

Algorithm Library

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Contents

1	头文件	4
2	暴力	4
2.1	枚举	4
2.2	子集生成	4
2.3	回溯	4
3	搜索	5
3.1	三分法	5
3.2	dfs	5
3.3	bfs	6
4	数据结构	7
4.1	并查集	7
4.2	heap	7
4.3	二叉树	7
4.3.1	各种遍历及合成	7
5	动态规划	8
5.1	背包	8
5.1.1	01 背包	8
5.1.2	多重背包	9
5.2	背包-其他	10
5.3	最长公共子序列	10
5.4	最长上升子序列	11
5.5	最长公共上升	13
5.6	maxsubsum	13
5.7	maxsubmatsum	14
5.8	tsp	14
5.9	拆分方案数	15
6	图论	15
6.1	tree	15
6.2	拓扑排序	15
6.3	单源最短路径	16
6.3.1	Bellman-Ford	16
6.3.2	Dijkstra	17
6.4	多源最短路径	18
6.4.1	Floyd	18
6.5	最小生成树	19
6.5.1	Prim	19
6.5.2	Kruskal	21

7 数论	22
7.1 进制转换	22
7.2 gcd	22
7.3 改进素数筛	23
7.4 模线性方程	23
7.5 中国剩余定理	24
7.6 快速幂	24
8 字符串	24
8.1 字典树	24
8.2 KMP	25
8.3 hash	26
8.4 表达式计算	26
8.4.1 前缀表达式	26
8.4.2 中缀表达式	28
8.5 find longest shortest word	29
9 bigint	30
10 others	33
10.1 funcs	33
10.2 vim	35

1 头文件

```
#include<iostream>
#include<cstdio>
#include<cmath>
#include<cstdlib>
#include<cstring>
#include<string>
#include<vector>
#include<stack>
#include<queue>
#include<set>
#include<map>
#include<algorithm>
using namespace std;
typedef long long ll;
typedef unsigned long long ull;
```

2 暴力

2.1 枚举

```
do{
    for(int i=0;i<n;++i) cout<<num[i]<<endl;
}while(next_permutation(num,num+n));    //prev_permutation
```

2.2 子集生成

```
void print_subset(int *A,int *B,int n,int cur){
    if(cur==n){
        for(int i=0;i<n;++i) if(B[i]) printf("%d ",A[i]);
        ↪ printf("\n");
        return;
    }
    B[cur]=0; print_subset(A,B,n,cur+1);
    B[cur]=1; print_subset(A,B,n,cur+1);
}
```

2.3 回溯

```
int vis[maxn];
void bt(int cur) { // (int x,int y)
    if(cur==n){
```

```
    }  
    for(int i=0;i<4;++i){  
        //改变  
  
        bt(cur+dx[i])  
  
        //恢复  
    }  
}
```

3 搜索

3.1 三分法

```
double ternarySearch(double low, double high)  
{  
    double mid, midmid;  
    while (low + EPS < high)  
    {  
        mid = (low + high) / 2;  
        midmid = (mid + high) / 2;  
        double mid_value = calc(mid);  
        double midmid_value = calc(midmid);  
        if (mid_value > midmid_value)  
            high = midmid;  
        else  
            low = mid;  
    }  
    return low;  
}
```

3.2 dfs

```
int cnt,vis[maxn][maxn];  
void dfs(int x,int y,int id){  
    // 判读边界  
    dfs(nx,ny,id);  
}  
  
for(int i=0;i<n;++i){  
    for(int j=0;j<n;++j){  
        if(!vis[i][j]){  
            vis[i][j]=1;  
            dfs(i,j,++cnt);  
        }  
    }  
}
```

```
        //vis[i][j]=0;
    }
}
//template
int search(int t)
{
    if(满足输出条件)
    {
        输出解;
    }
    else
    {
        for(int i=1;i<=尝试方法数;i++)
            if(满足进一步搜索条件)
            {
                为进一步搜索所需要的状态打上标记;
                search(t+1);
                恢复到打标记前的状态; //也就是说的 {回溯一步}
            }
    }
}
```

3.3 bfs

```
queue<int> que;
int vis[maxn];
while(que.size()) que.pop();
memset(vis,0,sizeof(vis));
que.push(0); vis[0]=1;
void bfs(){
    while(que.size()){
        int x=que.front(); que.pop();
        for( ){
            vis[ ]=1; //每加入队列就标记
            que.push( );
        }
    }
}
//template
int search()
{
    while(!que.empty)
    {
```

```

node cur = que.front(); que.pop();
    for(int i=1; i<=尝试方法数; i++)
    {
        node next = cur + ...
        if(next 满足进一步搜索条件)
        {
            que.push(next); //为进一步搜索所需要的状态打上标
                               ↪ 记;
            进行当前步的操作
        }
    }
}

```

4 数据结构

4.1 并查集

```

const int maxn=1010;
int fa[maxn]; //memset(fa,-1,sizeof(fa));
findroot(int x){
    if(fa[x]==-1) return x;
    return fa[x]=findroot(fa[x]);
}

void Union(int x,int y){
    x=findroot(x); y=findroot(y);
    if(x!=y) fa[x]=y;
}

