+1, se, si*2+2);

    tree[si] = tree[si*2 + 1] + tree[si*2 + 2];
}

/* Function to construct segment tree from given array.
   This function allocates memory for segment tree and
   calls constructSTUtil() to fill the allocated memory */
void constructST(int arr[], int n)
{
    // Fill the allocated memory st
    constructSTUtil(arr, 0, n-1, 0);
}


// Driver program to test above functions
int main()
{
    int arr[] = {1, 3, 5, 7, 9, 11};
    int n = sizeof(arr)/sizeof(arr[0]);

    // Build segment tree from given array
    constructST(arr, n);

    // Print sum of values in array from index 1 to 3
    printf("Sum of values in given range = %d\n",
           getSum(n, 1, 3));

    // Add 10 to all nodes at indexes from 1 to 5.
    updateRange(n, 1, 5, 10);

    // Find sum after the value is updated
    printf("Updated sum of values in given range = %d\n",
            getSum( n, 1, 3));

    return 0;
```

```
}
```

1.3 SegmentTree

```
/* RMQ */
class SegmentTree{
 private:
  vector<int> st, A;
  int n;
 public:
  int left(int p){
   return (p << 1);
  }
  int right(int p){
   return (p << 1) + 1;
  }
  void build(int p, int L, int R){
   if (L == r){
    st[p] = L;
   }else {
    int mid = (L + R) >> 1;
    build(left(p), L, mid);
    build(right(p), mid+1, r);
    int p1 = st[left(p)];
    int p2 = st[right(p)];
    st[p] = (A[p1] <= A[p2] ? p1 : p2);
   }
  }

  int rmq(int p, int L, int R, int i,int j){
   if (i > R || j < L) return -1; //outside range
   if (L >= i && R <= j) return st[p];
   int mid = (L + R) >> 1;
   int p1 = rmq(left(p), L, mid, i, j);
   int p2 = rmq(left(p), mid+1, R, i, j);
   if (p1 == -1) return p2;
   if (p2 == -1) return p1;
   return (A[p1] <= A[p2] ? p1 : p2);
  }

};
```

1.4 Trie

```
struct node2{
    node2 *children[26] = {NULL};
};
struct trie{
    node2 *head = new node2;
    node2 *cur = head;
    void insert(string x){
        head = cur;
        for(int i = 0; i < x.size(); i++){
            int val = x[i]-'a';
            if(head->children[val] == NULL){
                head->children[val] = new node2;
            }
            head = head->children[val];
        }
    }

    bool find(string x){
        head = cur;
        for(int i = 0; i < x.size(); i++){
            int val = x[i]-'a';
            if(head->children[val] == NULL)return false;
            head = head->children[val];
        }
        return true;
    }
};
```

2 Dynamic Programming

2.1 Convex Hull Trick

```
//DP convex hull trick (Beware on overflow)
const ll is_query = -(1LL<<62);
struct Line {
    ll m, b;
    mutable function<const Line*()> succ;
    bool operator<(const Line& rhs) const {
        if (rhs.b != is_query) return m < rhs.m;
        const Line* s = succ();
        if (!s) return 0;
        ll x = rhs.m;
        return b - s->b < (s->m - m) * x;
    }
};
struct HullDynamic : public multiset<Line> { // will
     maintain upper hull for maximum
    bool bad(iterator y) {
        auto z = next(y);
        if (y == begin()) {
            if (z == end()) return 0;
            return y->m == z->m && y->b <= z->b;
        }
        auto x = prev(y);
        if (z == end()) return y->m == x->m && y->b <= x->b;
        return (long double)(x->b - y->b)*(z->m - y->m) >= (
             long double)(y->b - z->b)*(y->m - x->m);
    }
    void insert_line(ll m, ll b) {
        auto y = insert({ m, b });
        y->succ = [=] { return next(y) == end() ? 0 : &*next(
             y); };
        if (bad(y)) { erase(y); return; }
        while (next(y) != end() && bad(next(y))) erase(next(y
             ));
        while (y != begin() && bad(prev(y))) erase(prev(y));
    }
    ll eval(ll x) {
        auto l = *lower_bound((Line) { x, is_query });
        return l.m * x + l.b;
    }
};
```

3 Geometry

3.1 2d

```
/* ftype = int, double, long long , dll */
struct point2d {
    ftype x, y;
    point2d() {}
    point2d(ftype x, ftype y): x(x), y(y) {}
    point2d& operator+=(const point2d &t) {
        x += t.x;
        y += t.y;
        return *this;
    }
    point2d& operator-=(const point2d &t) {
        x -= t.x;
        y -= t.y;
        return *this;
    }
    point2d& operator*=(ftype t) {
        x *= t;
        y *= t;
        return *this;
    }
    point2d& operator/=(ftype t) {
        x /= t;
        y /= t;
        return *this;
    }
    point2d operator+(const point2d &t) const {
        return point2d(*this) += t;
    }
    point2d operator-(const point2d &t) const {
        return point2d(*this) -= t;
    }
    point2d operator*(ftype t) const {
        return point2d(*this) *= t;
    }
    point2d operator/(ftype t) const {
        return point2d(*this) /= t;
    }
};
point2d operator*(ftype a, point2d b) {
    return b * a;
}
```

3.2 3d

