

# Team Contest Reference

## getRandomNumber(){return 4;}

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## 1 Mathematische Algorithmen

### 1.1 Primzahlen

Für Primzahlen gilt immer (aber nicht nur für Primzahlen)

$$a^p \equiv a \pmod{p} \quad \text{bzw.} \quad a^{p-1} \equiv 1 \pmod{p}.$$

#### 1.1.1 Sieb des Eratosthenes

```

1 static boolean[] sieve(int until) {
2     boolean[] a = new boolean[until + 1];
3     Arrays.fill(a, true);
4     for (int i = 2; i < Math.sqrt(a.length); i++) {
5         if (a[i]) {
6             for (int j = i * i; j < a.length; j += i) a[j] = false;

```

```

7     }
8 }
9 return a; // a[i] == true, iff. i is prime. a[0] is ignored
10 }

```

### 1.1.2 Primzahlentest

```

1 static boolean isPrim(int p) {
2     if (p < 2 || p > 2 && p % 2 == 0) return false;
3     for (int i = 3; i <= Math.sqrt(p); i += 2)
4         if (p % i == 0) return false;
5     return true;
6 }

```

## 1.2 Binomial Koeffizient

```

1 static int[][] mem = new int[MAX_N][(MAX_N + 1) / 2];
2 static int binoCo(int n, int k) {
3     if (k < 0 || k > n) return 0;
4     if (2 * k > n) binoCo(n, n - k);
5     if (mem[n][k] > 0) return mem[n][k];
6     int ret = 1;
7     for (int i = 1; i <= k; i++) {
8         ret *= n - k + i;
9         ret /= i;
10        mem[n][i] = ret;
11    }
12    return ret;
13 }

```

## 1.3 Modulare Arithmetik

Bedeutung der größten gemeinsamen Teiler:

$$d = \text{ggT}(a, b) = as + bt$$

Verwendung zu Berechnung des inversen Elements  $b$  zu  $a$  bezüglich einer Restklassengruppe  $n$  ( $a$  und  $n$  müssen teilerfremd sein):

$$ab \equiv 1 \pmod{n} \Leftrightarrow s \equiv b \pmod{n} \quad \text{für } 1 = \text{ggT}(a, n)$$

### 1.3.1 Erweiterter Euklidischer Algorithmus

```

1 static int[] eea(int a, int b) {
2     int[] dst = new int[3];
3     if (b == 0) {
4         dst[0] = a;
5         dst[1] = 1;
6         return dst; // a, 1, 0
7     }
8     dst = eea(b, a % b);
9     int tmp = dst[2];
10    dst[2] = dst[1] - ((a / b) * dst[2]);
11    dst[1] = tmp;
12    return dst;
13 }

```

## 1.4 Matrixmultiplikation

Strassen-Algorithmus:  $C = AB$   $A, B, C \in R^{2^n \times 2^n}$

$$\begin{aligned}
 C_{1,1} &= A_{1,1}B_{1,1} + A_{1,2}B_{2,1} \\
 C_{1,2} &= A_{1,1}B_{1,2} + A_{1,2}B_{2,2} \\
 C_{2,1} &= A_{2,1}B_{1,1} + A_{2,2}B_{2,1} \\
 C_{2,2} &= A_{2,1}B_{1,2} + A_{2,2}B_{2,2}
 \end{aligned}$$

## 2 Datenstrukturen

### 2.1 Fenwick Tree (Binary Indexed Tree)

```

1 class FenwickTree {
2     private int[] values;
3     private int n;
4     public FenwickTree(int n) {
5         this.n = n;
6         values = new int[n];
7     }
8     public int get(int i) { //get value of i
9         int x = values[0];
10        while (i > 0) {
11            x += values[i];
12            i -= i & -i; }
13        return x;
14    }
15    public void add(int i, int x) { // add x to interval [i,n]
16        if (i == 0) values[0] += x;
17        else {
18            while (i < n) {
19                values[i] += x;
20                i += i & -i; }
21        }
22    }
23 }