```

4.2 heap

```

vector<int> vec;
make_heap(vec.begin(),vec.end(),greater<int>());
    for(int i=k;i<n;++i){
        int x; cin>>x;
        if(*vec.begin()<x){
            ↪ pop_heap(vec.begin(),vec.end(),greater<int>());{
                cout<<"before pop "<<*(vec.end()-1)<<endl;
                vec.pop_back();
                cout<<"after pop "<<*(vec.end()-1)<<endl;
            }
            cout<<"before push "<<*(vec.end()-1)<<endl;

```

```

        vec.push_back(x);
        ⇨ push_heap(vec.begin(),vec.end(),greater<int>());
        cout<<"after push "<<*(vec.end()-1)<<endl;
    }
}
sort_heap(vec.begin(),vec.end(),greater<int>());
cout<<*(vec.end()-1)<<endl;

```

4.3 二叉树

4.3.1 各种遍历及合成

```

struct node{
    node *lc,*rc;
    char ch;
} nodes[maxn];

void preord(node *t){
    if(t==0) return;
    printf("%d",t->id);
    preord(t->lc); preord(t->rc);
}

int cur=0,idx=0;
node * newnode(){
    nodes[cur].lc=nodes[cur].rc=0;
    nodes[cur].ch=s[idx++];
    return &nodes[cur++];
}

node *build(){
    if(idx==len) return 0;
    char ch=s[idx];
    if(ch=='#') {++idx; return 0;}
    node *t=newnode();
    t->lc=build();
    t->rc=build();
    return t;
}

char s1[maxn],s2[maxn];
node *build(int l1,int r1,int l2,int r2){
    int idx;
    node *t=newnode(); t->ch=s1[l1];
    if(idx!=l2) t->lc=build(l1+1,idx-l2+l1+1,l2,idx);
    if(idx!=r2-1)t->rc=build(idx-l2+l1+1,r1,idx,r2);
}

```



```
    return t;
}
```

5 动态规划

5.1 背包

5.1.1 01 背包

```
int wei[maxn], val[maxn], dp[maxn], c;
memset(dp, 0, sizeof(dp)); //若要恰好放满 则 dp[0]=0 其余为负无
    ↪ 穷
for(int i=0; i<n; ++i){           //若 c 较小, n 较大, 可调整
    ↪ i, j 的内外顺序
    for(int j=c; j>=wei[i]; --j){ //完全背包的话, j 顺序反过来即
        ↪ 可
        dp[j]=max(dp[j], dp[j-wei[i]]+val[i]);
    }
}
```

5.1.2 多重背包

```
//HDU-2191
#include <stdio>
const int maxn = 110;
int dp[maxn];
struct rice{
    int p;
    int h;
    int c;
} r[maxn];
int V;
int max(int a, int b) { return a > b ? a : b; }
void ZeroOnePack(int cost, int value){
    for (int v = V; v >= cost; v--){
        dp[v] = max(dp[v], dp[v - cost] + value);
    }
}
void CompletePack(int cost, int value){
    for (int v = cost; v <= V; v++){
        dp[v] = max(dp[v], dp[v - cost] + value);
    }
}
void MultiplePack(int cost, int value, int amount){
```

```

    if (cost*amount >= V){
        CompletePack(cost, value);
        return;
    }
    else{
        int k = 1;
        while(k<amount){
            ZeroOnePack(k * cost, k * value);
            amount -= k;
            k *= 2;
        }
        ZeroOnePack(amount * cost, amount * value);
    }
}

int main(){
    int c, m;
    scanf("%d", &c);
    while(c--){
        scanf("%d%d", &V, &m);
        for (int i = 1; i <= m; i++){
            scanf("%d%d%d", &r[i].p, &r[i].h, &r[i].c);
        }
        for (int v = 0; v <= V; v++){
            dp[v] = 0;
        }
        for (int i = 0; i <= m; i++){
            MultiplePack(r[i].p, r[i].h, r[i].c);
        }
        printf("%d\n", dp[V]);
    }
    return 0;
}

```

5.2 背包-其他

```

//double cost bag(3d)
f[i][v][u]=max(f[i-1][v][u],f[i-1][v-a[i]][u-b[i]]+w[i])
//double cost bag(2d)
for v=V...cost
    for u=U...cost
        f[v][u]=max(f[u][v],f[u-ucost[i]][v-vcost[i]]+w[i])

//group bag
for group in groups

```

```

        for v=V...0
            for i in group
                f[v]=max(f[v],f[v-c[i]]+w[i])

//optimize
if cost[i]<=cost[j] && weight[i]==weight[j]
    remove item[j]

```

5.3 最长公共子序列

```

char s1[maxn],s2[maxn];
int dp[maxn][maxn];
for(int i=1;i<=n1;++i){ //从 1 开始存
    for(int j=1;j<=n2;++j){
        if(s1[i]==s2[j]) dp[i][j]=dp[i-1][j-1]+1;
        else dp[i][j]=max(dp[i-1][j],dp[i][j-1]);
    }
}

int i=n1,j=n2,path[maxn],k=-1;
while(dp[i][j]){
    if(dp[i-1][j]==dp[i][j]) --i;
    else if(dp[i][j-1]==dp[i][j]) --j;
    else {
        path[++k]=i;
        --i; --j;
    }
}
for(;k;--k) cout<<s1[path[k]]<<" ";
cout<<s1[path[0]]<<endl;

//两个相同列打乱范围求 lcs(在映射中求 lis)
int b[N],idx[N],n;
int read(){
    int x=0,f=1;char ch=getchar();
    while (ch<'0' || ch>'9'){if (ch=='-')f=-1;ch=getchar();}
    while ('0'<=ch &&
        ↪ ch<='9'){x=(x<<3)+(x<<1)+(ch^48);ch=getchar();}
    return x*f;
}

int main(){
    n=read();
    memset(b,0x3f,sizeof(b));

