Team Contest Reference
Ballmer Peak

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1 Mathematische Algorithmen

1.1 Primzahlen

Für Primzahlen gilt immer (aber nicht nur für Primzahlen)

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

Ein paar Primzahlen für den Hausgebrauch: $1000003, 2147483648(2^{31}), 4294967291(2^{32}), \ldots (2^{63})$

1.1.1 Sieb des Eratosthenes

```
static boolean[] sieve(int until) {
  boolean[] a = new boolean[until + 1];
  Arrays.fill(a, true);
  for (int i = 2; i < Math.sqrt(a.length); i++) {
    if (a[i]) {
      for (int j = i * i; j < a.length; j += i) a[j] = false;
    }
  }
  return a; // a[i] == true, iff. i is prime. a[0] is ignored
}
```

1.1.2 Primzahlentest

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

1.2 Binomial Koeffizient

```
static int[][] mem = new int[MAX_N][(MAX_N + 1) / 2];
static int binoCo(int n, int k) {
  if (k < 0 || k > n) return 0;
  if (2 * k > n) binoCo(n, n - k);
  if (mem[n][k] > 0) return mem[n][k];
  int ret = 1;
  for (int i = 1; i <= k; i++) {
    ret *= n - k + i;
    ret /= i;
    mem[n][i] = ret;
  }
  return ret;
}
```

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):

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

1.3.1 Erweiterter Euklidischer Algorithmus

```
static int[] eea(int a, int b) {
  int[] dst = new int[3];
  if (b == 0) {
    dst[0] = a;
    dst[1] = 1;
    return dst; // a, 1, 0
  }
  dst = eea(b, a % b);
  int tmp = dst[2];
  dst[2] = dst[1] - ((a / b) * dst[2]);
  dst[1] = tmp;
  return dst;
}
```

Zur Berechnung des Inversen von n im Restklassenring p gilt: $d = \text{eea}(p, n)$.

1.4 Matrixmultiplikation

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

$$\begin{aligned}
\mathbf{C}_{1,1} &= \mathbf{A}_{1,1}\mathbf{B}_{1,1} + \mathbf{A}_{1,2}\mathbf{B}_{2,1} \\
\mathbf{C}_{1,2} &= \mathbf{A}_{1,1}\mathbf{B}_{1,2} + \mathbf{A}_{1,2}\mathbf{B}_{2,2} \\
\mathbf{C}_{2,1} &= \mathbf{A}_{2,1}\mathbf{B}_{1,1} + \mathbf{A}_{2,2}\mathbf{B}_{2,1} \\
\mathbf{C}_{2,2} &= \mathbf{A}_{2,1}\mathbf{B}_{1,2} + \mathbf{A}_{2,2}\mathbf{B}_{2,2}
\end{aligned}$$

2 Datenstukturen

2.1 Fenwick Tree (Binary Indexed Tree)

```
class FenwickTree {
  private int[] values;
  private int n;
  public FenwickTree(int n) {
    this.n = n;
    values = new int[n];
  }
  public int get(int i) { //get value of i
    int x = values[0];
    while (i > 0) {
      x += values[i];
      i -= i & -i; }
    return x;
  }
  public void add(int i, int x) { // add x to interval [i,n]
    if (i == 0) values[0] += x;
    else {
      while (i < n) {
        values[i] += x;
        i += i & -i; }
    }
  }
}
```

3 Graphenalgorithmen

3.1 Topologische Sortierung

```
static List<Integer> topoSort(Map<Integer, List<Integer>> edges,
    Map<Integer, List<Integer>> revedges) {
  Queue<Integer> q = new LinkedList<Integer>();
  List<Integer> ret = new LinkedList<Integer>();
  Map<Integer, Integer> indeg = new HashMap<Integer, Integer>();
  for (int v : revedges.keySet()) {
    indeg.put(v, revedges.get(v).size());
    if (revedges.get(v).size() == 0)
      q.add(v);
  }
  while (!q.isEmpty()) {
    int tmp = q.poll();
    ret.add(tmp);
    for (int dest : edges.get(tmp)) {
      indeg.put(dest, indeg.get(dest) - 1);
      if (indeg.get(dest) == 0)
        q.add(dest);
    }
  }
  return ret;
}
```