```
/* ftype = int, double, long long , dll */
struct point3d {
    ftype x, y, z;
    point3d() {}
    point3d(ftype x, ftype y, ftype z): x(x), y(y), z(z) {}
    point3d& operator+=(const point3d &t) {
        x += t.x;
        y += t.y;
        z += t.z;
        return *this;
    }
    point3d& operator-=(const point3d &t) {
        x -= t.x;
        y -= t.y;
        z -= t.z;
        return *this;
    }
    point3d& operator*=(ftype t) {
        x *= t;
        y *= t;
        z *= t;
        return *this;
    }
    point3d& operator/=(ftype t) {
        x /= t;
        y /= t;
        z /= t;
        return *this;
    }
    point3d operator+(const point3d &t) const {
        return point3d(*this) += t;
    }
    point3d operator-(const point3d &t) const {
        return point3d(*this) -= t;
    }
    point3d operator*(ftype t) const {
        return point3d(*this) *= t;
    }
    point3d operator/(ftype t) const {
        return point3d(*this) /= t;
    }
};
point3d operator*(ftype a, point3d b) {
    return b * a;
}
```

3.3 AreaPolygon

```
// Let a simple polygon (i.e. without self intersection, not
      necessarily convex) be given. It is required to
// calculate its area given its vertices.

double area(const vector<point>& fig) {
    double res = 0;
    for (unsigned i = 0; i < fig.size(); i++) {
        point p = i ? fig[i - 1] : fig.back();
        point q = fig[i];
        res += (p.x - q.x) * (p.y + q.y);
    }
    return fabs(res) / 2;
}
```

3.4 OrientationTriangle

```
// Given three points p1, p2 and p3, calculate an oriented (
// signed) area of a triangle formed by them. The sign of
// the area is determined in the following way: imagine you
     are
// standing in the plane at point p1 and are facing p2. You
     go to
// p2 and if p3 is to your right (then we say the three
     vectors turn
// "clockwise"), the sign of the area is positive, otherwise
     it is
// negative. If the three points are collinear, the area is
     zero.

int signed_area_parallelogram(point2d p1, point2d p2,
     point2d p3) {
    return cross(p2 - p1, p3 - p2);
}

double triangle_area(point2d p1, point2d p2, point2d p3) {
    return abs(signed_area_parallelogram(p1, p2, p3)) / 2.0;
}

bool clockwise(point2d p1, point2d p2, point2d p3) {
    return signed_area_parallelogram(p1, p2, p3) < 0;
}

bool counter_clockwise(point2d p1, point2d p2, point2d p3) {
    return signed_area_parallelogram(p1, p2, p3) > 0;
}
```

3.5 circleLineIntersect

```
// Given the coordinates of the center of a circle and its
     radius,
// and the equation of a line, you're required to find the
     points
// of intersection.
double r, a, b, c; // given as input
double x0 = -a*c/(a*a+b*b), y0 = -b*c/(a*a+b*b);
if (c*c > r*r*(a*a+b*b)+EPS)
    puts ("no points");
else if (abs (c*c - r*r*(a*a+b*b)) < EPS) {
    puts ("1 point");
    cout << x0 << ' ' << y0 << '\n';
}
else {
    double d = r*r - c*c/(a*a+b*b);
    double mult = sqrt (d / (a*a+b*b));
    double ax, ay, bx, by;
    ax = x0 + b * mult;
    bx = x0 - b * mult;
    ay = y0 - a * mult;
    by = y0 + a * mult;
    puts ("2 points");
    cout << ax << ' ' << ay << '\n' << bx << ' ' << by << '\n
         ';
}
```

3.6 convexhullGrahamScan

```
struct pt {
    double x, y;
};

bool cmp(pt a, pt b) {
    return a.x < b.x || (a.x == b.x && a.y < b.y);
}

bool cw(pt a, pt b, pt c) {
    return a.x*(b.y-c.y)+b.x*(c.y-a.y)+c.x*(a.y-b.y) < 0;
}

bool ccw(pt a, pt b, pt c) {
    return a.x*(b.y-c.y)+b.x*(c.y-a.y)+c.x*(a.y-b.y) > 0;
}

void convex_hull(vector<pt>& a) {
    if (a.size() == 1)
        return;

    sort(a.begin(), a.end(), &cmp);
    pt p1 = a[0], p2 = a.back();
    vector<pt> up, down;
    up.push_back(p1);
    down.push_back(p1);
    for (int i = 1; i < (int)a.size(); i++) {
        if (i == a.size() - 1 || cw(p1, a[i], p2)) {
            while (up.size() >= 2 && !cw(up[up.size()-2], up[
                 up.size()-1], a[i]))
                up.pop_back();
            up.push_back(a[i]);
        }
        if (i == a.size() - 1 || ccw(p1, a[i], p2)) {
            while(down.size() >= 2 && !ccw(down[down.size()
                 -2], down[down.size()-1], a[i]))
                down.pop_back();
            down.push_back(a[i]);
        }
    }

    a.clear();
    for (int i = 0; i < (int)up.size(); i++)
        a.push_back(up[i]);
    for (int i = down.size() - 2; i > 0; i--)
        a.push_back(down[i]);
}
```

3.7 crossProduct

```
/* ftype = int, double, long long , dll */

point3d cross(point3d a, point3d b) {
    return point3d(a.y * b.z - a.z * b.y,
                   a.z * b.x - a.x * b.z,
                   a.x * b.y - a.y * b.x);
}
ftype triple(point3d a, point3d b, point3d c) {
    return dot(a, cross(b, c));
}
ftype cross(point2d a, point2d b) {
    return a.x * b.y - a.y * b.x;
}
```

3.8 dotProduct