```

```
    for (int i=1;i<=n;i++)
        idx[read()]=i;
    for (int i=1;i<=n;i++){
        int x=idx[read()];
        *lower_bound(b+1,b+n+1,x)=x;
    }
    printf("%d",lower_bound(b+1,b+n+1,b[0])-b-1);
    return 0;
}
```

5.4 最长上升子序列

```
int n,num[1010],dp[1010];
const int inf=10000000;
int lis(){ // nlogn 但是不能打印路径
    fill(dp,dp+n,inf);
    for(int i=0;i<n;++i){
        *lower_bound(dp,dp+n,num[i])=num[i];
    }
    return lower_bound(dp,dp+n,inf)-dp;
}

int n,num[maxn],dp[maxn],pre[maxn]; //n^2 能打印路径
int ans,idx;
void lis(){
    memset(pre,-1,sizeof(pre));
    for(int i=0;i<n;++i){
        dp[i]=0;
        for(int j=0;j<i;++j){
            if(num[i]>num[j]&&dp[j]+1>dp[i]){
                dp[i]=dp[j]+1;
                pre[i]=j;
                if(dp[i]>ans){
                    ans=dp[i];
                    idx=i;
                }
            }
        }
    }
}

//safe
void lis(){
    for(int i=0;i<n;++i){
```

```

        dp[i]=0;
        pre[i]=-1;
    }
    for(int i=0;i<n;++i){
        for(int j=0;j<i;++j){
            if(num[i]>num[j]&&dp[j]+1>dp[i]){
                dp[i]=dp[j]+1;
                pre[i]=j;
            }
        }
    }
    ans=dp[0];
    for(int i=1;i<n;++i){
        if(dp[i]>ans){
            ans=dp[i];
            idx=i;
        }
    }
}

void print(int i){
    if(pre[i]!=-1) print(pre[i]);
    printf("%d",num[i]);
}

int main(){
    while(scanf("%d",&n)==1){
        for(int i=0;i<n;++i) scanf("%d",&num[i]);
        lis();
        printf("%d\n",ans);
        print(idx);
        printf("\n");
    }
    return 0;
}

```

5.5 最长公共上升

```

int
↪ n,m,num1[maxn],num2[maxn],pre[maxn],dp[maxn],ans,Max,last,idx;
void lcis(){
    ans=0;
    memset(dp,0,sizeof(dp));
    memset(pre,-1,sizeof(pre));
    for(int i=0;i<n;++i){
        Max=0;

```

```
for(int j=0;j<m;++j){ //dp[j] 表示串 1 的前 i 个和串的
    ↪ 前 j 个, 且以 num2[j] 结尾
    if(num1[i]>num2[j]) {
        Max=max(Max,dp[j]); //最大的 dp[i-1][k]
        last=j;
    }
    if(num1[i]==num2[j]) {
        dp[j]=Max+1;
        pre[j]=last;
    }
    if(dp[j]>ans){
        ans=dp[j];
        idx=j;
    }
}
}
}
void print(int idx){
    if(pre[idx]!=-1) print(pre[idx]);
    printf("%d",num2[idx]);
}
```

5.6 maxsubsum

```
int max_sub_sum(int *line,int *dp,int n){
    fill(dp,dp+n,0);
    dp[0]=line[0];
    for(int i=1;i<n;++i) dp[i]=max(dp[i],dp[i-1]+line[i]);
    int res=-inf;
    for(int i=0;i<n;++i) res=max(res,dp[i]);
    return res;
}
```

5.7 maxsubmatsum

```
for(int i=0;i<n;++i) {
    for(int j=0;j<n;++j) scanf("%d",&mat[i][j]);
}
fill(tot[0],tot[0]+n,0);
for(int i=1;i<=n;++i){
    for(int j=0;j<n;++j) tot[i][j]=tot[i-1][j]+mat[i-1][j];
}
int res=-inf;
for(int i=0;i<n;++i){
```

```
    for(int j=i+1;j<=n;++j){
        for(int k=0;k<n;++k) line[k]=tot[j][k]-tot[i][k];
        res=max(res,max_sub_sum(line,dp,n));
    }
}
```

5.8 tsp

```
int solve(){ //上回到起始点, 如果需要回到起始点,
    int s;
    for( s=0;s< (1<<n)-1;++s) fill(dp[s],dp[s]+n,inf);
    fill(dp[s],dp[s]+n,0);
    for(s=(1<<n)-2;s>0;--s){
        for(int u=0;u<n;++u ){
            if((s&(1<<u))==0) continue;
            for(int v=0;v<n;++v){
                if(s&(1<<v)) continue;

                ⇨ dp[s][u]=min(dp[s][u],dp[s|(1<<v)][v]+mat[u][v]);
            }
        }
    }
    s=1;
    int res=inf;
    for(int i=0;i<n;++i){
        res=min(res,dp[s][i]);
        s<<=1;
    }
    return res;
}
```