3.2 Minimum Spanning Tree

3.2.1 Prim's Algorithm

```
#define WHITE 0
#define BLACK 1
#define INF INT_MAX

int baum( int **matrix, int N){
  int i, sum = 0;

  int color[N];
  int dist[N];

    // markiere alle Knoten ausser 0 als unbesucht
  color[0] = BLACK;
  for( i=1; i<N; i++){
    color[i] = WHITE;
    dist[i] = INF;
  }
```

```
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 }
```

3.2.2 Union and Find: Kruskal's Algorithm

Amortized time per operation is $O(\alpha(n))$.

```
1  // Only the tree root is stored. The edges must be stored separately.
2  // Path compression and union by rank
3
4  int *par = (int *) malloc(n * sizeof(int));
5  int *rank = (int *) malloc(n * sizeof(int));
6
7  // Create new forest of n vertices
8  void init(int n, int *par, int *rank) {
9    int i;
10   for (i = 1; i <= n; i++) {
11     par[i] = i; // every vertex is its on root
12     rank[i] = 0;
13   }
14 }
15
16 // Union two trees which contain x and y respectively, returns new root
17 int union(int n, int *par, int *rank, int x, int y) {
18   y = find(n, par, y);
19   x = find(n, par, x);
20   if (rank[x] > rank[y]) return par[y] = x;
21   if (rank[x] < rank[y]) return par[x] = y;
22   rank[x]++; // rank[x] == rank[y]
23   return par[y] = x;
24 }
25
26 // Find the tree root of x
27 int find(int n, int *par, int x) {
28   // if parent is not a tree root
29   if (par[x] != par[par[x]]) par[x] = find(n, par, par[x]);
30   return par[x];
31 }
```

3.3 Maximaler Fluss (Ford-Fulkerson)

```
/* die folgende Zeile anpassen! */

#define N_MAX 30*30+30

/* hier drunter nichts anfassen! */
/* ---------------------------- */
#define SIZE_MAX (N_MAX+2)
#define SIZE (N+2)
#define QUELLE (N)
#define SENKE (N+1)
extern int capacity[SIZE_MAX][SIZE_MAX];
extern int N;

int maxFlow();
void reset();
```

```
#include <stdio.h>
#include <limits.h>
#include <string.h>
#include "flow.h"

#define NONE -1
#define INF INT_MAX/2

int N;
int capacity[SIZE_MAX][SIZE_MAX];
int flow[SIZE_MAX][SIZE_MAX];
int queue[SIZE_MAX], *head, *tail;
int state[SIZE_MAX];
int pred[SIZE_MAX];

enum { UNVISITED, WAITING, PROCESSED };

void enqueue( int x){
    *tail++ = x;
    state[x] = WAITING;
}

int dequeue(){
    int x = *head++;
    state[x] = PROCESSED;
    return x;
}

void reset(){
    int i, j;
    for(i=0; i<SIZE;i++){
        memset( capacity[i], 0, sizeof(int)*SIZE );
    }
}

int bfs( int start, int target){
    int u, v;
    for( u=0; u< SIZE; u++){
        state[u] = UNVISITED;
    }
    head = tail = queue;
    pred[start] = NONE;

    enqueue(start);

    while( head < tail){
        u = dequeue();

        for( v= 0; v< SIZE; v++){
            if( state[v] == UNVISITED &&
                capacity[u][v] - flow[u][v] > 0){

                enqueue(v);
                pred[v] = u;
            }
        }
    }