```

## 3 Graphenalgorithmen

### 3.1 Topologische Sortierung

```

1 static List<Integer> topoSort(Map<Integer, List<Integer>> edges,
2     Map<Integer, List<Integer>> revedges) {
3     Queue<Integer> q = new LinkedList<Integer>();
4     List<Integer> ret = new LinkedList<Integer>();
5     Map<Integer, Integer> indeg = new HashMap<Integer, Integer>();
6     for (int v : revedges.keySet()) {
7         indeg.put(v, revedges.get(v).size());
8         if (revedges.get(v).size() == 0)
9             q.add(v);
10    }
11    while (!q.isEmpty()) {
12        int tmp = q.poll();
13        ret.add(tmp);
14        for (int dest : edges.get(tmp)) {
15            indeg.put(dest, indeg.get(dest) - 1);
16            if (indeg.get(dest) == 0)
17                q.add(dest);
18        }
19    }
20    return ret;
21 }

```

### 3.2 Prim (Minimum Spanning Tree)

```

1 #define WHITE 0
2 #define BLACK 1
3 #define INF INT_MAX
4
5 int baum( int **matrix, int N){
6     int i, sum = 0;
7
8     int color[N];
9     int dist[N];
10
11     // markiere alle Knoten ausser 0 als unbesucht
12     color[0] = BLACK;
13     for( i=1; i<N; i++){
14         color[i] = WHITE;
15         dist[i] = INF;
16     }
17
18     // berechne den Rand
19     for( i=1; i<N; i++){
20         if( dist[i] > matrix[i][nextIndex]){
21             dist[i] = matrix[i][nextIndex];
22         }
23     }

```

```

24
25 while( 1){
26     int nextDist = INF, nextIndex = -1;
27
28     /* Den naechsten Knoten waehlen */
29     for(i=0; i<N; i++){
30         if( color[i] != WHITE) continue;
31
32         if( dist[i] < nextDist){
33             nextDist = dist[i];
34             nextIndex = i;
35         }
36     }
37
38     /* Abbruchbedingung*/
39     if( nextIndex == -1) break;
40
41     /* Knoten in MST aufnehmen */
42     color[nextIndex] = RED;
43     sum += nextDist;
44
45     /* naechste kuerzeste Distanzen berechnen */
46     for( i=0; i<N; i++){
47         if( i == nextIndex || color[i] == BLACK ) continue;
48
49         if( dist[i] > matrix[i][nextIndex]){
50             dist[i] = matrix[i][nextIndex];
51         }
52     }
53 }
54
55 return sum;
56 }

```

### 3.3 Maximaler Fluss (Ford-Fulkerson)

```

1 #include <stdio.h>
2 #include <limits.h>
3
4 #define n_MAX 36
5 #define m_MAX 30
6 #define SIZE (m+6+2)
7 #define SIZE_MAX 38
8 #define QUELLE (m+6)
9 #define SENKE (m+7)
10 #define NONE -1
11 #define INF INT_MAX/2
12
13 int n, m;
14 int capacity[SIZE_MAX][SIZE_MAX];
15 int flow[SIZE_MAX][SIZE_MAX];
16 int queue[SIZE_MAX], *head, *tail;
17 int state[SIZE_MAX];
18 int pred[SIZE_MAX];
19
20 enum { XS, S, M, L, XL, XXL };
21 enum { UNVISITED, WAITING, PROCESSED };
22
23 int strToOffset( char *str);
24 int maxFlow( int quelle, int senke);
25
26 int main(){
27
28     int numOfProps;
29     scanf("%d\n", &numOfProps);
30
31     while( numOfProps--){
32         scanf("%d_%d\n", &n, &m);
33
34         int i, j;
35
36         /* Matrix initialisieren */
37         for( i=0; i< SIZE; i++){
38             for( j=0; j< SIZE; j++){
39                 capacity[i][j] = flow[i][j] = 0;
40