5.9 拆分方案数

```
void cnt(){
    fill(dp,dp+m+1,0); dp[0]=1; //恰好凑齐
    for(int i=0;i<n;++i){
        for(int j=m;j>=num[i];--j){
            dp[j]=(dp[j-num[i]]+dp[j]);
        }
    }
}
```

6 图论

6.1 tree

```
const int maxn=110;
int lc[maxn],rc[maxn],p[maxn]; //若节点编号严格是 1-n
int n,m;
```

```
const int maxn=1010;
struct node{
    int val;
    node *lc,*rc;
} nodes[maxn];
int cur=0;
node *newnode(int v=0){
    nodes[cur].val=v;
    nodes[cur].lc=nodes[cur].rc=0;
    return &nodes[cur++];
}
```

6.2 拓扑排序

```
const int maxn=510;
vector<int> edges[maxn],ans;
int ind[maxn],n,m,used[maxn];
int dfs(int k){ // void dfs(int k) 只输出一组值 后面 return 处
    ↪ 也要修改
    if(k==n){
        for(int i=0;i<n-1;++i) printf("%d ",ans[i]);
        printf("%d\n",ans[n-1]);
        return 1;
    }
    for(int i=1;i<=n;++i){
        if(!ind[i]&&!used[i]){
            used[i]=1; ans.push_back(i);
            for(int j=0;j<edges[i].size();++j)
                ↪ ind[edges[i][j]]--;
            if(dfs(k+1)) return 1;
            for(int j=0;j<edges[i].size();++j)
                ↪ ind[edges[i][j]]++;
            used[i]=0; ans.pop_back();
        }
    }
```



```
    }  
    return 0;  
}
```

6.3 单源最短路径

6.3.1 Bellman-Ford

```
const int maxm=5210,maxn=510;  
struct edge{  
    int u,v,c;  
}edges[maxm];  
  
int e,n,dis[maxn];  
bool bellman(){  
    const int inf=100000000; //不能用-1, 在判断负环时有问题  
    fill(dis,dis+n,inf);  
    dis[1]=0;  
    for(int i=0;i<n;++i){  
        for(int j=0;j<e;++j){  
            edge eg=edges[j];  
            if(dis[eg.v]>dis[eg.u]+eg.c){  
                dis[eg.v]=dis[eg.u]+eg.c;  
                if(i==n-1) return 1;  
            }  
        }  
    }  
    return 0;  
}  
  
void bellman(){ //无负边  
    const int inf=100000000;  
    fill(dis,dis+n,inf);  
    dis[1]=0;  
    while(1){  
        int update=0;  
        for(int i=0;i<e;++i){  
            edge eg=edges[i];  
            if(dis[eg.v]>dis[eg.u]+eg.c){  
                dis[eg.v]=dis[eg.u]+eg.c;  
                update = 1;  
            }  
        }  
        if(!update) break;
```

```
    }
}
```

6.3.2 Dijkstra

```
struct edge{
    int to,w;
    bool operator<(const edge&b) const {return w>b.w;}
    edge(){to=w=0;}
    edge(int to,int w){this->to=to; this->w=w;}
};
const int maxn=1010,inf=1000000;
vector<edge> edges[maxn];
int n,dis[maxn],cnt[maxn]; //如不计最短路径数不需要 cnt
priority_queue<edge> que;
void dijkstra(int s){
    while(que.size()) que.pop();
    fill(dis,dis+n+1,inf); //根据情况修改
    que.push(edge(s,0)); dis[s]=0;
    while(que.size()){
        edge eg=que.top(); que.pop();
        int u=eg.to;
        if(eg.w!=dis[u]) continue;
        for(int i=0;i<edges[u].size();++i){
            int v=edges[u][i].to;
            if(dis[v]>dis[u]+edges[u][i].w){
                dis[v]=dis[u]+edges[u][i].w;
                cnt[v] = cnt[u];
                que.push(edge(v,dis[v]));
            }
            else if (dis[v] == dis[u] +
                ↪ edges[u][i].w)
                cnt[v] += cnt[u]; //不计数可删
        }
    }
}

int main()
{
    int m,s,from,to,w;
    scanf("%d%d%d",&n,&m,&s);
    while(m--){
        scanf("%d%d%d",&from,&to,&w);
        edges[from].push_back(edge(to,w));
    }
}
```

```

    }
    //cnt[1]=1;
    dijkstra(s);
    printf("%d",dis[i]);
}

```

6.4 多源最短路径

6.4.1 Floyd

```

const int inf=1000000,maxn=210;    //支持负边
int n,dis[maxn][maxn];
void floyd(){
    //dis[i][i]=0;   inf
    for(int k=1;k<=n;++k){
        for(int i=1;i<=n;++i){
            for(int j=1;j<=n;++j){
                dis[i][j]=min(dis[i][j],dis[i][k]+dis[k][j]);
            }
        }
    }
    //通过检查 dis[i][i] 有没有为负的 可以判断有无负圈
}

