Contents

1 Flow

1.1 MinCostMaxFlow

```
struct MincostMaxflow {
  struct Edge {
    int to, rev, cap, w;
    Edge() {}
    Edge(int a, int b, int c, int d): to(a), cap(b), w(
    c), rev(d) {}
  };
  int n, s, t, p[maxn], id[maxn];
  int d[maxn];
  bool inque[maxn];
  vector<Edge> G[maxn];
  pair<int, int> spfa() {
    memset(p, -1, sizeof(-1));
    fill(d, d + maxn, inf);
    memset(id, -1, sizeof(id));
    d[s] = 0; p[s] = s;
    queue<int> que; que.push(s); inque[s] = true;
    while (que.size()) {
      int tmp = que.front(); que.pop();
      inque[tmp] = false;
      int i = 0;
      for (auto e : G[tmp]) {
        if (e.cap > 0 && d[e.to] > d[tmp] + e.w) {
          d[e.to] = d[tmp] + e.w;
          p[e.to] = tmp;
          id[e.to] = i;
          if (!inque[e.to]) que.push(e.to), inque[e.to]
     = true;
        }
        ++i;
      }
    }
    if (d[t] == inf) return make_pair(-1, -1);
    int a = inf;
    for (int i = t; i != s; i = p[i]) {
      a = min(a, G[p[i]][id[i]].cap);
    }
    for (int i = t; i != s; i = p[i]) {
      Edge &e = G[p[i]][id[i]];
      e.cap -= a; G[e.to][e.rev].cap += a;
    }
    return make_pair(a, d[t]);
  }
  MincostMaxflow(int _n, int _s, int _t): n(_n), s(_s),
     t(_t) {
    fill(G, G + maxn, vector<Edge>());
  }
  void add_edge(int a, int b, int cap, int w) {
    G[a].push_back(Edge(b, cap, w, (int)G[b].size()));
    G[b].push_back(Edge(a, 0, -w, (int)G[a].size() - 1)
    );
  }
  pair<int, int> maxflow() {
    int mxf = 0, mnc = 0;
    while (true) {
      pair<int, int> res = spfa();
      if (res.first == -1) break;
      mxf += res.first; mnc += res.first * res.second;
    }
    return make_pair(mxf, mnc);
  }
};
```

2 Graph

2.1 Heavy-Light Decomposition

```
struct HeavyLightDecomp {
  vector<int> G[maxn];
  int tin[maxn], top[maxn], dep[maxn], maxson[maxn], sz
    [maxn], p[maxn], n, clk;
  void dfs(int now, int fa, int d) {
    dep[now] = d;
```

```
    maxson[now] = -1;
    sz[now] = 1;
    p[now] = fa;
    for (int u : G[now]) if (u != fa) {
      dfs(u, now, d + 1);
      sz[now] += sz[u];
      if (maxson[now] == -1 || sz[u] > sz[maxson[now]])
       maxson[now] = u;
    }
  }
  void link(int now, int t) {
    top[now] = t;
    tin[now] = ++clk;
    if (maxson[now] == -1) return;
    link(maxson[now], t);
    for (int u : G[now]) if (u != p[now]) {
      if (u == maxson[now]) continue;
      link(u, u);
    }
  }
  HeavyLightDecomp(int n): n(n) {
    clk = 0;
    memset(tin, 0, sizeof(tin)); memset(top, 0, sizeof(
    top)); memset(dep, 0, sizeof(dep));
    memset(maxson, 0, sizeof(maxson)); memset(sz, 0,
    sizeof(sz)); memset(p, 0, sizeof(p));
  }
  void add_edge(int a, int b) {
    G[a].push_back(b);
    G[b].push_back(a);
  }
  void solve() {
    dfs(0, -1, 0);
    link(0, 0);
  }
  int lca(int a, int b) {
    int ta = top[a], tb = top[b];
    while (ta != tb) {
      if (dep[ta] < dep[tb]) {
        swap(ta, tb); swap(a, b);
      }
      a = p[ta]; ta = top[a];
    }
    if (a == b) return a;
    return dep[a] < dep[b] ? a : b;
  }
  vector<pair<int, int>> get_path(int a, int b) {
    int ta = top[a], tb = top[b];
    vector<pair<int, int>> ret;
    while (ta != tb) {
      if (dep[ta] < dep[tb]) {
        swap(ta, tb); swap(a, b);
      }
      ret.push_back(make_pair(tin[ta], tin[a]));
      a = p[ta]; ta = top[a];
    }
    ret.push_back(make_pair(min(tin[a], tin[b]), max(
    tin[a], tin[b])));
    return ret;
  }
};
```