```

```

41         if( i == QUELLE && j < m){
42             capacity[i][j] = 1;
43             continue;
44         }
45
46         if( j == SENKE && i >= m && i < QUELLE){
47             capacity[i][j] = n/6;
48             continue;
49         }
50     }
51 }
52
53 char str[4];
54
55 /* Matrix einlesen */
56 for( i=0; i< m; i++){
57     scanf("%s", str);
58     capacity[i][m+strToOffset(str)] = 1;
59     scanf("%s", str);
60     capacity[i][m+strToOffset(str)] = 1;
61 }
62
63
64 int foo = maxFlow( QUELLE, SENKE);
65 printf("%s\n", foo >= m ? "YES" : "NO");
66
67 }
68
69 return 0;
70 }
71
72 int strToOffset( char *str){
73     /*snip*/
74 }
75
76 void enqueue( int x){
77     *tail++ = x;
78     state[x] = WAITING;
79 }
80
81 int dequeue(){
82     int x = *head++;
83     state[x] = PROCESSED;
84     return x;
85 }
86
87 int bfs( int start, int target){
88     int u, v;
89     for( u=0; u< SIZE; u++){
90         state[u] = UNVISITED;
91     }
92     head = tail = queue;
93     pred[start] = NONE;
94
95     enqueue(start);
96
97     while( head < tail){
98         u = dequeue();
99
100         for( v= 0; v< SIZE; v++){
101             if( state[v] == UNVISITED &&
102                 capacity[u][v] - flow[u][v] > 0){
103
104                 enqueue(v);
105                 pred[v] = u;
106             }
107         }
108     }
109
110     return state[target] == PROCESSED;
111 }
112
113 int maxFlow( int quelle, int senke){
114     int max_flow = 0;
115
116     int u;

```

```

117
118     while( bfs( quelle, senke)){
119         int increment = INF, temp;
120
121         for( u= senke; pred[u] != NONE; u = pred[u]){
122             temp = capacity[pred[u]][u] - flow[pred[u]][u];
123             if( temp < increment){
124                 increment = temp;
125             }
126         }
127
128         for( u= senke; pred[u] != NONE; u = pred[u]){
129             flow[pred[u]][u] += increment;
130             flow[u][pred[u]] -= increment;
131         }
132
133         max_flow += increment;
134     }
135
136     return max_flow;
137 }

1 /**
2  * Ford Fulkersen
3  * @param s source
4  * @param d destination
5  * @param c capacity
6  * @param f flow, init with 0
7  * @return
8  */
9 static int ff(int s, int d, int[][] c, int[][] f) {
10     List<Integer> path = dfs(s, d, c, f, new boolean[c.length]); // find path
11     if (path.size() < 2) {
12         int flow = 0;
13         for (int i = 0; i < f[s].length; i++) { // leaving flow of source
14             flow += f[s][i];
15         }
16         return flow;
17     }
18     int cap = Integer.MAX_VALUE; // capacity of current path
19     for (int i = 0; i < path.size() - 1; i++) {
20         int a = path.get(i), b = path.get(i + 1);
21         cap = Math.min(cap, c[a][b] - f[a][b]);
22     }
23     for (int i = 0; i < path.size() - 1; i++) { //update flow
24         int a = path.get(i), b = path.get(i + 1);
25         f[a][b] += cap;
26         f[b][a] -= cap;
27     }
28     return ff(s, d, c, f); // tail recursion
29 }

30
31 /**
32  * depth first search in flow network
33  * @param s source
34  * @param d destination
35  * @param c capacity
36  * @param f flow
37  * @param v visited, init with false
38  * @return
39  */
40 static List<Integer> dfs(int s, int d, int[][] c, int[][] f, boolean[] v) {
41     v[s] = true;
42     if (s == d) { // destination found
43         LinkedList<Integer> path = new LinkedList<Integer>();
44         path.add(d);
45         return path;
46     }
47     for (int i = 0; i < c[s].length; i++) {
48         if (!v[i] && c[s][i] - f[s][i] > 0) {
49             List<Integer> path = dfs(i, d, c, f, v);
50             if (path.size() > 0) {
51                 ((LinkedList<Integer>) path).addFirst(s);
52                 return path;
53             }
54         }
55     }