```

```
    return state[target] == PROCESSED;
}

int maxFlow(){
    int max_flow = 0;
    int u;

    int i, j;
    for(i=0; i<SIZE;i++){
        memset( flow[i], 0, sizeof(int)*SIZE );
    }

    while( bfs( QUELLE, SENKE)){
        int increment = INF, temp;

        for( u= SENKE; pred[u] != NONE; u = pred[u]){
            temp = capacity[pred[u]][u] - flow[pred[u]][u];
            if( temp < increment){
                increment = temp;
            }
        }

        for( u= SENKE; pred[u] != NONE; u = pred[u]){
            flow[pred[u]][u] += increment;
            flow[u][pred[u]] -= increment;
        }

        max_flow += increment;
    }

    return max_flow;
}
```

```
/**
 * Ford Fulkersen
 * @param s source
 * @param d destination
 * @param c capacity
 * @param f flow, init with 0
 * @return
 */
static int ff(int s, int d, int[][] c, int[][] f) {
  List<Integer> path = dfs(s, d, c, f, new boolean[c.length]); // find path
  if (path.size() < 2) {
    int flow = 0;
    for (int i = 0; i < f[s].length; i++) { // leaving flow of source
      flow += f[s][i];
    }
    return flow;
  }
  int cap = Integer.MAX_VALUE; // capacity of current path
  for (int i = 0; i < path.size() - 1; i++) {
    int a = path.get(i), b = path.get(i + 1);
    cap = Math.min(cap, c[a][b] - f[a][b]);
  }
  for (int i = 0; i < path.size() - 1; i++) { //update flow
    int a = path.get(i), b = path.get(i + 1);
    f[a][b] += cap;
    f[b][a] -= cap;
  }
  return ff(s, d, c, f); // tail recursion
}

/**
 * depth first search in flow network
 * @param s source
 * @param d destination
 * @param c capacity
 * @param f flow
 * @param v visited, init with false
 * @return
 */
static List<Integer> dfs(int s, int d, int[][] c, int[][] f, boolean[] v) {
  v[s] = true;
  if (s == d) { // destination found
    LinkedList<Integer> path = new LinkedList<Integer>();
    path.add(d);
```

```
    return path;
  }
  for (int i = 0; i < c[s].length; i++) {
    if (!v[i] && c[s][i] - f[s][i] > 0) {
      List<Integer> path = dfs(i, d, c, f, v);
      if (path.size() > 0) {
        ((LinkedList<Integer>) path).addFirst(s);
        return path;
      }
    }
  }
  return ((List<Integer>) Collections.EMPTY_LIST);
}
```

3.4 Floyd-Warshall

```
static int n;
static int[][] path = new int[n][n];
static int[][] next = new int[n][n];
static void floyd(int[][] ad) {
  for (int i = 0; i < n; i++)
    path[i] = Arrays.copyOf(ad[i], n);
  for (int i = 0; i < n; i++)
    for (int j = 0; j < n; j++)
      for (int k = 0; k < n; k++)
        if (path[i][k] + path[k][j] < path[i][j]) {
          path[i][j] = path[i][k] + path[k][j];
          next[i][j] = k;
        }
  // there is a negative circle iff. there is a i such that path[i][i] < 0
}
```

3.5 Dijkstra

```
 Funktion Dijkstra(Graph, Startknoten):
    initialisiere(Graph,Startknoten,abstand[],vorgaenger[],Q)
    solange Q nicht leer:                 // Der eigentliche Algorithmus
        u := Knoten in Q mit kleinstem Wert in abstand[]
        entferne u aus Q                          // fuer u ist der kuerzeste Weg nun bestimmt
        fuer jeden Nachbarn v von u:
            falls v in Q:
               distanz_update(u,v,abstand[],vorgaenger[]) // pruefe Abstand vom Startknoten zu v
    return vorgaenger[]

 Methode initialisiere(Graph,Startknoten,abstand[],vorgaenger[],Q):
    fuer jeden Knoten v in Graph:
        abstand[v] := unendlich
        vorgaenger[v] := null
    abstand[Startknoten] := 0
    Q := Die Menge aller Knoten in Graph

 Methode distanz_update(u,v,abstand[],vorgaenger[]):
    alternativ := abstand[u] + abstand_zwischen(u, v) // Weglaenge vom Startknoten nach v ueber u
    falls alternativ < abstand[v]:
        abstand[v] := alternativ
        vorgaenger[v] := u
```

3.6 Bellmann-Ford

Single source all paths, negative weights.

```
// returns true iff negative-weight cycle reachable
private static boolean bellmannford(Node start, int n, List<Edge> edges) {
  start.dist = 0; // others: dist = Integer.MAX_VALUE
  while (n-- > 0) { // number of nodes --> for all vertices
    for (Edge edge : edges) { // --> for all edges
     if (edge.from.dist < Integer.MAX_VALUE
         && edge.from.dist + edge.w < edge.to.dist)
       edge.to.dist = edge.from.dist + edge.w; // update predecessor
  } }
  for (Edge edge : edges) {
    if (edge.from.dist < Integer.MAX_VALUE
       && edge.from.dist + edge.w < edge.to.dist)
     return true;
  }
  return false;
```

```
}
class Node {}
class Edge {
  Node from, to;
  int w;
  public Edge(Node from, Node to, int w) {
    this.from = from; this.to = to; this.w = w;
  }
}
```