3 Math

3.1 FFT

```
const double pi = acos(-1);
const complex<double> I(0, 1);
complex<double> omega[maxn + 1];

void prefft() {
  for (int i = 0; i <= maxn; ++i) omega[i] = exp(i * 2
    * pi / maxn * I);
}
void fft(vector<complex<double>>& a, int n, bool inv=
    false) {
  int basic = maxn / n;
  int theta = basic;
  for (int m = n; m >= 2; m >>= 1) {
    int h = m >> 1;
    for (int i = 0; i < h; ++i) {
      complex<double> w = omega[inv ? maxn - (i * theta
     % maxn) : i * theta % maxn];
      for (int j = i; j < n; j += m) {
        int k = j + h;
        complex<double> x = a[j] - a[k];
        a[j] += a[k];
        a[k] = w * x;
      }
    }
    theta = (theta * 2) % maxn;
  }
  int i = 0;
  for (int j = 1; j < n - 1; ++j) {
    for (int k = n >> 1; k > (i ^= k); k >>= 1);
    if (j < i) swap(a[i], a[j]);
  }
  if (inv) for (int i = 0; i < n; ++i) a[i] /= (double)
    n;
}
void invfft(vector<complex<double>>& a, int n) {
  fft(a, n, true);
}
```

3.2 Miller Rabin

```
// n < 4759123141   chk = [2, 7, 61]
// n < 1122004669633 chk = [2, 13, 23, 1662803]
// n < 2^64      chk = [2, 325, 9375, 28178, 450775,
    9780504, 1795265022]

long long fpow(long long a, long long n, long long mod)
     {
  long long ret = 1LL;
  for (; n; n >>= 1) {
    if (n & 1) ret = (__int128)ret * (__int128)a % mod;
    a = (__int128)a * (__int128)a % mod;
  }
  return ret;
}
bool check(long long a, long long u, long long n, int t
    ) {
  a = fpow(a, u, n);
  if (a == 0) return true;
  if (a == 1 || a == n - 1) return true;
  for (int i = 0; i < t; ++i) {
    a = (__int128)a * (__int128)a % n;
    if (a == 1) return false;
    if (a == n - 1) return true;
  }
  return false;
}
bool is_prime(long long n) {
  if (n < 2) return false;
  if (n % 2 == 0) return n == 2;
  long long u = n - 1; int t = 0;
  for (; u & 1; u >>= 1, ++t);
  for (long long i : chk) {
    if (!check(i, u, n, t)) return false;
  }
  return true;
}
```

4 Geometry

4.1 Convex Hull

```
typedef pt pair<double, double>
#define first x
#define second y

double cross(const pt& o, const pt& a, const pt& b) {
  return (a.x - o.x) * (b.y - o.y) - (a.y - o.y) * (b.x
     - o.x);
```

```
}

vector<pt> convex_hull(const vector<pt>& p) {
  sort(p.begin(), p.end());
  int m = 0;
  vector<pt> ret(2 * p.size());
  for (int i = 0; i < p.size(); ++i) {
    while (m >= 2 && cross(ret[m - 2], ret[m - 1], p[i
    ]) < 0) --m;
    ret[m++] = p[i];
  }
  for (int i = p.size() - 2, t = m + 1; i >= 0; --i) {
    while (m >= t && cross(ret[m - 2], ret[m - 1], p[i
    ]) < 0) --m;
    ret[m++] = p[i];
  }
  ret.resize(m - 1);
  return ret;
}
```

4.2 Rotating Caliper

```
struct pnt {
  int x, y;
  pnt(): x(0), y(0) {};
  pnt(int xx, int yy): x(xx), y(yy) {};
} p[maxn];

pnt operator-(const pnt &a, const pnt &b) { return pnt(
    b.x - a.x, b.y - a.y); }
int operator^(const pnt &a, const pnt &b) { return a.x
    * b.y - a.y * b.x; } //cross
int operator*(const pnt &a, const pnt &b) { return (a -
     b).x * (a - b).x + (a - b).y * (a - b).y; } //
    distance
int tb[maxn], tbz, rsd;

int dist(int n1, int n2){
  return p[n1] * p[n2];
}
int cross(int t1, int t2, int n1){
  return (p[t2] - p[t1]) ^ (p[n1] - p[t1]);
}
bool cmpx(const pnt &a, const pnt &b) { return a.x == b
    .x ? a.y < b.y : a.x < b.x; }

void RotatingCaliper() {
  sort(p, p + n, cmpx);
  for (int i = 0; i < n; ++i) {
    while (tbz > 1 && cross(tb[tbz - 2], tb[tbz - 1], i
    ) <= 0) --tbz;
    tb[tbz++] = i;
  }
  rsd = tbz - 1;
  for (int i = n - 2; i >= 0; --i) {
    while (tbz > rsd + 1 && cross(tb[tbz - 2], tb[tbz -
     1], i) <= 0) --tbz;
    tb[tbz++] = i;
  }
  --tbz;
  int lpr = 0, rpr = rsd;
  // tb[lpr], tb[rpr]
  while (lpr < rsd || rpr < tbz - 1) {
    if (lpr < rsd && rpr < tbz - 1) {
      pnt rvt = p[tb[rpr + 1]] - p[tb[rpr]];
      pnt lvt = p[tb[lpr + 1]] - p[tb[lpr]];
      if ((lvt ^ rvt) < 0) ++lpr;
      else ++rpr;
    }
    else if (lpr == rsd) ++rpr;
    else ++lpr;
    // tb[lpr], tb[rpr]
  }
}
```