// ========= FFT 傅里叶=========

```
#include <algorithm>
#include <cmath>
using namespace std;
const double PI = acos(-1.0);
struct complex {
  double r,i;
  complex(double _r = 0.0,double _i = 0.0)
  {r = _r; i = _i;}
  complex operator +(const complex &b)
  {return complex(r+b.r,i+b.i);}
  complex operator -(const complex &b)
  {return complex(r-b.r,i-b.i);}
  complex operator *(const complex &b)
  {return complex(r*b.r-i*b.i,r*b.i+i*b.r);}
};
void change(complex y[],int len) {
  int i,j,k;
  for(i = 1, j = len/2;i < len-1; i++)
  {
    if(i < j)swap(y[i],y[j]);
    k = len/2;
    while( j >= k) {j -= k;k /= 2;}
    if(j < k) j += k;
  }
}
void fft(complex y[],int len,int on)
//on==-1 IDFT
{
  change(y,len);
  for(int h = 2; h <= len; h <<= 1)
  {
    complex wn(cos(-on*2*PI/h),sin(-on*2*PI/h));
    for(int j = 0;j < len;j+=h)
    {
      complex w(1,0);
      for(int k = j;k < j+h/2;k++)
      {
        complex u = y[k];
        complex t = w*y[k+h/2];
        y[k] = u+t;
        y[k+h/2] = u-t;
        w = w*wn;
      }
    }
  }
  if(on == -1)
    for(int i = 0;i < len;i++) y[i].r /= len;
}
const int MAXN = 200011;
complex x[MAXN * 4];
LL num[MAXN * 4]; int a[MAXN];
int main() {
  memset(num, 0, sizeof(num));
  for (int i = 0;i < N; i++) {
    scanf("%d", &a[i]);
    num[a[i]]++;
  }
  sort(a, a+N);
  int len_tmp = a[N-1]+1, len = 1;
  while (len < len_tmp*2)
    len <<= 1;
  for (int i=0;i<len;i++)
    x[i] = complex(num[i],0);
  fft(x, len, 1);//DFT
  for(int i = 0;i < len;i++)
    x[i] = x[i]*x[i];
  fft(x, len, -1);//IDFT
  for (int i = 0;i < len;i++)
    num[i] = (LL)round(x[i].r);
  //可能要：求组合而不是求排列
  num[i] /= 2;
  //可能要：扣除 a[i]+a[i]的情况
  num[a[i]+a[i]]--;
  //可能要：扣除带 0 的特殊情况
  Cnt -= (LL)Cnt0 * (N-1) * 2LL;// 0+ai=ai &&
ai+0=ai
  printf("%lld\n", Cnt);      }
```

// =========== Catalan ===========

Catalan 数

Cat[n]=C[2*n][n]/(n+1)

组合性质

Cat[n+1]=sum(Cat[i]*Cat[n-i] for i from 0 to n)

Cat[0]=1, Cat[n+1]=2*(2*n+1)/(n+2)*Cat[n]

Cat[n]为长度为 2*n 的 Dyck 词总数(长度为 2*n 的 Dyck 词由 n 个'X'和 n 个'Y'组成, 对于其任意前缀, 有 count('X')>=count('Y'))

Cat[n]为给长度(n+1)的序列打上括号的不同方案数

Cat[n]为有(n+1)片叶子的不同完全二叉树数

Cat[n]为 n*n 网格线从左下角到右上角不经过左上部分的最短路径数

Cat[n]为用不相交直线将凸(n+2)边形划分为 n 个三角形的方案数

Cat[n]为有 n 个非叶子节点的不同二叉树数

// ========== Combination ==========

```
ll fast_pow(ll x, ll k, ll p);
int Combination(int m, int n, int p){
      ll nom=1, den=1;
      for(int i=m-n+1; i<=m; i++)
      {nom*=i; nom%=p; }
      for(int i=2; i<=n; i++)
      {den*=i; den%=p; }
      den=fast_pow(den, p-2, p);
      return (nom*den)%p;
}
ll C[maxn][maxn];
int Combination_table(int n, ll MOD){
      memset(C, 0, sizeof(C));
      C[0][0]=1;
```

```
	for(int i=1; i<=n; i++){
		C[i][0]=1;
		for(int j=1; j<=i; j++)
		C[i][j]=(C[i-1][j-1]+C[i-1][j])%MOD;
	}
}
```