```
/* ftype = int, double, long long , dll */
ftype dot(point2d a, point2d b) {
    return a.x * b.x + a.y * b.y;
}
ftype dot(point3d a, point3d b) {
    return a.x * b.x + a.y * b.y + a.z * b.z;
}

ftype norm(point2d a) {
    return dot(a, a);
}
double abs(point2d a) {
    return sqrt(norm(a));
}
double proj(point2d a, point2d b) {
    return dot(a, b) / abs(b);
}
double angle(point2d a, point2d b) {
    return acos(dot(a, b) / abs(a) / abs(b));
}
```

3.9 findIntersectionTwoSegment

```
// You are given two segments AB and
// CD, described as pairs of their endpoints. Each segment
    can
// be a single point if its endpoints are the same. You have
    to
// find the intersection of these segments, which can be
    empty
// (if the segments don't intersect),
// a single point or a segment (if the given segments
    overlap).

const double EPS = 1E-9;

struct pt {
    double x, y;

    bool operator<(const pt& p) const
    {
        return x < p.x - EPS || (abs(x - p.x) < EPS && y < p.
            y - EPS);
    }
};

struct line {
    double a, b, c;

    line() {}
    line(pt p, pt q)
    {
        a = p.y - q.y;
        b = q.x - p.x;
        c = -a * p.x - b * p.y;
        norm();
    }

    void norm()
    {
        double z = sqrt(a * a + b * b);
        if (abs(z) > EPS)
            a /= z, b /= z, c /= z;
    }

    double dist(pt p) const { return a * p.x + b * p.y + c; }
};

double det(double a, double b, double c, double d)
{
    return a * d - b * c;
}


inline bool betw(double l, double r, double x)
{
    return min(l, r) <= x + EPS && x <= max(l, r) + EPS;
}

inline bool intersect_1d(double a, double b, double c,
     double d)
{
    if (a > b)
        swap(a, b);
    if (c > d)
        swap(c, d);
    return max(a, c) <= min(b, d) + EPS;
}

bool intersect(pt a, pt b, pt c, pt d, pt& left, pt& right)
{
    if (!intersect_1d(a.x, b.x, c.x, d.x) || !intersect_1d(a.
         y, b.y, c.y, d.y))
        return false;
    line m(a, b);
    line n(c, d);
    double zn = det(m.a, m.b, n.a, n.b);
    if (abs(zn) < EPS) {
        if (abs(m.dist(c)) > EPS || abs(n.dist(a)) > EPS)
            return false;
        if (b < a)
            swap(a, b);
        if (d < c)
            swap(c, d);
        left = max(a, c);
        right = min(b, d);
        return true;
    } else {
        left.x = right.x = -det(m.c, m.b, n.c, n.b) / zn;
        left.y = right.y = -det(m.a, m.c, n.a, n.c) / zn;
        return betw(a.x, b.x, left.x) && betw(a.y, b.y, left.
             y) &&
               betw(c.x, d.x, left.x) && betw(c.y, d.y, left.y
                   );
    }
}
```

3.10 lengthUnionSegment

```
// Given n segments on a line, each described
// by a pair of coordinates (ai1,ai2). We have
// to find the length of their union
int length_union(const vector<pair<int, int>> &a) {
    int n = a.size();
    vector<pair<int, bool>> x(n*2);
    for (int i = 0; i < n; i++) {
        x[i*2] = {a[i].first, false};
        x[i*2+1] = {a[i].second, true};
    }

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

    int result = 0;
    int c = 0;
    for (int i = 0; i < n * 2; i++) {
        if (i > 0 && x[i].first > x[i-1].first && c > 0)
            result += x[i].first - x[i-1].first;
        if (x[i].second)
            c++;
        else
            --c;
    }
    return result;
}
```

3.11 lineIntersection

```
point2d intersect(point2d a1, point2d d1, point2d a2,
     point2d d2) {
    return a1 + cross(a2 - a1, d2) / cross(d1, d2) * d1;
}

point3d intersect(point3d a1, point3d n1, point3d a2,
     point3d n2, point3d a3, point3d n3) {
    point3d x(n1.x, n2.x, n3.x);
    point3d y(n1.y, n2.y, n3.y);
    point3d z(n1.z, n2.z, n3.z);
    point3d d(dot(a1, n1), dot(a2, n2), dot(a3, n3));
    return point3d(triple(d, y, z),
                   triple(x, d, z),
                   triple(x, y, d)) / triple(n1, n2, n3);
}
```

3.12 twoSegmentIntersect

```
struct pt {
    long long x, y;
    pt() {}
    pt(long long _x, long long _y) : x(_x), y(_y) {}
    pt operator-(const pt& p) const { return pt(x - p.x, y -
         p.y); }
    long long cross(const pt& p) const { return x * p.y - y *
         p.x; }
    long long cross(const pt& a, const pt& b) const { return
         (a - *this).cross(b - *this); }
};

int sgn(const long long& x) { return x >= 0 ? x ? 1 : 0 :
     -1; }

bool inter1(long long a, long long b, long long c, long long
     d) {
    if (a > b)
        swap(a, b);
    if (c > d)
        swap(c, d);
    return max(a, c) <= min(b, d);
}

bool check_inter(const pt& a, const pt& b, const pt& c,
     const pt& d) {
    if (c.cross(a, d) == 0 && c.cross(b, d) == 0)
        return inter1(a.x, b.x, c.x, d.x) && inter1(a.y, b.y,
             c.y, d.y);
    return sgn(a.cross(b, c)) != sgn(a.cross(b, d)) &&
           sgn(c.cross(d, a)) != sgn(c.cross(d, b));
}
```

4 Graph

4.1 Flow

4.1.1 Bipartite Matching

```
//To handle some corner cases, don't forget to randomize the
     edge order
struct BipartiteMatcher {
  vector<vector<int>> G;
  vector<int> L, R, Viz;