```

```

56 return ((List<Integer>) Collections.EMPTY_LIST);
57 }

```

### 3.4 Floyd-Warshall

```

1 static int n;
2 static int[][] path = new int[n][n];
3 static int[][] next = new int[n][n];
4 static void floyd(int[][] ad) {
5     for (int i = 0; i < n; i++)
6         path[i] = Arrays.copyOf(ad[i], n);
7     for (int i = 0; i < n; i++)
8         for (int j = 0; j < n; j++)
9             for (int k = 0; k < n; k++)
10                if (path[i][k] + path[k][j] < path[i][j]) {
11                    path[i][j] = path[i][k] + path[k][j];
12                    next[i][j] = k;
13                }
14    // there is a negative circle iff. there is a i such that path[i][i] < 0
15 }

```

### 3.5 Dijkstra

```

1 Funktion Dijkstra(Graph, Startknoten):
2     initialisiere(Graph, Startknoten, abstand[], vorgaenger[], Q)
3     solange Q nicht leer: // Der eigentliche Algorithmus
4         u := Knoten in Q mit kleinstem Wert in abstand[]
5         entferne u aus Q // fuer u ist der kuerzeste Weg nun bestimmt
6         fuer jeden Nachbarn v von u:
7             falls v in Q:
8                 distanz_update(u, v, abstand[], vorgaenger[]) // pruefe Abstand vom Startknoten zu v
9     return vorgaenger[]
10
11 Methode initialisiere(Graph, Startknoten, abstand[], vorgaenger[], Q):
12     fuer jeden Knoten v in Graph:
13         abstand[v] := unendlich
14         vorgaenger[v] := null
15     abstand[Startknoten] := 0
16     Q := Die Menge aller Knoten in Graph
17
18 Methode distanz_update(u, v, abstand[], vorgaenger[]):
19     alternativ := abstand[u] + abstand_zwischen(u, v) // Weglaenge vom Startknoten nach v ueber u
20     falls alternativ < abstand[v]:
21         abstand[v] := alternativ
22         vorgaenger[v] := u

```

## 4 Geometrische Algorithmen

### 4.1 Graham Scan (Convex Hull)

```

1 class P {
2     double x, y;
3
4     P(double x, double y) {
5         this.x = x;
6         this.y = y;
7     }
8     // polar coordinates (not used in graham scan)
9     double r() { return Math.sqrt(x * x + y * y); }
10    double d() { return Math.atan2(y, x); }
11 }
12
13 // turn is counter-clockwise if > 0; collinear if = 0; clockwise else
14 static double ccw(P p1, P p2, P p3) {
15     return (p2.x - p1.x) * (p3.y - p1.y) - (p2.y - p1.y) * (p3.x - p1.x);
16 }
17
18 static List<P> graham(List<P> l) {
19     if (l.size() < 3)
20         return l;
21     P temp = l.get(0);
22     for (P p : l)
23         if (temp.y > p.y || temp.y == p.y && temp.x > p.x)
24             temp = p;