// ====== cont_frac 连分数逼近 ======

```
ll a[maxn];
/* 连分数逼近由欧几里德算法求解
n/d=a[0]+1/(a[1]+1/(a[2]+1/(a[3]+1/(...+1/ a[len-1]))))  */
int cont_frac(ll n, ll d){
	ll r;
	int len=0;
	while(d){
		a[len++]=n/d;
		r=n%d; n=d; d=r;
	}
	return len;
}
```

// ========== Euler_Phi ==========

```
int euler_phi(int n){
	int m=int(sqrt(n+0.5)), res=n;
	for(int i=2; i<=m; i++) if(n%i==0){
		res=res/i*(i-1);
		while(n%i==0) n/=i;
	}
	if(n>1) res=res/n*(n-1);
	return res;
}
int phi[maxn];
void phi_table(int n){
	memset(phi, 0, sizeof(phi));
	phi[1]=1;
	for(int i=2; i<=n; i++) if(!phi[i])
		for(int j=i; j<=n; j+=i){
			if(!phi[j]) phi[j]=j;
			phi[j]=phi[j]/i*(i-1);
		}
}
```

// ======== Fibonacci 数 ========

F[0]=F[1]=1;
F[n]=F[n-1]+F[n-2];
组合性质
F[n]=sum(C[n-k-1][k] for k=0 to floor((n-1)/2))
C[i][j]表示组合数
sum(F[i] for i=1 to n)=F[n+2]-1
sum(F[2*i+1] for i=0 to n-1)=F[2*n]
sum(F[2*i] for i=1 to n)=F[2*n+1]-1
sum(F[i]*F[i] for i=1 to n)=F[n]*F[n+1]
Catalan 性质:
F[n]*F[n]-F[n-r]*F[n+r]=(-1)^(n-r)*F[r]*F[r]
Vajda 性质: F[n+i]*F[n+j]-F[n]*F[n+i+j]=(-1)^n*F[i]*F[j]
d'Ocagne 性质:
F[k*n+c]=sum(C[k][i]*F[c-i]*F[n]^i*F[n+1]^(k-i) for i=0 to k)

母函数: s(x)=sum(F[k]*x^k for k=0 to infinity)=x/(1-x-x^2)
数论性质:
gcd(F[m], F[n])=F[gcd(m, n)]
整数 N 为 Fibonacci 数的充要条件为 5*N^2+4 或 5*N^2-4 为完全平方数
p|F[p-(5/p)] (此处括号为 Legendre 标记)
如果从 1 开始计数, 则除了 F[4]=3 以外, 若下标 n 为合数则 F[n]也为合数
除了 1 以外 Fibonacci 数中仅有 8 和 144 为整次方数
除了 1, 8, 144, 所有 Fibonacci 数都有至少一个质因数不在所有比其下标更小的 Fibonacci 数的质因数的集合中
若构造一数列 A[i]=F[i]%n, n 为任意正整数, 则数列 A 有周期性且其周期不超过 6*n

// ============ primes ============

Legendre 符号 (p 为质数)
(a|p)=0 if a%p=0
(a|p)=1 if a%p!=0 and 存在整数 x x^2=a (mod p)
(a|p)=-1 otherwise
Euler 准则: 若 p 为奇质数且 p 不能整除 d 则 d^((p-1)/2)=(d|p) (mod p)
Legendre 符号是完全积性函数
二次互反律: 若 p, q 为奇质数, 则(q|p)=(p|q)*(-1)^((p-1)/2*(q-1)/2)

Mersenne 数
M[n]=2^n-1
Euclid-Euler 定理: 若 M[p]为素数, 则(2^p-1)*2^(p-1)为完全数
若 p 为奇质数, 则 M[p]的所有质因子模 2*p 同余 1
若 p 为奇质数, 则 M[p]的所有质因子模 8 同余 +/-1
M[m]与 M[n]互质的充要条件为 m 与 n 互质
若 p 与 2*p+1 皆为素数且 p 模 4 同余 3, 则(2*p+1)为 M[p]的因子