  BipartiteMatcher(int n, int m) :
  G(n), L(n, -1), R(m, -1), Viz(n) {}

  void AddEdge(int a, int b) {
    G[a].push_back(b);
  }

  bool Match(int node) {
    if (Viz[node])
```

```
      return false;
    Viz[node] = true;

    for (auto vec : G[node]) {
      if (R[vec] == -1) {
        L[node] = vec;
        R[vec] = node;
        return true;
      }
    }

    for (auto vec : G[node]) {
      if (Match(R[vec])) {
        L[node] = vec;
        R[vec] = node;
        return true;
      }
    }

    return false;
  }

  int Solve() {
    int ok = true;
    while (ok--) {
      fill(Viz.begin(), Viz.end(), 0);
      for (int i = 0; i < (int)L.size(); ++i)
        if (L[i] == -1)
          ok |= Match(i);
    }

    int ret = 0;
    for (int i = 0; i < L.size(); ++i)
      ret += (L[i] != -1);
    return ret;
  }
};
```

4.1.2 Dinic

```
struct FlowEdge {
    int v, u;
    long long cap, flow = 0;
    FlowEdge(int v, int u, long long cap) : v(v), u(u), cap(
        cap) {}
};

struct Dinic {
    const long long flow_inf = 1e18;
    vector<FlowEdge> edges;
    vector<vector<int>> adj;
    int n, m = 0;
    int s, t;
    vector<int> level, ptr;
    queue<int> q;

    Dinic(int n, int s, int t) : n(n), s(s), t(t) {
        adj.resize(n);
        level.resize(n);
        ptr.resize(n);
    }

    void add_edge(int v, int u, long long cap) {
        edges.emplace_back(v, u, cap);
        edges.emplace_back(u, v, 0);
        adj[v].push_back(m);
        adj[u].push_back(m + 1);
        m += 2;
    }

    bool bfs() {
        while (!q.empty()) {
            int v = q.front();
            q.pop();
            for (int id : adj[v]) {
                if (edges[id].cap - edges[id].flow < 1)
                    continue;
                if (level[edges[id].u] != -1)
                    continue;
                level[edges[id].u] = level[v] + 1;
                q.push(edges[id].u);
            }
        }
        return level[t] != -1;
    }

    long long dfs(int v, long long pushed) {
        if (pushed == 0)
            return 0;
        if (v == t)
            return pushed;
        for (int& cid = ptr[v]; cid < (int)adj[v].size(); cid
            ++) {
            int id = adj[v][cid];
            int u = edges[id].u;
            if (level[v] + 1 != level[u] || edges[id].cap -
                edges[id].flow < 1)
                continue;
            long long tr = dfs(u, min(pushed, edges[id].cap -
                edges[id].flow));
            if (tr == 0)
                continue;
            edges[id].flow += tr;
            edges[id ^ 1].flow -= tr;
            return tr;
        }
        return 0;
    }

    long long flow() {
        long long f = 0;
        while (true) {
            fill(level.begin(), level.end(), -1);
            level[s] = 0;
            q.push(s);
            if (!bfs())
                break;
            fill(ptr.begin(), ptr.end(), 0);
            while (long long pushed = dfs(s, flow_inf)) {
                f += pushed;
            }
        }
        return f;
    }
};
```

4.1.3 Edmond-Karp Max flow

```
#define MAXNODE 1000
#define INF 1000000007
int capacity[MAXNODE+5][MAXNODE+5];
vector<vector<int>> adj;

int bfs(int s, int t, vector<int>& parent) {
    fill(parent.begin(), parent.end(), -1);
    parent[s] = -2;
    queue<pair<int, int>> q;
    q.push({s, INF});

    while (!q.empty()) {
        int cur = q.front().first;
        int flow = q.front().second;
        q.pop();

        for (int next : adj[cur]) {
            if (parent[next] == -1 && capacity[cur][next]) {
                parent[next] = cur;
                int new_flow = min(flow, capacity[cur][next]);
                if (next == t)
                    return new_flow;
                q.push({next, new_flow});
            }
        }
    }

    return 0;
}

int maxflow(int s, int t) {
    int flow = 0;
    vector<int> parent(MAXNODE);
    int new_flow;

    while (new_flow = bfs(s, t, parent)) {
        flow += new_flow;
        int cur = t;
        while (cur != s) {
            int prev = parent[cur];
            capacity[prev][cur] -= new_flow;
            capacity[cur][prev] += new_flow;
            cur = prev;
        }
    }

    return flow;
}
```

4.1.4 Min-cost flow

```
struct Edge
{
    int from, to, capacity, cost;
    Edge(int from, int to, int capacity, int cost){
     this->from = from;
     this->to = to;
     this->capacity = capacity;
     this->cost = cost;
    }
};

vector<vector<int>> adj, cost, capacity;

const int INF = 1e9;

void shortest_paths(int n, int v0, vector<int>& d, vector<
     int>& p) {
    d.assign(n, INF);
    d[v0] = 0;
    vector<int> m(n, 2);
    deque<int> q;
    q.push_back(v0);
    p.assign(n, -1);

    while (!q.empty()) {
        int u = q.front();
        q.pop_front();
        m[u] = 0;
        for (int v : adj[u]) {
            if (capacity[u][v] > 0 && d[v] > d[u] + cost[u][v
                 ]) {
                d[v] = d[u] + cost[u][v];
                p[v] = u;
                if (m[v] == 2) {
                    m[v] = 1;
                    q.push_back(v);
                } else if (m[v] == 0) {
                    m[v] = 1;
                    q.push_front(v);
                }
            }
        }
    }
}

int min_cost_flow(int N, vector<Edge> edges, int K, int s,
     int t) {
    adj.assign(N, vector<int>());
    cost.assign(N, vector<int>(N, 0));
    capacity.assign(N, vector<int>(N, 0));
    for (Edge e : edges) {
        adj[e.from].push_back(e.to);
        adj[e.to].push_back(e.from);
        cost[e.from][e.to] = e.cost;
        cost[e.to][e.from] = -e.cost;
        capacity[e.from][e.to] = e.capacity;
    }

    int flow = 0;
    int cost = 0;
    vector<int> d, p;
    while (flow < K) {
        shortest_paths(N, s, d, p);
        if (d[t] == INF)
            break;