```

```

//支持打印路径
const int maxn=40;
int p,q,r;
const int inf=1000000;
map<string,int> Id;
map<int,string> Name;
struct dis{
    int len,pre;
} Dis[maxn][maxn];
void print(int u,int v){
    if(u==v){
        cout<<Name[v]; return;
    }
    print(u,Dis[u][v].pre);

    ↪ cout<<"->("<<Dis[Dis[u][v].pre][v].len<<")"<<"->"<<Name[v];
}
for(int k=0;k<p;++k){
    for(int i=0;i<p;++i){
        for(int j=0;j<p;++j){
            int tmp=Dis[i][k].len+Dis[k][j].len;

```

```

        if(tmp<Dis[i][j].len){
            Dis[i][j].len=tmp;
            Dis[i][j].pre=Dis[k][j].pre;
        }
    }
}

```

6.5 最小生成树

6.5.1 Prim

```

const int maxn=110,inf=10000000;
int n,dis[maxn],used[maxn],mat[maxn][maxn];
int prim(){
    memset(used,0,sizeof(used));
    fill(dis,dis+n+1,inf);
    dis[1]=0;
    int res=0;
    while(1){
        int u=-1;
        for(int v=1;v<=n;++v){
            if(!used[v]&&(u==-1||dis[v]<dis[u])) u=v;
        }
        if(u==-1) break;
        used[u]=1;
        res+=dis[u];
        for(int v=1;v<=n;++v){
            dis[v]=min(dis[v],mat[u][v]); //注意不是
            ↪ dis[u]+mat[u][v]
        }
    }
    return res;
}

```

```

const int maxn=30,maxm=100,inf=100000;
int vis[maxn],mat[maxn][maxn],dis[maxn];
int n;
int prim(){
    memset(vis,0,sizeof(vis));

    fill(dis,dis+n,inf);

```

```

int res=0;
dis[0]=0;
while(1){
    int u=-1;
    for(int v=0;v<n;++v){
        if(!vis[v]&&(u==-1||dis[v]<dis[u])) u=v;
    }
    if(u==-1) break;
    vis[u]=1;
    res+=dis[u];
    for(int i=0;i<n;++i) dis[i]=min(dis[i],mat[u][i]);
}
return res;
}

```

```

struct edge{
    int v,l;
    bool operator<(const edge &b) const {return l>b.l;}
    edge(int v=0,int l=inf){
        this->v=v; this->l=l;
    }
};

priority_queue<edge> que;
int prim(){
    fill(dis,dis+n,inf);
    int res=0;
    dis[0]=0;
    memset(vis,0,sizeof(vis));
    while(que.size()) que.pop();
    que.push(edge(0,0));
    while(que.size()){
        int u=que.top().v,l=que.top().l;
        que.pop();
        if(dis[u]!=l||vis[u]) continue;
        res+=l;
        vis[u]=1;
        for(int v=0;v<n;++v) {
            if(dis[v]>mat[u][v]&&!vis[v]){
                dis[v]=mat[u][v];
                que.push(edge(v,dis[v]));
            }
        }
    }
}

```

```

    }
}
return res;
}

```

6.5.2 Kruskal

```

const int maxn=110,maxm=5010;
int n,m,fa[maxn];
int findroot(int u){
    if(fa[u]==-1) return u;
    return fa[u]=findroot(fa[u]);
}
/*int findroot(int u) { //初始化操作不同
    if (u != fa[u]) {
        fa[u] = findroot(fa[u]);
    }
    return fa[u];
}*/
void Union(int u,int v){
    u=findroot(u); v=findroot(v); //上能直接 fa[u]=v;
    fa[u]=v;
}
struct edge {
    int u, v, w;
    bool operator<(const edge& b) const { return w < b.w;
    ⇐ }
    edge() :u(), v(), w() {}
    edge(int u, int v, int w) :
        u(u), v(v), w(w) {}
} edges[maxn];
int kruskal(){
    memset(fa,-1,sizeof(fa));
    //for (int i = 1; i <= n; i++) fa[i] = i; //另一种
    sort(edges,edges+m);
    int res=0;
    for(int i=0;i<m;++i){
        edge eg=edges[i];
        int u=eg.u,v=eg.v;
        if(findroot(u)!=findroot(v)){
            res+=eg.w;
            Union(u,v);
        }
    }
}

```

```
    return res;
}
```

7 数论

7.1 进制转换

```
int idx(char ch){
    if(ch>='0'&&ch<='9') return ch-'0';
    if(ch>='A'&&ch<='Z') return ch-'A'+10;
    if(ch>='a'&&ch<='z') return ch-'a'+10;
}
char ch(int x){
    if(x<10) return '0'+x;
    else return 'A'+x-10;
}
int toten(int b,char *s){
    int res=0;
    int n=strlen(s);
    for(int i=0;i<n;++i){
        int t=idx(s[i]);
        res=res*b+t;
    }
    return res;
}
void tob(int x,int b,char *s){
    int i=0;
    char s1[10000];
    while(x){
        s1[i++]=ch(x%b);
        x/=b;
    }
    for(int j=0;j<i;++j) s[j]=s1[i-1-j];
    if(i==0) s[i++]='0';
    s[i]=0;
}
```

7.2 gcd

```
int gcd(int a,int b){
    if(b==0) return a;
    return gcd(b,a%b);
}
int lcm(int a, int b)
```

```
{
    return a * b / gcd(a, b);
}
int exgcd(int a, int n, int &x, int &y){
    if(n==0) {x=1; y=0; return a;}
    int res= exgcd(n, a%n, y, x);
    y-=x*(a/n);
    return res;
}
```