Wilson 定理
大于 1 的自然数 n 为素数的充要条件为(n-1)!=-1 (mod n)

Fermat 多边形数定理
每一个正整数最多可以表示为 n 个 n 边形数之和

Euler 引理
对于任意奇素数 p, 同余方程 x^2+y^2+1=0 (mod p) 必有一组正整数解(x, y)满足 0<=x<p/2, 0<=y<p/2
Lagrange 的四平方和定理
每个正整数均可以表示为 4 个整数的平方和

// ============ log_mod ============

```
//解方程 a^x=b (mod n) n 为素数
int shank(int a, int b, int n){
	int m, v, e=1, i;
	m=int(sqrt(n+0.5));//复杂度为 O((m+n/m)logm) 所以 m==n/m 时最快
	v=inv(fast_pow(a, m, n), n);//fast_pow(a, m, n)=(a^m)%n
	map<int, int> x;//x[j]=min(i|e[i]==j)
	x[1]=0;
	for(int i=1; i<m; i++){
		e=a*e%n;//e=(a^i)%n
		if(!x.count(e)) x[e]=i;
	}
	for(int i=0; i<m; i++){
		//a^(im)到 a^(im+m-1)
		if(x.count(b)) return i*m+x[b];
		b=b*v%n;//递推更新 b
	}
	return -1;//无解
}
```

// ============ matrix ============

```
struct parametre{int c, r;};
struct Matrix{
   long long matrix[maxn][maxn];
   parametre DIM;
   Matrix(){}
   Matrix(int c, int r){
      DIM={c, r};
      memset(matrix, 0, sizeof(matrix));
   }
   Matrix operator*(Matrix &A){
      Matrix C(DIM.c, A.DIM.r);
      memset(C.matrix, 0, sizeof(C.matrix));
      for(int i=0; i<DIM.c; i++)
         for(int j=0; j<A.DIM.r; j++)
            for(int k=0; k<DIM.r; k++)
C.matrix[i][j]=(C.matrix[i][j]+A.matrix[i][k]*matrix[k][j])%MOD;
      return C;
   }
   Matrix operator+(Matrix &A){
      Matrix C(A.DIM.c, A.DIM.r);
      for(int i=0; i<DIM.c; i++)
         for(int j=0; j<DIM.r; j++)
         C.matrix[i][j]=A.matrix[i][j]+matrix[i][j];
      return C;
   }
   void print(){
      for(int i=0; i<DIM.c; i++){
         for(int j=0; j<DIM.r; j++)
cout<<matrix[i][j]<<'\t';
         cout<<endl;
      }
   }
};
Matrix BigMatrixExpo(Matrix &A, long long n){
   Matrix B=A;
   Matrix C(A.DIM.c, A.DIM.r);
   for(int i=0; i<C.DIM.c; i++)
      for(int j=0; j<C.DIM.r; j++)
         C.matrix[i][j]=i==j;
   while(n){
      if(n&1) C=C*B;
      B=B*B;
      n>>=1;
   }
   return C;
}
//定义新矩阵 Matrix a(3, 5); a.matrix={{},{},{}};
//乘法 c=a*b; 注意 a 的第一个 parametre 等于 b 的第二个 parametre;
//加法 c=a+b;  //输出 c.print();
```