        // find max flow on that path
        int f = K - flow;
        int cur = t;
        while (cur != s) {
            f = min(f, capacity[p[cur]][cur]);
            cur = p[cur];
        }

        // apply flow
        flow += f;
        cost += f * d[t];
        cur = t;
        while (cur != s) {
            capacity[p[cur]][cur] -= f;
            capacity[cur][p[cur]] += f;
            cur = p[cur];
        }
    }

    if (flow < K)
        return 1;
    else
        return cost;
}
```

4.2 LCABinaryLifting

```
int n, l;
vector<vector<int>> adj;

int timer;
vector<int> tin, tout;
vector<vector<int>> up;

void dfs(int v, int p)
{
    tin[v] = ++timer;
    up[v][0] = p;
    for (int i = 1; i <= l; ++i)
        up[v][i] = up[up[v][i-1]][i-1];

    for (int u : adj[v]) {
        if (u != p)
            dfs(u, v);
    }

    tout[v] = ++timer;
}

bool is_ancestor(int u, int v)
```

```
{
    return tin[u] <= tin[v] && tout[u] >= tout[v];
}

int lca(int u, int v)
{
    if (is_ancestor(u, v))
        return u;
    if (is_ancestor(v, u))
        return v;
    for (int i = l; i >= 0; --i) {
        if (!is_ancestor(up[u][i], v))
            u = up[u][i];
    }
    return up[u][0];
}

void preprocess(int root) {
    tin.resize(n);
    tout.resize(n);
    timer = 0;
    l = ceil(log2(n));
    up.assign(n, vector<int>(l + 1));
    dfs(root, root);
}
```

4.3 LCATarjan

```
vector<vector<int>> adj;
vector<vector<int>> queries;
vector<int> ancestor;
vector<bool> visited;

void dfs(int v)
{
    visited[v] = true;
    ancestor[v] = v;
    for (int u : adj[v]) {
        if (!visited[u]) {
            dfs(u);
            union_sets(v, u);
            ancestor[find_set(v)] = v;
        }
    }
    for (int other_node : queries[v]) {
        if (visited[other_node])
            cout << "LCA of " << v << " and " << other_node
                 << " is " << ancestor[find_set(other_node)]
                      << ".\n";
    }
}

void compute_LCAs() {
    // initialize n, adj and DSU
    // for (each query (u, v)) {
    //    queries[u].push_back(v);
    //    queries[v].push_back(u);
    // }

    ancestor.resize(n);
    visited.assign(n, false);
    dfs(0);
}
```

5 Math

5.1 BigInt

```
const int BASE_LENGTH = 2;
const int BASE = (int) pow(10, BASE_LENGTH);
const int MAX_LENGTH = 500;

string int_to_string(int i, int width, bool zero) {
    string res = "";
    while (width--) {
        if (!zero && i == 0) return res;
        res = (char)(i%10 + '0') + res;
        i /= 10;
    }
    return res;
}

struct bigint {
    int len, s[MAX_LENGTH];

    bigint() {
        memset(s, 0, sizeof(s));
        len = 1;
    }

    bigint(unsigned long long num) {
        len = 0;
        while (num >= BASE) {
            s[len] = num % BASE;
            num /= BASE;
            len ++;
        }
        s[len++] = num;
    }

    bigint(const char* num) {
        int l = strlen(num);
        len = l/BASE_LENGTH;
        if (l % BASE_LENGTH) len++;
        int index = 0;
        for (int i = l - 1; i >= 0; i -= BASE_LENGTH) {
            int tmp = 0;
            int k = i - BASE_LENGTH + 1;
            if (k < 0) k = 0;
            for (int j = k; j <= i; j++) {
                tmp = tmp*10 + num[j] - '0';
            }
            s[index++] = tmp;
        }
    }

    void clean() {
        while(len > 1 && !s[len-1]) len--;
    }

    string str() const {
        string ret = "";
        if (len == 1 && !s[0]) return "0";
        for(int i = 0; i < len; i++) {
            if (i == 0) {
                ret += int_to_string(s[len - i - 1],
                    BASE_LENGTH, false);
            } else {
                ret += int_to_string(s[len - i - 1],
                    BASE_LENGTH, true);
            }
        }
        return ret;
    }

    unsigned long long ll() const {
        unsigned long long ret = 0;
        for(int i = len-1; i >= 0; i--) {
            ret *= BASE;
            ret += s[i];
        }
        return ret;
    }

    bigint operator + (const bigint& b) const {
        bigint c = b;
        while (c.len < len) c.s[c.len++] = 0;
        c.s[c.len++] = 0;
        bool r = 0;
        for (int i = 0; i < len || r; i++) {
            c.s[i] += (i<len)*s[i] + r;
            r = c.s[i] >= BASE;
            if (r) c.s[i] -= BASE;
        }
        c.clean();
        return c;
    }

    bigint operator - (const bigint& b) const {
        if (operator < (b)) throw "cannot do subtract";
        bigint c = *this;
        bool r = 0;
        for (int i = 0; i < b.len || r; i++) {
            c.s[i] -= b.s[i];
            r = c.s[i] < 0;
            if (r) c.s[i] += BASE;
        }
        c.clean();
        return c;
    }