4 Geometrische Algorithmen

4.1 Rotate a Point

```
static P rotate(P origin, P p, double ccw) {
  double x = (p.x - origin.x) * Math.cos(ccw) - (p.y - origin.y) Math.sin(ccw);
  double y = (p.x - origin.x) * Math.sin(ccw) + (p.y - origin.y) Math.cos(ccw);
  return new P(x, y);
}
```

4.2 Graham Scan (Convex Hull)

```
class P {
  double x, y;

  P(double x, double y) {
    this.x = x;
    this.y = y;
  }
  // polar coordinates (not used in graham scan)
  double r() { return Math.sqrt(x * x + y * y); }
  double d() { return Math.atan2(y, x); }
}

// turn is counter-clockwise if > 0; collinear if = 0; clockwise else
static double ccw(P p1, P p2, P p3) {
  return (p2.x - p1.x) * (p3.y - p1.y) - (p2.y - p1.y) * (p3.x - p1.x);
}

static List<P> graham(List<P> l) {
  if (l.size() < 3)
    return l;
  P temp = l.get(0);
  for (P p : l)
    if (temp.y > p.y || temp.y == p.y && temp.x > p.x)
      temp = p;
  final P start = temp; // min y (then leftmost)

  Collections.sort(l, new Comparator<P>() {
    public int compare(P o1, P o2) {
      if (new Double(Math.atan2(o1.y - start.y, o1.x - start.x)) // same angle
          .compareTo(Math.atan2(o2.y - start.y, o2.x - start.x)) == 0)
        return new Double((o1.x - start.x) * (o1.x - start.x)
            + (o1.y - start.y) * (o1.y - start.y))
            .compareTo((o2.x - start.x) * (o2.x - start.x)
            + (o2.y - start.y) * (o2.y - start.y)); // use distance
      return new Double(Math.atan2(o1.y - start.y, o1.x - start.x))
          .compareTo(Math.atan2(o2.y - start.y, o2.x - start.x));
    }
  });
  Stack<P> s = new Stack<P>();
  s.add(start);
  s.add(l.get(1));
  for (int i = 2; i < l.size(); i++) {
    while (s.size() >= 2
        && ccw(s.get(s.size() - 2), s.get(s.size() - 1), l.get(i)) <= 0)
      s.pop();
    s.push(l.get(i));
  }
  return s;
}
```

4.3 Maximum Distance in a Point Set

```
List<P> hull = graham(list);
maxDist(hull);

static double dist(P p1, P p2) {
  return Math.sqrt((p1.x - p2.x) * (p1.x - p2.x)
      + (p1.y - p2.y) * (p1.y - p2.y));
}

static double maxDist(List<P> hull) {
  double max = 0, tmp = 0;
  int j = 0, n = hull.size();
  for (P p : hull) {
    while (tmp < dist(p, hull.get((j + 1) % n))) {
      j = (j + 1) % n;
      tmp = dist(p, hull.get(j));
    }
    max = Math.max(max, tmp);
  }
  return max;
}
```

4.4 Area of a Polygon

```
// area of a polygon, e.g. area(graham(list))
static double area(List<P> l) {
  double sum = 0;
  // points must be in ccw order, otherwise negative area returned
  for (int i = 0; i < l.size(); i++) {
    sum += l.get(i).x * l.get((i + 1) % l.size()).y;
    sum -= l.get(i).y * l.get((i + 1) % l.size()).x;
  }
  return sum / 2;
}
```