// ============ 莫比乌斯 ============

```
//完全积性函数 mo[i*j]=mo[i]*mo[j]
//sum(mo[d] for d|n)=(n==1)
//反演公式
//若 f(n)=sum(g(d) for d|n) 则 g(n)=sum(mo[n/d]*f(d) for d|n)=sum(mo[d]*f(n/d) for d|n)
//If f(i)=sum(g(d*i) for d from 1 to floor(n/i)) then g(i)=sum(f(d*i)*mo[d] for d from 1 to floor(n/i))
bool vis[maxn+123];
int mo[maxn+123], primes[maxn+123], a[maxn+123], pcnt, N;
void mobius(){//预处理
	mo[1]=1;
	for(int i=2; i<=maxn; i++){
		if(!vis[i])
		{ mo[i]=-1; primes[pcnt++]=i; }
		for(int j=0; j<pcnt&&ll(i)*primes[j]<=maxn; j++){
			vis[i*primes[j]]=true;
			if(i%primes[j]) mo[i*primes[j]]=-mo[i];
			else{
				mo[i*primes[j]]=false;
				break;
			}
		}
	}
	for(int i=2; i<=maxn; i++) mo[i]+=mo[i-1];//mo 记录前缀和
}
```

```
//O(sqrt(n)+sqrt(m))
ll cnt_gcd(ll n, ll m, ll k){//for i from 1 to n for j from 1 to m cnt gcd(i, j)=k
	if(n>m) swap(n, m);
	ll res=0;
	n/=k, m/=k;
	for(int i=1, j=1; i<=n; i=j+1){
		j=min(n/(n/i), m/(m/i));
		res+=ll(mo[j]-mo[i-1])*(n/i)*(m/i);//前缀和 Mobius
	}
	return res;
}
```

// =========== 高斯消元 ============

```
typedef int Matrix[maxn][maxn];
void exgcd(int a, int b, int& d, int& x, int& y){
	!b?(d=a, x=1, y=0):(exgcd(b, a%b, d, y, x), y-=x*(a/b));
}
int inv(int a){
	int d, x, y;
	exgcd(a, MOD, d, x, y);
	return d==1?(x+MOD)%MOD:-1;
}
int gauss_jordan(Matrix A, int n, int m){//A 是增广矩阵, n 个未知数, m 个方程, MOD 是模, 如果 MOD 不是质数的话每次 inv 完先检测是否是-1
	int i=0, j=0;
	while(i<m&&j<n){
		int row=i;
		for(int k=i; k<m; k++){
			if(A[k][j]){
				row=k;
				break;
			}
		}
		if(row!=i) for(int k=0; k<=n; k++)
			swap(A[i][k], A[row][k]);
		if(!A[i][j]){
			j++; continue;
		}
		for(int k=0; k<m; k++){
			if(!A[k][j]||i==k) continue;
			int cur=A[k][j]*inv(A[i][j])%MOD;
			for(int t=j; t<=n; t++)
			A[k][t]=( (A[k][t]-cur*A[i][t])%MOD+MOD)%MOD;
		}
		i++;
	}
	for(int k=i; k<m; k++)
		if(A[k][n]) return -1;//无解
	if(i<n) return 0;//无限解
	for(int k=0; k<n; k++)
		A[k][n]=A[k][n]*inv(A[k][k])%MOD;
	//解存在 A[k][n]里面
	return 1;
}
```