```

```

25 final P start = temp; // min y (then leftmost)
26
27 Collections.sort(l, new Comparator<P>() {
28     public int compare(P o1, P o2) {
29         if (new Double(Math.atan2(o1.y - start.y, o1.x - start.x)) // same angle
30             .compareTo(Math.atan2(o2.y - start.y, o2.x - start.x)) == 0)
31             return new Double((o1.x - start.x) * (o1.x - start.x)
32                 + (o1.y - start.y) * (o1.y - start.y))
33                 .compareTo((o2.x - start.x) * (o2.x - start.x)
34                     + (o2.y - start.y) * (o2.y - start.y)); // use distance
35             return new Double(Math.atan2(o1.y - start.y, o1.x - start.x))
36                 .compareTo(Math.atan2(o2.y - start.y, o2.x - start.x));
37     }
38 });
39 Stack<P> s = new Stack<P>();
40 s.add(start);
41 s.add(l.get(1));
42 for (int i = 2; i < l.size(); i++) {
43     while (s.size() >= 2
44         && ccw(s.get(s.size() - 2), s.get(s.size() - 1), l.get(i)) <= 0)
45         s.pop();
46     s.push(l.get(i));
47 }
48 return s;
49 }

```

## 4.2 Maximum Distance in a Point Set

```

1 List<P> hull = graham(list);
2 maxDist(hull);
3
4 static double dist(P p1, P p2) {
5     return Math.sqrt((p1.x - p2.x) * (p1.x - p2.x)
6         + (p1.y - p2.y) * (p1.y - p2.y));
7 }
8
9 static double maxDist(List<P> hull) {
10     double max = 0, tmp = 0;
11     int j = 0, n = hull.size();
12     for (P p : hull) {
13         while (tmp < dist(p, hull.get((j + 1) % n))) {
14             j = (j + 1) % n;
15             tmp = dist(p, hull.get(j));
16         }
17         max = Math.max(max, tmp);
18     }
19     return max;
20 }

```

## 4.3 Punkt in Polygon

```

1 /**
2  * -1: A liegt links von BC (ausser unterer Endpunkt)
3  * 0: A auf BC
4  * +1: sonst
5  */
6 public static int KreuzProdTest(double ax, double ay, double bx, double by,
7     double cx, double cy) {
8     if (ay == by && by == cy) {
9         if ((bx <= ax && ax <= cx) || (cx <= ax && ax <= bx)) return 0;
10        else return +1;
11    }
12    if (by > cy) {
13        double tmpx = bx, tmpy = by;
14        bx = cx;
15        by = cy;
16        cx = tmpx;
17        cy = tmpy;
18    }
19    if (ay == by && ax == bx) return 0;
20    if (ay <= by || ay > cy) return +1;
21    double delta = (bx - ax) * (cy - ay) - (by - ay) * (cx - ax);
22    if (delta > 0) return -1;
23    else if (delta < 0) return +1;
24    else return 0;
25 }

```



```

26
27 /**
28  * Input: P[i] (x[i],y[i]); P[0]:=P[n]
29  * -1: Q ausserhalb Polygon
30  * 0: Q auf Polygon
31  * +1: Q innerhalb des Polygons
32 */
33 public static int PunktInPoly(double[] x, double[] y, double qx, double qy) {
34     int t = -1;
35     for (int i = 0; i < x.length - 1; i++)
36         t = t * KreuzProdTest(qx, qy, x[i], y[i], x[i + 1], y[i + 1]);
37     return t;
38 }

```

## 5 Verschiedenes

### 5.1 Potenzmenge

```

1 static <T> Iterator<List<T>> powerSet(final List<T> l) {
2     return new Iterator<List<T>>() {
3         int i; // careful: i becomes 2^l.size()
4         public boolean hasNext() {
5             return i < (1 << l.size());
6         }
7         public List<T> next() {
8             Vector<T> temp = new Vector<T>();
9             for (int j = 0; j < l.size(); j++)
10                 if (((i >>> j) & 1) == 1)
11                     temp.add(l.get(j));
12             i++;
13             return temp;
14         }
15         public void remove() {}
16     };
17 }