4.5 Punkt in Polygon

```
/**
 * -1: A liegt links von BC (ausser unterer Endpunkt)
 * 0: A auf BC
 * +1: sonst
 */
public static int KreuzProdTest(double ax, double ay, double bx, double by,
    double cx, double cy) {
  if (ay == by && by == cy) {
    if ((bx <= ax && ax <= cx) || (cx <= ax && ax <= bx)) return 0;
    else return +1;
  }
  if (by > cy) {
    double tmpx = bx, tmpy = by;
    bx = cx;
    by = cy;
    cx = tmpx;
    cy = tmpy;
  }
  if (ay == by && ax == bx) return 0;
  if (ay <= by || ay > cy) return +1;
  double delta = (bx - ax) * (cy - ay) - (by - ay) * (cx - ax);
  if (delta > 0) return -1;
  else if (delta < 0) return +1;
  else return 0;
}

/**
 * Input: P[i] (x[i],y[i]); P[0]:=P[n]
 * -1: Q ausserhalb Polygon
 * 0: Q auf Polygon
 * +1: Q innerhalb des Polygons
 */
public static int PunktInPoly(double[] x, double[] y, double qx, double qy) {
  int t = -1;
  for (int i = 0; i < x.length - 1; i++)
    t = t * KreuzProdTest(qx, qy, x[i], y[i], x[i + 1], y[i + 1]);
  return t;
}
```

5 Verschiedenes

5.1 Potenzmenge

```
static <T> Iterator<List<T>> powerSet(final List<T> l) {
  return new Iterator<List<T>>() {
    int i; // careful: i becomes 2^l.size()
    public boolean hasNext() {
      return i < (1 << l.size());
    }
    public List<T> next() {
      Vector<T> temp = new Vector<T>();
      for (int j = 0; j < l.size(); j++)
        if (((i >>> j) & 1) == 1)
          temp.add(l.get(j));
      i++;
      return temp;
    }
    public void remove() {}
    };
  }
```

5.2 Longest Common Subsequence

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>


int lcs( char *a, char *b){
    int len = strlen( a);
    int lenb =strlen(b);

    int *zeile = malloc( (len+1) * sizeof(int)), *temp,
        *neue = malloc( (len+1) * sizeof(int)), i, j;

    for(i=0; i<len+1; i++){
        zeile[i] = neue[i] = 0;
    }

    for(j=0; j<lenb; j++){
        for(i=0; i<len; i++){
            if( a[i] == b[j]){
                neue[i+1] = zeile[i] + 1;
            } else {
                neue[i+1] = neue[i] > zeile[i+1] ? neue[i] : zeile[i+1];
            }
        }
        temp = zeile;
        zeile = neue;
        neue = temp;
    }

    int res = zeile[len];
    free( zeile);
    free( neue);
    return res;
}
```

5.3 Longest Increasing Subsequence

```
#include <stdio.h>
#include <stdlib.h>

int lis( int *list, int n){
    int *sorted = malloc( n*sizeof(int)), sorted_n;
    int i, *lower, *upper, *mid, *pos;

    if( n == 0) return 0;

    sorted[0] = list[0];
    sorted_n = 1;

    for( i=1; i<n; i++){
        /* 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 fnc(*type*$_1$,...)	function declarations
type name	external variable declarations
`main() {`	main routine
declarations	local variable declarations
statements	
`}`	
type fnc(*arg*$_1$,...) {	function definition
declarations	local variable declarations
statements	
`return` *value*`;`	
`}`	
`/* */`	comments
`main(int argc, char *argv[])`	main with args
`exit(`*arg*`)`	terminate execution

C Preprocessor

include library file	`#include <`*filename*`>`
include user file	`#include "`*filename*`"`
replacement text	`#define` *name text*
replacement macro	`#define` *name*`(`*var*`)` *text*
Example. `#define max(A,B) ((A)>(B) ? (A) : (B))`	
undefine	`#undef` *name*
quoted string in replace	`#`
concatenate args and rescan	`##`
conditional execution	`#if, #else, #elif, #endif`
is *name* defined, not defined?	`#ifdef, #ifndef`
name defined?	`defined(`*name*`)`
line continuation char	`\`

Data Types/Declarations

character (1 byte)	`char`
integer	`int`
float (single precision)	`float`
float (double precision)	`double`
short (16 bit integer)	`short`
long (32 bit integer)	`long`
positive and negative	`signed`
only positive	`unsigned`
pointer to `int`, `float`,...	`*int, *float`,...
enumeration constant	`enum`
constant (unchanging) value	`const`
declare external variable	`extern`
register variable	`register`
local to source file	`static`
no value	`void`
structure	`struct`
create name by data type	`typedef` *typename*
size of an object (type is `size_t`)	`sizeof` *object*
size of a data type (type is `size_t`)	`sizeof(`*type name*`)`