// ======= pell equation 佩尔方程======

```
//用于求解标准型 Pell 方程的第(k+1)组非平凡解 (x^2-n*y^2=1)
//输入 n, k 和 MOD
//递推关系为 x[i+1]=x[0]*x[i]+n*y[0]*y[i];
//y[i+1]=y[0]*x[i]+x[0]*y[i];
//上述递推关系可由 sqrt(n)的连分数表示推出
typedef pair<ll, ll> pii;
pii res;//(xk, yk)
ll MOD;//模<必须是全局变量>
void Find(ll n, ll& x, ll& y){
	//暴力寻找特解(x0, y0)
	y=1;
	while(true){
		x=sqrt(y*y*n+1);
		if(x*x-n*y*y==1) break;
		y++;
	}
}
struct parameter{int c, r;};
struct Matrix{
  ll matrix[maxn][maxn];
  parameter DIM;
  Matrix(){}
  Matrix(int c, int r);
  Matrix operator*(Matrix &A);//带模乘法
  Matrix operator+(Matrix &A);
  void print();
};
Matrix BigMatrixExpo(Matrix &A, ll n);//带模快速幂
bool Pell(ll n, ll k){//k 为第 k 组解, 从 0 开始数
	ll t=sqrt(n)+0.5, x, y;
	if(t*t==n) return false;//仅有平凡解 (1, 0) 和 (-1, 0)
	Matrix A(2, 2);
	Find(n, x, y);
	A.matrix[0][0]=A.matrix[1][1]=x;
	A.matrix[0][1]=n*y;
	A.matrix[1][0]=y;
	A=BigMatrixExpo(A, k-1);
	res=make_pair((A.matrix[0][0]*x+A.matrix[0][1]*y)%MOD, (A.matrix[1][0]*x+A.matrix[1][1]*y)%MOD);
	return true;
}
```

```
// ============ CRT===========
typedef long long ll;
//n 个方程为 x=a[i] (mod m[i])
ll china(int n, int* a, int* m){
	ll M=1, d, y, x=0;//M 是等价以后的模
	for(int i=0; i<n; i++) M*=m[i];
	for(int i=0; i<n; i++){
		ll w=M/m[i];
		exgcd(m[i], w, d, d, y);
		x=(x+y*w*a[i])%M;
	}
	return (x+M)%M;
}
// ============ Fraction ===========
ll gcd(ll a, ll b){ return !b?a:gcd(b, a%b); }
struct fraction{
ll num, den;
fraction(){ num=0; den=1; }
fraction(ll a, ll b)
{num=a; den=b; simplify();}
inline void reset(){ num=0; den=1;}
void simplify(){
		ll d=gcd(num, den);
		num/=d;
		den/=d;
		if(den<0){num=-num;den=-den;}
}
inline ll convert(){return num/den;}
fraction& operator = (int rhs){
		(*this).num=rhs;
		(*this).den=1;
		return *this;
}
fraction operator + (const fraction &rhs) const{
		fraction res;
		res.den=lcm(den, rhs.den);
res.num=res.den/den*num+res.den/rhs.den*rhs.n
um;
		res.simplify();
		return res;
}
fraction operator += (const fraction &rhs)
{return *this=*this+rhs;}
fraction operator + (const int &rhs) const{
		fraction r(rhs, 1);
		return *this+r;
}
fraction operator += (const int &rhs)
{return *this=*this+rhs;}
fraction operator - (const fraction &rhs) const{
		fraction res;
		res=*this+fraction(-1, 1)*rhs;
		res.simplify();
		return res;
}
fraction operator -= (const fraction &rhs)
{return *this=*this-rhs;}
fraction operator - (const int &rhs) const
{fraction r(rhs, 1);return *this-r;}
fraction operator -= (const int &rhs)
{return *this=*this-rhs;}
fraction operator * (const fraction &rhs) const{
		fraction res;
		res.num=num*rhs.num;
		res.den=den*rhs.den;
		res.simplify();
		return res;
}
fraction operator *= (const fraction &rhs)
{return *this=(*this)*rhs;}
fraction operator * (const int &rhs) const
{fraction r(rhs, 1); return (*this)*r;}
fraction operator *= (const int &rhs)
{return *this=(*this)*rhs;}
fraction operator / (const fraction &rhs) const{
		fraction res;
		res.num=num*rhs.den;
		res.den=den*rhs.num;
		res.simplify();
		return res;
}
fraction operator /= (const fraction &rhs)
{return *this=(*this)/rhs;}
fraction operator / (const int &rhs) const
{ fraction r(rhs, 1); return (*this)/r; }
fraction operator /= (const int &rhs)
	{return *this=(*this)/rhs;}
bool operator == (const fraction &rhs) const
	{return num*rhs.den==den*rhs.num;}
bool operator == (const int &rhs) const
	{return num==den*rhs;}
bool operator != (const fraction &rhs) const
	{return !(*this==rhs);}
bool operator != (const int &rhs) const
	{return !(*this==rhs);}
bool operator < (const fraction &rhs) const
	{return num*rhs.den<den*rhs.num;}
bool operator < (const int &rhs) const
	{return num<den*rhs;}
bool operator > (const fraction &rhs) const
	{return num*rhs.den>den*rhs.num;}
bool operator > (const int& rhs) const
	{return num>den*rhs;}
bool operator <= (const fraction &rhs) const
	{return *this==rhs||*this<rhs;}
bool operator <= (const int& rhs) const
	{return *this==rhs||*this<rhs;}
bool operator >= (const fraction &rhs) const
	{return *this>rhs||*this==rhs;}
bool operator >= (const int &rhs) const
	{return *this>rhs||*this==rhs;}
};
```