7.3 改进素数筛

```
const int maxn = 10000010;
bool is_prime[maxn];
int primes[maxn/3], pi;
long long tmp;
void GenPrime(int n){
    int i, j;
    pi = 0;
    for (i = 2; i <= n; i++)
        is_prime[i] = 1;
    for (i = 2; i <= n; i++){
        if (is_prime[i])
            primes[pi++] = i;
        for (j = 0; j < pi; j++){
            tmp = i * primes[j];
            if (tmp > n) break;
            is_prime[tmp] = 0;
            if (i % primes[j] == 0) break;
        }
    }
}
```

7.4 模线性方程

```
int modequ(int a, int b, int n){ //ax=b(mod n)
    int d=gcd(a,n);
    if(b%d!=0) return -1;
    a/=d; b/=d; n/=d; n=abs(n); //a'x=b(mod n)
    int x,y;
    exgcd(a,n,x,y);
    int p=x*b; //x=(a')^(-1)b'
    return ((p%n)+n)%n;
}
```


7.5 中国剩余定理

```
ll exgcd(ll a,ll b,ll &x,ll &y){
    if(b==0) {x=1; y=0; return a;}
    ll res=exgcd(b,a%b,y,x);
    y-=x*(a/b);
    return res;
}
ll M;
ll china(int n,int *a,int *m){    //  $x=a_i \pmod{m_i} \quad i=1,2,\dots,n$ 
    ll x,y,res=0;
    M=1;
    for(int i=0;i<n;++i) M*=m[i];
    for(int i=0;i<n;++i){
        ll w=M/m[i];
        exgcd(w,(ll)m[i],x,y);
        res=(res+w*x*a[i])%M;
    }
    return (res+M)%M;
}
```

7.6 快速幂

```
int pow_mod(ll a,ll p,ll n){
    if(a==0) return 0;
    if(p==0) return 1;
    ll tmp=pow_mod(a,p/2,n);
    tmp=tmp*tmp%n;
    if(p%2) tmp=tmp*a%n;
    return (int) tmp;
}
```

8 字符串

8.1 字典树

```
const int maxnode=100010,sigma_size=10;
struct trie{
    int ch[maxnode][sigma_size],val[maxnode];
    int sz;
    void init(){
        sz=1;
        memset(ch[0],0,sizeof(ch[0]));
        memset(val,0,sizeof(val));
    }
}
```

```

}
trie(){init();}
bool insert(char *s){
    int ok=1;
    int u=0,n=strlen(s);
    for(int i=0;i<n;++i){
        int c=s[i]-'0';
        if(!ch[u][c]){
            memset(ch[sz],0,sizeof(ch[sz]));
            ch[u][c]=sz++;
        }
        else{
            if(val[ch[u][c]]||i==n-1) ok=0;
        }
        u=ch[u][c];
    }
    val[u]=1;
    return ok;
}
} ;

```

8.2 KMP

```

int kmp(char *t,char *p){
    int n=strlen(t),m=strlen(p);
    int *next=new int[m];
    next[0]=-1;
    for(int i=1,k=-1;i<m;++i){
        while(k>=0&&p[k+1]!=p[i]) k=next[k];
        if(p[k+1]==p[i]) ++k;
        next[i]=k; //k 保存的是 p[0,1...i] 的最长的同时
        ↪ 是前缀和后缀的, 那个前缀的最后一个字符的下标
    }
    for(int i=0,k=-1;i<n;++i){
        while(k>=0&&p[k+1]!=t[i]) k=next[k];
        if(p[k+1]==t[i]) ++k; //k 保存的是 p 中已经匹配的最后一
        ↪ 个字符的下标
        if(k==m-1) return i-m+1;
    }
    return -1; //不匹配
}

```

8.3 hash

`const ull B=1000000007; //实在不行 可以用两个 hash 另外用 1e9+9`

```
bool contatin(string a,string b){
    int la=a.length(),lb=b.length();
    if(la>lb) return 0;
    ull ha=0,hb=0,t=1;
    for(int i=0;i<la;++i){
        t*=B;
        ha=ha*B+a[i];
        hb=hb*B+b[i];
    }
    for(int i=0;i+la<=lb;++i){
        if(hb==ha) return 1;
        if(i+la<lb) hb=hb*B+b[i+la]-b[i]*t;
    }
    return 0;
}
```