    bigint operator * (const bigint& b) const {
        bigint c;
        c.len = len + b.len;
        for(int i = 0; i < len; i++)
            for(int j = 0; j < b.len; j++)
                c.s[i+j] += s[i] * b.s[j];
        for(int i = 0; i < c.len-1; i++){
            c.s[i+1] += c.s[i] / BASE;
            c.s[i] %= BASE;
        }
        c.clean();
        return c;
    }

    bigint operator / (const int b) const {
        bigint ret;
        int down = 0;
        for (int i = len - 1; i >= 0; i--) {
            ret.s[i] = (s[i] + down * BASE) / b;
            down = s[i] + down * BASE - ret.s[i] * b;
        }
        ret.len = len;
        ret.clean();
        return ret;
    }

    bool operator < (const bigint& b) const {
        if (len < b.len) return true;
        else if (len > b.len) return false;
        for (int i = 0; i < len; i++)
            if (s[i] < b.s[i]) return true;
            else if (s[i] > b.s[i]) return false;
        return false;
    }

    bool operator == (const bigint& b) const {
        return !(*this<b) && !(b<(*this));
    }

    bool operator > (const bigint& b) const {
        return b < *this;
    }
};
```

5.2 Number Theory

5.2.1 CRT

```
// A C++ program to demonstrate working of Chinise remainder
// Theorem
#include <bits/stdc++.h>
using namespace std;

// Returns modulo inverse of a with respect to m using
    extended
// Euclid Algorithm. Refer below post for details:
// https://www.geeksforgeeks.org/multiplicative-inverse-
    under-modulo-m/
int inv(int a, int m)
{
    int m0 = m, t, q;
    int x0 = 0, x1 = 1;

    if (m == 1)
       return 0;

    // Apply extended Euclid Algorithm
    while (a > 1)
    {
        // q is quotient
        q = a / m;

        t = m;

        // m is remainder now, process same as
        // euclid's algo
        m = a % m, a = t;

        t = x0;

        x0 = x1 - q * x0;

        x1 = t;
    }

    // Make x1 positive
    if (x1 < 0)
       x1 += m0;

    return x1;
}

// k is size of num[] and rem[]. Returns the smallest
// number x such that:
//  x % num[0] = rem[0],
//  x % num[1] = rem[1],
//  ..................
//  x % num[k-2] = rem[k-1]
// Assumption: Numbers in num[] are pairwise coprime
// (gcd for every pair is 1)
int findMinX(int num[], int rem[], int k)
{
    // Compute product of all numbers
    int prod = 1;
    for (int i = 0; i < k; i++)
        prod *= num[i];

    // Initialize result
    int result = 0;

    // Apply above formula
    for (int i = 0; i < k; i++)
    {
        int pp = prod / num[i];
        result += rem[i] * inv(pp, num[i]) * pp;
    }

    return result % prod;
}

// Driver method
int main(void)
{
    int num[] = {3, 4, 5};
    int rem[] = {2, 3, 1};
    int k = sizeof(num)/sizeof(num[0]);
    cout << "x is " << findMinX(num, rem, k);
    return 0;
}
```

5.2.2 InverseModulo

```
/**
* Description : find x such that ax = 1 mod m
*/

/* case 1 : when(gcd(a,m) = 1) */
/* use extended euclid : find x such that ax + my = 1 */

/* store x, y, and d as global variables */
void extendedEuclid(int a, int b) {
  if (b == 0) { x = 1; y = 0; d = a; return; }
  /* base case */
  extendedEuclid(b, a % b);
  /* similar as the original gcd */
  int x1 = y;
  int y1 = x - (a / b) * y;
  x = x1;
  y = y1;
}

/* compute the first case inverse modulo*/
int firstInverseModulo(int a, int m){
  /* produces x and y, such that ax + my = 1 */
  extendedEuclid(a, m);
  return (x + m)%m;
}

/* case 2 : m is prime */
/* a^(m-1) = 1 mod m */
/* a^(m-2) = a^-1 mod m */

int power(int a,int b){
  int res = 1;
  while (b > 0){
    if (b%2 == 1)
      res *= a;
    b /= 2;
    a *= a;
  }
  return res;
}

int secondInverseModulo(int a,int m){
  return power(a, m-2);
}
```

5.2.3 PrimeFactor

```
/**
* Description : some function that have relation with prime
    factor
*/

/* find prime factor */
vector<long long> primefactor(long long N){
    vector<long long> factors;
    long long idx = 0;
    long long PF = primes[idx];
    while (PF <= (long long)sqrt(N)){
      while (N%PF == 0){
          N /= PF;
          factors.push_back(PF);
      }
      PF = primes[++idx];
    }
    if (N != 1) factors.push_back(N);
    return factors;
}

/* number of divisor */
long long numDiv(long long N){
    long long ans = 1;
    long long idx = 0;
    long long PF = primes[idx];
    while (PF <= (long long)sqrt(N)){
        long long power = 0;
        while (N%PF == 0){
            power++;
            N /= PF;
        }
        ans *= (power + 1);
        PF = primes[++idx];
    }
    if (N != 1) ans *= 2;
    return ans;
}