```

### 5.2 Longest Common Subsequence

```

1 #include <stdio.h>
2 #include <stdlib.h>
3 #include <string.h>
4
5
6 int lcs( char *a, char *b){
7     int len = strlen( a);
8     int lenb =strlen(b);
9
10    int *zeile = malloc( (len+1) * sizeof(int)), *temp,
11        *neue = malloc( (len+1) * sizeof(int)), i, j;
12
13    for(i=0; i<len+1; i++){
14        zeile[i] = neue[i] = 0;
15    }
16
17    for(j=0; j<lenb; j++){
18        for(i=0; i<len; i++){
19            if( a[i] == b[j]){
20                neue[i+1] = zeile[i] + 1;
21            } else {
22                neue[i+1] = neue[i] > zeile[i+1] ? neue[i] : zeile[i+1];
23            }
24        }
25        temp = zeile;
26        zeile = neue;
27        neue = temp;
28    }
29
30    int res = zeile[len];
31    free( zeile);
32    free( neue);
33    return res;
34 }

```

### 5.3 Longest Increasing Subsequence

```
1 #include <stdio.h>
2 #include <stdlib.h>
3
4 int lis( int *list, int n){
5     int *sorted = malloc( n*sizeof(int)), sorted_n;
6     int i, *lower, *upper, *mid, *pos;
7
8     if( n == 0) return 0;
9
10    sorted[0] = list[0];
11    sorted_n = 1;
12
13    for( i=1; i<n; i++){
14        /* binaere Suche */
15        lower = list;
16        upper = list + sorted_n;
17        mid = list + sorted_n / 2;
18
19
20        while( lower < upper-1){
21            if( list[i] < *mid){
22                upper = mid;
23            } else {
24                lower = mid;
25            }
26
27            mid = lower + (upper-lower) / 2;
28        }
29
30        if( mid == list + sorted_n -1 && *mid < list[i]){
31            *mid = list[i];
32            sorted_n++;
33        }
34
35        if( list[i] < *mid){
36            *mid = list[i];
37        }
38    }
39
40    free( sorted);
41
42    return sorted_n;
43 }
```

## 6 Eine kleine C-Referenz

## C Reference Card (ANSI)

### Program Structure/Functions

```

type func(type_1,...)
type name
main() {
    declarations
    statements
}
type func(arg_1,...) {
    declarations
    statements
}
return value;
/* */
main(int argc, char *argv[])
exit(arg)

```

### C Preprocessor

```

#include <filename>
#include "filename"
#define name text
#define name(var) text
Example. #define max(A,B) ((A)>(B) ? (A) : (B))
#undef name
#
#
#if, #else, #elif, #endif
#ifdef, #ifndef
defined(name)
\

```

### Data Types/Declarations

```

character (1 byte)
integer
float (single precision)
float (double precision)
short (16 bit integer)
long (32 bit integer)
positive and negative
only positive
pointer to int, float,...
enumeration constant
constant (unchanging) value
declare external variable
register variable
local to source file
no value
structure
create name by data type
size of an object (type is size_t)
size of a data type (type is size_t)

```

### Initialization

```

initialize variable
initialize array
initialize char string
type name=value
type name[]={value_1,...}
char name[]="string"

```

### Constants

```

long (suffix)
float (suffix)
exponential form
octal (prefix zero)
hexadecimal (prefix zero-ex)
character constant (char, octal, hex)
newline, cr, tab, backspace
special characters
string constant (ends with '\0')

```

### Pointers, Arrays & Structures

```

declare pointer to type
declare function returning pointer to type type *f()
declare pointer to function returning type type (*pf)()
generic pointer type
void *
NULL
object pointed to by pointer
address of object name
array
multi-dim array
name[dim_1][dim_2]...

```

### Structures

```

struct tag {
    declarations
};
create structure
member of structure from template
member of pointed to structure
Example. (*p).x and p->x are the same
single value, multiple type structure
union
member : b

```

### Operators (grouped by precedence)

```

structure member operator
structure pointer
increment, decrement
plus, minus, logical not, bitwise not
indirection via pointer, address of object
cast expression to type
size of an object
multiply, divide, modulus (remainder)
add, subtract
left, right shift [bit ops]
comparisons
comparisons
bitwise and
bitwise exclusive or
bitwise or (incl)
logical and
logical or
conditional expression
assignment operators
expression evaluation separator
Unary operators, conditional expression and assignment operators group right to left; all others group left to right.