8.4 表达式计算

8.4.1 前缀表达式

```
#include<cstdlib>
#include<cstdio>
using namespace std;
char s[100];
double exp(){
    scanf("%s",s);
    char c=s[0];
    if(c=='+') return exp()+exp();
    else if(c=='-') return exp()-exp();
    else if(c=='*') return exp()*exp();
    else if(c=='/') return exp()/exp();
    else return atof(s);
}
int main(){
    printf("%f\n",exp());
}
```

```
//#include<cstdlib>
//#include<cstdio>
```

```
//#include<cstring>
//#include<string>
//#include<iostream>
//#include<queue>
//#include<stack>
//#include<sstream>
//using namespace std;
//typedef long long ll;
//stack<string> stk; //这个方法有问题
//string s,s1;
//bool isnum(string str){
//    return (str.size()>1)|| (str[0]>='0' && str[0]<='9');
//}
//bool isop(string str){
//    char op=str[0];
//    return (op=='+'||op=='-'||op=='*'||op=='/');
//}
//double getres(double a,double b,string op){
//    if(op[0]=='+' ) return a+b;
//    if(op[0]=='-' ) return a-b;
//    if(op[0]=='*' ) return a*b;
//    else return a/b;
//}
//void calu(){
//    while(stk.size()>=3){
//        string s3,s2,s1;
//        s3=stk.top(); stk.pop();
//        s2=stk.top(); stk.pop();
//        s1=stk.top(); stk.pop();
//        if(isnum(s3)&&isnum(s2)&&isop(s1)){
//            double a=stod(s2),b=stod(s3);
//            stk.push(to_string(getres(a,b,s1)));
//        }else{
//            stk.push(s1); stk.push(s2); stk.push(s3);
//            break;
//        }
//    }
//}
//int main(){
//    while(getline(cin,s)){
//        stringstream ss(s);
//        while(stk.size()) stk.pop();
//        while(ss>>s1){
//            stk.push(s1);
```

```
//          calu();
//      }
//      printf("%f\n", stod(stk.top()));
//  }
//      return 0;
//}
```

8.4.2 中缀表达式

```
char s[610];
stack<char> ops;
stack<int> num;
int calu(int a, int b, char op){
    if(op=='+') return a+b;
    if(op=='-') return a-b;
    if(op=='*') return a*b;
    if(op=='/') return a/b;
    return -10000000;
}
bool higher(char op1, char op2){
    if(op2=='(') return 1;
    if((op1=='*' || op1=='/') && (op2=='+' || op2=='-')) return 1;
    return 0;
}
int solve(){
    while(ops.size()) ops.pop();
    while(num.size()) num.pop();
    int n=strlen(s);
    for(int i=0; i<n; ++i){
        if(s[i]=='(') ops.push(s[i]);
        else if(s[i]>='0' && s[i]<='9'){
            int x=s[i]-'0';
            while(i+1<n && s[i+1]>='0' && s[i+1]<='9'){
                ++i;
                x=x*10+s[i+1]-'0';
            }
            num.push(x);
        } else if(s[i]==')'){
            while(ops.size() && ops.top()!='('){
                int b, a;
                b=num.top(); num.pop();
                a=num.top(); num.pop();
                num.push(calu(a, b, ops.top()));
                ops.pop();
            }
            ops.pop();
        }
    }
}
```

```

    }
    if(ops.size() && ops.top() == '(') ops.pop();
} else {
    char op1 = s[i];
    while(ops.size() && !higher(op1, ops.top())) {
        int b, a;
        b = num.top(); num.pop();
        a = num.top(); num.pop();
        num.push(calu(a, b, ops.top()));
        ops.pop();
    }
    ops.push(op1);
}
}
return num.top();
}

```

8.5 find longest shortest word

```

char s[210];
const int inf = 10000;
bool isala(char c) { // is alphabet
    return (c >= 'a' && c <= 'z') || (c >= 'A' && c <= 'Z');
}
void find_longest_shortest_word() {
    int n = strlen(s);
    int l = 0, r = 0, lmin, rmin, lmax, rmax;
    lmin = -1; rmin = inf;
    lmax = -1; rmax = -inf;
    while(l < n) {
        while(l < n && !isala(s[l])) ++l;
        if(l == n) break;
        r = l + 1;
        while(r < n && isala(s[r])) ++r;
        s[r] = 0;
        if(r - l < rmin - lmin) { lmin = l; rmin = r; }
        if(r - l >= rmax - lmax) { lmax = l; rmax = r; }
        l = r + 1;
    }
    if(lmax < 0) printf("\n");
    else printf("%s\n", s + lmax);
    if(lmin < 0) printf("\n");
    else printf("%s\n", s + lmin);
}

```

```
void find_longest_shortest_word(string s){
    stringstream ss;
    for(int i=0;i<s.size();++i)
        if(!isalpha(s[i])) s[i]=' ';
    ss.clear();
    ss.str(s);
    string Max="",Min("a");
    string t;
    while(ss>>t){
        if(t.size()>=Max.size()) Max=t;
        if(t.size()<Min.size()) Min=t;
    }
    cout<<Max<<endl;
    cout<<Min<<endl;
}
```