/* sum of divisor */
long long sumDiv(long long N){
    long long ans = 1;
    long long idx = 0;
    long long PF = primes[idx];
    while (PF <= (long long)sqrt(N)){
        long long power = 0;
        while (N%PF == 0){
            power++;
            N /= PF;
        }
        /* 1 + PF + PF^2 + PF^3 + ... + PF^pow = (a.r^n - 1)
            / (r-1) */
        ans *= ((long long)pow((double)PF, power + 1.0) - 1)
            / (PF - 1);
        PF = primes[++idx];
    }
    if (N != 1) ans *= ((long long)pow((double)N, 2.0) - 1) /
        (N - 1);
    return ans;
}

/* Euler Phi */
long long eulerPhi(long long N){
    long long idx = 0;
    long long PF = primes[idx];
    long long ans = N;
    while (PF <= (long long)sqrt(N)){
        if (N%PF == 0) ans -= ans / PF;
        while (N%PF == 0) N /= PF;
        PF = primes[++idx];
    }
    if (N != 1) ans -= ans / N;
    return ans;
}
```

5.2.4 Sieve

```
/**
* Description :Test Primality up to n in O(nlog(logn))
*/

const int SZ = 1e7;
bitset<SZ> bs;
vector<long long> primes;

void sieve(){
    bs.set();
    bs[0] = false; bs[1] = false;
    for (long long i = 2; i <= SZ; i++){
        if (bs[i]){
            primes.push_back(i);
            for (long long j = i * i; j <= SZ; j+=i)
                bs[j] = false;
        }
    }
}
```

5.2.5 extendedEuclid

```
/**
* Description : find x and y such that ax + by = 1
*/

/* store x, y, and d as global variables */
void extendedEuclid(int a, int b) {
  if (b == 0) { x = 1; y = 0; d = a; return; }
  /* base case */
  extendedEuclid(b, a % b);
  /* similar as the original gcd */
  int x1 = y;
  int y1 = x - (a / b) * y;
  x = x1;
  y = y1;
}
```

6 Misc

6.1 Mo

```
bool comp(query a, query b){
 if (a.L / block == b.L/block)
  return a.R < b.R;
 return a.L/block < b.L/block;
}

void add(int x){
 cnt[x]++;
 if (cnt[x] == 1) distinct++;
}

void del(int x){
 cnt[x]--;
 if (cnt[x] == 0) distinct--;
}

int main(){
  OPTIMATION
  cin >> N;
  for (int i = 0; i < N; i++)
   cin >> arr[i];
  block = (int)sqrt(N) + 1;
  cin >> Q;
  for (int i = 0; i < Q; i++){
   int tl, tr;
   cin >> tl >> tr;
   tl--; tr--;
   q[i].L = tl;
   q[i].R = tr;
   q[i].no = i;
  }
  sort(q, q+Q, comp);
  currL = 0;
  currR = 0;
  for (int i = 0; i < Q; i++){
   int L = q[i].L;
   int R = q[i].R;
   while (currL < L) {
    del(arr[currL]);
    currL++;
   }
   while (currL > L){
    add(arr[currL-1]);
    currL--;
   }
   while (currR <= R) {
    add(arr[currR]);
    currR++;
   }
   while (currR > R+1){
    del(arr[currR-1]);
    currR--;
   }
   ans[q[i].no] = distinct;
  }
  for (int i = 0; i < Q; i++){
   cout << ans[i] << '\n';
  }
  return 0;
}
```

6.2 mt19937

```
#include <bits/stdc++.h>
using namespace std;
//Application of mt199937

const int N = 3000000;

double average_distance(const vector<int> &permutation) {
    double distance_sum = 0;

    for (int i = 0; i < N; i++)
        distance_sum += abs(permutation[i] - i);

    return distance_sum / N;
}

int main() {
    mt19937 rng(chrono::steady_clock::now().time_since_epoch
         ().count());
    vector<int> permutation(N);

    for (int i = 0; i < N; i++)
        permutation[i] = i;

    shuffle(permutation.begin(), permutation.end(), rng);
    cout << average_distance(permutation) << '\n';

    for (int i = 0; i < N; i++)
        permutation[i] = i;

    for (int i = 1; i < N; i++)
        swap(permutation[i], permutation[
             uniform_int_distribution<int>(0, i)(rng)]);

    cout << average_distance(permutation) << '\n';
}
```

6.3 ternary

```
/*We are given a function f(x) which is unimodal on an
     interval [l;r]. By unimodal function, we mean one of
     two behaviors of the function:

The function strictly increases first, reaches a maximum (at
      one point or at a segment), and then strictly
     decreases.

The function strictly decreases first, reaches a minimum,
     and then strictly increases.

In this article we will assume the first scenario, and the
     second is be completely symmetrical to it.

The task is to find the maximum of function f(x) on the
     interval [l;r].*/
double ternary_search(double l, double r) {
    double eps = 1e-9;          //set the error limit here
    while (r - l > eps) {
        double m1 = l + (r - l) / 3;
        double m2 = r - (r - l) / 3;
        double f1 = f(m1);    //evaluates the function at m1
        double f2 = f(m2);    //evaluates the function at m2
        if (f1 < f2)
            l = m1;
        else
            r = m2;
    }
    return f(l);                //return the maximum of f(x)
        in [l, r]
}
```

7 Setup

7.1 C++Template

```
#pragma GCC optimize ("O3")
#pragma GCC target ("sse4")

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

#define fi first
#define se second
#define pb push_back

typedef long long LL;
typedef vector<int> vi;
typedef pair<int,int> ii;

const int MOD = 1e9 + 7;
const LL INF = 1e18;

void fastscan(int &number) {
    //variable to indicate sign of input number
    bool negative = false;
    register int c;

    number = 0;

    // extract current character from buffer
    c = getchar();
    if (c=='-')
    {
        // number is negative
        negative = true;