```

### Flow of Control

```

statement terminator
block delimiters
exit from switch, while, do, for
next iteration of while, do, for
goto label
label
return value from function
Flow Constructions
if statement
if (expr) statement
else if (expr) statement
else statement
while (expr)
statement
for (expr_1; expr_2; expr_3)
statement
do statement
while(expr);
switch statement
switch (expr) {
    case const_1: statement_1 break;
    case const_2: statement_2 break;
    default: statement
}

```

### ANSI Standard Libraries

```

<assert.h> <ctype.h> <errno.h> <float.h> <limits.h>
<locale.h> <math.h> <setjmp.h> <signal.h> <stdarg.h>
<stddef.h> <stdio.h> <stdlib.h> <string.h> <time.h>

```

### Character Class Tests <ctype.h>

```

alphanumeric?
alphanumeric?
control character?
decimal digit?
lower case letter?
printing character (incl space)?
printing char except space, letter, digit?
space, formfeed, newline, cr, tab, vtab?
upper case letter?
hexadecimal digit?
convert to lower case?
convert to upper case?

```

### String Operations <string.h>

```

s, t are strings, cs, ct are constant strings
length of s
strcpy(s, ct)
strncpy(s, ct, n)
strcat(s, ct)
strncat(s, ct, n)
strcmp(cs, ct)
strncmp(cs, ct, n)
strchr(cs, c)
strrchr(cs, c)
memcpy(s, ct, n)
memmove(s, ct, n)
memcmp(cs, ct, n)
memchr(cs, c, n)
memset(s, c, n)

```

## C Reference Card (ANSI)

### Input/Output <stdio.h>

#### Standard I/O

standard input stream  
standard output stream  
standard error stream  
end of file  
get a character  
print a character  
print formatted data  
read from string s  
read formatted data  
read from string s  
read line to string s (< max chars)  
print string s  
**File I/O**  
declare file pointer  
pointer to named file  
modes: **r** (read), **w** (write), **a** (append)  
get a character  
write a character  
write to file  
read from file  
close file  
non-zero if error  
non-zero if EOF  
read line to string s (< max chars)  
write string s  
**Codes for Formatted I/O: "%-+ 0w.pmic"**  
- left justify  
+ print with sign  
space print space if no sign  
0 pad with leading zeros  
w min field width  
p precision  
m conversion character:  
h short, l long, L long double  
c conversion character:  
d,i integer u unsigned  
c single char s char string  
f double e,E exponential  
o octal x,X hexadecimal  
p pointer n number of chars written  
g,G same as f or e,E depending on exponent

### Variable Argument Lists <stdarg.h>

declaration of pointer to arguments **va\_list name**;  
initialization of argument pointer **va\_start(name, lastarg)**  
*lastarg* is last named parameter of the function  
access next unnamed arg, update pointer **va\_arg(name, type)**  
call before exiting function **va\_end(name)**

### Standard Utility Functions <stdlib.h>

absolute value of int n  
absolute value of long n  
quotient and remainder of ints n,d  
return structure with div.t.quot and div.t.rem  
quotient and remainder of longs n,d  
returns structure with lddiv.t.quot and lddiv.t.rem  
pseudo-random integer [0, RAND\_MAX]  
rand()  
set random seed to n  
strand(n)  
terminate program execution  
pass string s to system for execution  
system(s)  
**Conversions**  
convert string s to double  
atof(s)  
convert string s to integer  
atoi(s)  
convert string s to long  
atol(s)  
convert prefix of s to double  
strtod(s, endp)  
convert prefix of s (base b) to long  
strtol(s, endp, b)  
same, but unsigned long  
strtoul(s, endp, b)