9 bigint

```
#include<cstdio>
#include<iostream>
#include<cstdlib> //for "exit()"
#include<algorithm> //for "reverse()"
#include<string>
#include<cstring>
using namespace std;
const int M = 10, P = 1, DIGITS=20000; // M=10^P 压位
//const int M = 100000000, P = 8, DIGITS = 20000;

struct BigNum
{
    int n[DIGITS], l, Y; //最大 DIGITS 位
    BigNum() { l = 1, memset(n, 0, sizeof(n)); }
    void init()
    {
        string s; cin >> s;
        int now = 0, ct = 0, c1 = 1;
        for (int i = s.length() - 1; i >= 0; i--)
        {
            n[now] += (s[i] - '0')*c1; c1 *= 10;
            ↪ ct++;
            if (ct == P && i != 0) { now++; c1 = 1; ct = 0; }
        }
    }
};
```

```

    }
    l = now + 1;
}
void print()
{
    if (n[l - 1] == 0) { printf("0"); exit(0);
    ↪ } //对 0 特殊处理
    printf("%d", n[l - 1]);
    for (int i = l - 2; i >= 0; i--)
    ↪ printf("%0*d", P, n[i]);
    printf("\n");
}
BigNum operator +(BigNum x) const
{
    BigNum t=*this;
    if(x.l>t.l)t.l=x.l;
    for(int i=0;i<t.l;i++)
    {
        t.n[i]+=x.n[i];
        if(t.n[i]>=M){t.n[i+1]+=t.n[i]/M;t.n[i]%=M;}
    }
    while(t.n[t.l])
    {
        t.n[t.l+1]+=t.n[t.l]/M;
        t.n[t.l++]%=M;
    }
    return t;
}
bool operator < (BigNum x) const
{
    BigNum t=*this;
    if(t.l!=x.l)return t.l<x.l;
    for(int i=t.l-1;i>=0;i--)
    {
        if(t.n[i]!=x.n[i])return t.n[i]<x.n[i];
    }
    return 0;
}
BigNum operator -(BigNum x) const
{
    BigNum t=*this;
    if(t<x){printf("-");swap(t,x);}
    for(int i=0;i<t.l;i++)
    {

```



```

        t.n[i]-=x.n[i];
        if(t.n[i]<0)
        {
            t.n[i]+=M;
            --t.n[i+1];
        }
    }
    while(!t.n[t.l-1]&& t.l>1)t.l--;
    return t;
}

BigNum operator * (BigNum x) const
{
    BigNum c, t = *this;
    c.l = t.l + x.l - 1;
    for (int i = 0; i < t.l; i++)
        for (int j = 0; j < x.l; j++)
        {
            c.n[i + j] += t.n[i] * x.n[j];
            if (c.n[i + j] >= M)
            {
                c.n[i + j + 1] +=
                    c.n[i + j] / M;
                c.n[i + j] %= M;
            }
        }
    while (c.n[c.l])
    {
        c.n[c.l + 1] += c.n[c.l] / M;
        c.n[c.l++] %= M;
    }
    return c;
}

void Add(int x){if(x||l)n[l++]=x;}
void Re(){reverse(n,n+l);}
BigNum operator /(const BigNum &x) const
{
    BigNum t=*this,r,y;
    y.l=0,r.l=t.l;
    for(int i=t.l-1;i>=0;--i)
    {
        y.Add(t.n[i]);
        y.Re();
        while(!(y<x))y=y-x,r.n[i]++;
    }
}

```

```

        while(!y.n[y.l-1] && y.l>1)--y.l;
        y.Re();
    }
    while(!r.n[r.l-1] && r.l>1)--r.l;
    return r;
}
BigNum operator /(const int &x) const
{
    BigNum t=*this,r;
    r.l=t.l;
    int tmp=0;
    for(int i=t.l-1;i>=0;--i)
    {
        tmp+=t.n[i];
        if(tmp>=x)
            r.n[i]+=tmp/x,tmp%=x;
        tmp*=M;
    }
    while(!r.n[r.l-1] && r.l>1)--r.l;
    return r;
}
}a, b, c;//给 a,b,c 定义

int main()
{
    a.init();
    b.init();
    c = a * b;
    c.print();//自带换行
    c = a - b;
    c.print();
    c = a + b;
    c.print();
    c = a / b;
    c.print();
    return 0;
}

```

10 others

10.1 funcs

```

//if not support to_string() (C++11,<string>)
#include <sstream>

```

```

string my_to_string(int n)
{
    ostringstream stream;
    stream << n;
    return stream.str();
}

//qsort3
int a[100000];
int lt, rt, i, tmp;
void qsort3(int l, int r)
{
    if (l >= r) return;
    tmp = a[l];
    lt = l;
    rt = r;
    i = l + 1;
    while (i <= rt)
    {
        if (a[i] < tmp)
            swap(a[lt++], a[i++]);
        else if (a[i] > tmp)
            swap(a[i], a[rt--]);
        else
            i++;
    }
    qsort3(l, lt - 1);
    qsort3(rt + 1, r);
}

//heapsort
#include <cstdio>
using namespace std;
int n, a[100001], len;
int main()
{
    scanf("%d", &n);
    for (int b = 1; b <= n; ++b)
    {
        scanf("%d", &a[b]);
        len = b;
        while (len != 1)
        {
            if (a[len] < a[len / 2])

```

```

        {
            int t = a[len / 2];
            a[len / 2] = a[len];
            a[len] = t;
        }
        else break;
        len /= 2;
    }
}
for (int b = 1; b <= n; ++b)
{
    printf("%d ", a[1]);
    a[1] = a[n - b + 1]; len = 1;
    while (len * 2 <= n - b)
    {
        int next = len * 2;
        if ((a[next] > a[next + 1] && next < n
            ↪ - b))next++;
        if (a[len] <= a[next])break;
        int t = a[len]; a[len] = a[next];
        ↪ a[next] = t;
        len = next;
    }
}
return 0;
}

```

10.2 vim

```

set nu
set nobackup
set nocompatible
"set whichwrap=h,l
set encoding=utf-8
set clipboard+=unnamed
set autoindent
set smartindent
set shiftwidth=4
set tabstop=4
set expandtab
set softtabstop=4
set ruler
syntax on

```