        // extract the next character from the buffer
        c = getchar();
    }

    // Keep on extracting characters if they are integers
    // i.e ASCII Value lies from '0'(48) to '9' (57)
    for (; (c>47 && c<58); c=getchar())
        number = number *10 + c - 48;

    // if scanned input has a negative sign, negate the
    // value of the input number
    if (negative)
        number *= -1;
}

int main(){
    //cin / cout user
    //ios_base::sync_with_stdio(0); cin.tie(0); cout.tie(0)


    return 0;
}
```

7.2 FastScanner

```
class FastScanner {
    private InputStream stream;
    private byte[] buf = new byte[1024];
    private int curChar;
    private int numChars;

    public FastScanner(InputStream stream) {
        this.stream = stream;
    }

    int read() {
        if (numChars == -1)
            throw new InputMismatchException();
        if (curChar >= numChars) {
            curChar = 0;
            try {
                numChars = stream.read(buf);
            } catch (IOException e) {
                throw new InputMismatchException();
            }
            if (numChars <= 0) return -1;
        }
        return buf[curChar++];
    }

    boolean isSpaceChar(int c) {
        return c ==        || c ==   \ n  || c ==   \ r  || c
            ==   \ t  || c == -1;
    }

    public int nextInt() {
        return Integer.parseInt(next());
    }

    public long nextLong() {
        return Long.parseLong(next());
    }

    public double nextDouble() {
        return Double.parseDouble(next());
    }

    public String next() {
        int c = read();
        while (isSpaceChar(c)) c = read();
        StringBuilder res = new StringBuilder();
        do {
            res.appendCodePoint(c);
            c = read();
        } while (!isSpaceChar(c));
        return res.toString();
    }

    public String nextLine() {
        int c = read();
        while (isEndline(c))
            c = read();
        StringBuilder res = new StringBuilder();
        do {
            res.appendCodePoint(c);
            c = read();
        } while (!isEndline(c));
        return res.toString();
    }
}
```

8 String

8.1 Hashing

```
/*use double hashing */

long long compute_hash(string const& s) {
    const int p = 31; //another good option : p = 53
    const int m = 1e9 + 9;
    long long hash_value = 0;
    long long p_pow = 1;
    for (char c : s) {
        hash_value = (hash_value + (c - 'a' + 1) * p_pow) % m
            ;
        p_pow = (p_pow * p) % m;
    }
    return hash_value;
}
```

8.2 KMP

```
#define HHH 10003

int ne[HHH]; // next[], if par[i] not matched, jump to i =
     ne[i]
int kmp(string& par, string& ori) {
    ne[0] = -1;
    for (int p = ne[0], i = 1; i < par.length(); i++) {
        while (p >= 0 && par[p+1] != par[i])
            p = ne[p];
        if (par[p+1] == par[i])
            p++;
        ne[i] = p;
    }

    int match = 0;
    for (int p = -1, q = 0; q < ori.length(); q++) {
        while (p >= 0 && par[p+1] != ori[q])
            p = ne[p];
        if (par[p+1] == ori[q])
            p++;
        if (p + 1 == par.length()) { // match!
            p = ne[p];
            match++;
        }
    }

    return match; // return number of occurance
}

int main () {
    int n; cin >> n;
    string par, ori;
    while (cin >> par >> ori)
        cout << kmp(par, ori) << endl;
    return 0;
}
```

8.3 Manacher

```
int dp[HHH];
int lengthLongestPalindromSubstring(string& s) {
    memset(dp, 0, sizeof(dp));
    int ans = 0;
    int pivot = 1;
    int len = s.length() * 2; // _s0_s1_s2 = 2 * length
    for (int i = 1; i < len; i++) {
        int pBorder = pivot + dp[pivot];
        int iBorder = i;
        if (iBorder < pBorder && 2 * pivot - i > 0) {
            dp[i] = dp[2*pivot-i];
            iBorder = min(pBorder, i + dp[i]);
        }

        if (iBorder >= pBorder) {
            int j = iBorder + (iBorder % 2 ? 2 : 1);
            for (; j < len && 2*i-j > 0 && s[j/2] == s[(2*i-j
                )/2]; j += 2)
                ;
            iBorder = j - 2;
            dp[i] = iBorder - i;
            pivot = i;
        }
        ans = max(ans, dp[i] + 1);
    }

    return ans;
}

int main () {
    int n; cin >> n;
    string s;
    while (cin >> s)
        cout << lengthLongestPalindromSubstring(s) << endl;
    return 0;
}
```

8.4 rabinkarp

```
/* Problem: Given two strings - a pattern s and a text t,
determine if the pattern appears in the text and if it does,
enumerate all its occurrences in O(|s|+|t|) time.*/
vector<int> rabin_karp(string const& s, string const& t) {
    const int p = 31;
    const int m = 1e9 + 9;
    int S = s.size(), T = t.size();

    vector<long long> p_pow(max(S, T));
    p_pow[0] = 1;
    for (int i = 1; i < (int)p_pow.size(); i++)
        p_pow[i] = (p_pow[i-1] * p) % m;

    vector<long long> h(T + 1, 0);
    for (int i = 0; i < T; i++)
        h[i+1] = (h[i] + (t[i] - 'a' + 1) * p_pow[i]) % m;
    long long h_s = 0;
    for (int i = 0; i < S; i++)
        h_s = (h_s + (s[i] - 'a' + 1) * p_pow[i]) % m;

    vector<int> occurences;
    for (int i = 0; i + S - 1 < T; i++) {
        long long cur_h = (h[i+S] + m - h[i]) % m;
        if (cur_h == h_s * p_pow[i] % m)
            occurences.push_back(i);
    }
    return occurences;
}
```