// ========= 辛普森积分 =========

```
double simpson(double a, double b) {
        double c = (a + b) / 2.0;
        return (F(a)+4*F(c)+F(b)) * (b-a) / 6.0;
} // 这里 F 为自定义函数
//given A as the simpson Value for the whole interval [a,b]
double asr(double a, double b, double eps, double A) {
        double c = (a + b) / 2.0;
        double L = simpson(a, c) ;
        double R = simpson(c, b);
        if  (fabs(L+R-A) <= 15*eps)
                return L + R + (L+R-A)/15.0;
return asr(a, c, eps/2, L) + asr(c, b, eps/2, R);
}
double asr(double a, double b, double eps)
{ return asr(a, b, eps, simpson(a, b)); } //接口
// int main(): 调用 asr(left, right, 1e-5)
// 得到 F(x) 在[left, right]上的积分 eps 也可改为 1e-6
```

// ============ 凸包 ============

```
const double eps=1e-10;
const double PI=acos(-1);
struct Point{  double x, y;
   Point(double x=0, double y=0):x(x), y(y){}
} p[maxn], ch[maxn];
typedef Point Vector;
Vector operator + (Vector A, Vector B)
        { return Vector(A.x+B.x, A.y+B.y); }
Vector operator - (Vector A, Vector B)
        { return Vector(A.x-B.x, A.y-B.y); }
Vector operator * (Vector A, double p)
        { return Vector(A.x*p, A.y*p); }
Vector operator / (Vector A, double p)
        { return Vector(A.x/p, A.y/p); }
int dcmp(double x) {
   if(fabs(x) < eps) return 0;
   else return x < 0 ? -1 : 1; }
bool operator == (const Point& a, const Point& b)
{ return dcmp(a.x-b.x) == 0 && dcmp(a.y-b.y) == 0; }
bool operator < (const Point& a, const Point& b)
{ return a.x < b.x || (a.x == b.x && a.y < b.y); }

double cross(Vector A, Vector B)
        { return A.x*B.y - A.y*B.x; }
double torad(double deg)
        { return deg / 180 * PI; }
double PolygonArea(Point* p, int n){
   double area=0;
   for(int i=1; i<n-1; i++)
      area+=cross(p[i]-p[0], p[i+1]-p[0]);
   return area/2;
}
int convexhull(Point* p, int n, Point* ch) {
   sort(p, p+n);
   int m = 0;
   for(int i = 0; i < n; i++) {
      while(m > 1 && cross(ch[m-1]-ch[m-2], p[i]-ch[m-2]) <= 0) m--;
      ch[m++] = p[i];
   }
   int k = m;
   for(int i = n-2; i >= 0; i--) {
      while(m > k && cross(ch[m-1]-ch[m-2], p[i]-ch[m-2]) <= 0) m--;
      ch[m++] = p[i];
   }
   if(n > 1) m--; return m;
}
Vector Rotate(Vector A, double rad){
        // 这里 rad 是逆时针旋转的角度
        return Vector(A.x*cos(rad)-A.y*sin(rad),
        A.x*sin(rad)+A.y*cos(rad));
}
// int main()
Point o(tmpx, tmpy);
p[point_cnt++]=o; ... ...
int m=convexhull(p, point_cnt, ch);
double convex_area=PolygonArea(ch, m);
// Rotate vector(10,10) clockwise by 90 degree
// new_o = o + Rotate(Vector(10.0,10.0),-torad(90.0));
```

// ========== 点在多边形内 ==========

```
bool PNPoly(int u, int deg) {
        if (!  (vertxmin <= x[u] <= vertxmax)  ||  ! ( vertymin <= y[u] <= vertymax ) ) return 0;
        bool is_in = 0;  int i,j;
        for(i=0;i<deg;i++) {
        if(!i) j= deg-1;
        else  j= i-1;
        if ( ((poy[i] > y[u]) != (poy[j] > y[u])) && (x[u] < (pox[j] - pox[i]) * (y[u] - poy[i]) / (poy[j] - poy[i]) + pox[i]) )
                        is_in = ! is_in;
        }
        return is_in;
}
```