#### Storage Allocation

allocate storage  
change size of object  
deallocate space  
realloc(pts, size)  
free(ptr)

#### Array Functions

search array for key  
sort array ascending order  
bsearch(key, array, n, size, cmp())  
qsort(array, n, size, cmp())

### Time and Date Functions <time.h>

processor time used by program  
Example: clock()/CLOCKS\_PER\_SEC is time in seconds  
current calendar time  
time()  
time2-time1 in seconds (double)  
difftime(time2, time1)  
arithmetic types representing times  
clock\_t, time\_t  
structure type for calendar time comps  
tm  
tm\_sec seconds after minute  
tm\_min minutes after hour  
tm\_hour hours since midnight  
tm\_mday day of month  
tm\_mon months since January  
tm\_year years since 1900  
tm\_wday days since Sunday  
tm\_yday days since January 1  
tm\_isdst Daylight Savings Time flag  
convert local time to calendar time  
mktime(tp)  
convert time in tp to string  
asctime(tp)  
convert calendar time in tp to local time  
ctime(tp)  
convert calendar time to GMT  
gmtime(tp)  
convert calendar time to local time  
localtime(tp)  
format date and time info  
strftime(s, smax, "format", tp)  
tp is a pointer to a structure of type tm

### Mathematical Functions <math.h>

Arguments and returned values are double

trig functions  
inverse trig functions  
asin(x), acos(x), atan(x)  
atan2(y,x)  
hyperbolic trig functions  
sinh(x), cosh(x), tanh(x)  
exponentials & logs  
exp(x), log(x), log10(x)  
exponentials & logs (2 power)  
ldexp(x,n), frexp(x,\*e)  
division & remainder  
modf(x,\*ip), fmod(x,y)  
powers  
pow(x,y), sqrt(x)  
rounding  
ceil(x), floor(x), fabs(x)

### Integer Type Limits <limits.h>

The numbers given in parentheses are typical values for the constants on a 32-bit Unix system.

CHAR\_BIT bits in char (8)  
CHAR\_MAX max value of char (127 or 255)  
CHAR\_MIN min value of char (-128 or 0)  
INT\_MAX max value of int (+32,767)  
INT\_MIN min value of int (-32,768)  
LONG\_MAX max value of long (+2,147,483,647)  
LONG\_MIN min value of long (-2,147,483,648)  
SCHAR\_MAX max value of signed char (+127)  
SCHAR\_MIN min value of signed char (-128)  
SHRT\_MAX max value of short (+32,767)  
SHRT\_MIN min value of short (-32,768)  
UCHAR\_MAX max value of unsigned char (255)  
UINT\_MAX max value of unsigned int (65,535)  
ULONG\_MAX max value of unsigned long (4,294,967,295)  
USHRT\_MAX max value of unsigned short (65,536)

### Float Type Limits <float.h>

FLT\_RADIX radix of exponent rep (2)  
FLT\_ROUNDS floating point rounding mode (6)  
FLT\_DIG decimal digits of precision (10-5)  
FLT\_EPSILON smallest x so 1.0 + x ≠ 1.0 (10-37)  
FLT\_MANT\_DIG number of digits in mantissa (10-37)  
FLT\_MAX maximum floating point number (10-37)  
FLT\_MAX\_EXP maximum exponent (10-37)  
FLT\_MIN minimum floating point number (10-37)  
FLT\_MIN\_EXP minimum exponent (10)  
DBL\_DIG decimal digits of precision (10-9)  
DBL\_EPSILON smallest x so 1.0 + x ≠ 1.0 (10-37)  
DBL\_MANT\_DIG number of digits in mantissa (10-37)  
DBL\_MAX max double floating point number (10-37)  
DBL\_MAX\_EXP maximum exponent (10-37)  
DBL\_MIN min double floating point number (10-37)  
DBL\_MIN\_EXP minimum exponent

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