Initialization

initialize variable	*type name*=*value*
initialize array	*type name*`[]={`*value*$_1$,...`}`
initialize char string	`char` *name*`[]="`*string*`"`

Constants

long (suffix)	`L` or `l`
float (suffix)	`F` or `f`
exponential form	`e`
octal (prefix zero)	`0`
hexadecimal (prefix zero-ex)	`0x` or `0X`
character constant (char, octal, hex)	`'a', '\`*ooo*`', '\x`*hh*`'`
newline, cr, tab, backspace	`\n, \r, \t, \b`
special characters	`\\, \?, \', \"`
string constant (ends with `'\0'`)	`"abc...de"`

Pointers, Arrays & Structures

declare pointer to *type*	*type* `*`*name*
declare function returning pointer to *type*	*type* `*f()`
declare pointer to function returning *type*	*type* `(*pf)()`
generic pointer type	`void *`
null pointer	`NULL`
object pointed to by *pointer*	`*`*pointer*
address of object *name*	`&`*name*
array	*name*`[`*dim*`]`
multi-dim array	*name*`[`*dim*$_1$`][`*dim*$_2$`]...`

Structures

`struct` *tag* `{`	structure template
declarations	declaration of members
`};`	

create structure	`struct` *tag name*
member of structure from template	*name*`.`*member*
member of pointed to structure	*pointer* `->` *member*
Example. `(*p).x` and `p->x` are the same	
single value, multiple type structure	`union`
bit field with *b* bits	*member* `:` *b*

Operators (grouped by precedence)

structure member operator	*name*`.`*member*
structure pointer	*pointer*`->`*member*
increment, decrement	`++, --`
plus, minus, logical not, bitwise not	`+, -, !, ~`
indirection via pointer, address of object	`*`*pointer*`, &`*name*
cast expression to type	`(`*type*`)` *expr*
size of an object	`sizeof`
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	*expr*$_1$ `?` *expr*$_2$ `:` *expr*$_3$
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 delimeters	`{ }`
exit from `switch`, `while`, `do`, `for`	`break`
next iteration of `while`, `do`, `for`	`continue`
go to	`goto` *label*
label	*label*`:`
return value from function	`return` *expr*

Flow Constructions

`if` statement	`if (`*expr*`)` *statement* `else if (`*expr*`)` *statement* `else` *statement*
`while` statement	`while (`*expr*`)` *statement*
`for` statement	`for (`*expr*$_1$`;` *expr*$_2$`;` *expr*$_3$`)` *statement*
`do` 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?	`isalnum(c)`
alphabetic?	`isalpha(c)`
control character?	`iscntrl(c)`
decimal digit?	`isdigit(c)`
printing character (not incl space)?	`isgraph(c)`
lower case letter?	`islower(c)`
printing character (incl space)?	`isprint(c)`
printing char except space, letter, digit?	`ispunct(c)`
space, formfeed, newline, cr, tab, vtab?	`isspace(c)`
upper case letter?	`isupper(c)`
hexadecimal digit?	`isxdigit(c)`
convert to lower case?	`tolower(c)`
convert to upper case?	`toupper(c)`

String Operations `<string.h>`

`s`,t are strings, `cs`,`ct` are constant strings

length of `s`	`strlen(s)`
copy `ct` to `s`	`strcpy(s,ct)`
up to `n` chars	`strncpy(s,ct,n)`
concatenate `ct` after `s`	`strcat(s,ct)`
up to `n` chars	`strncat(s,ct,n)`
compare `cs` to `ct`	`strcmp(cs,ct)`
only first `n` chars	`strncmp(cs,ct,n)`
pointer to first `c` in `cs`	`strchr(cs,c)`
pointer to last `c` in `cs`	`strrchr(cs,c)`
copy `n` chars from `ct` to `s`	`memcpy(s,ct,n)`
copy `n` chars from `ct` to `s` (may overlap)	`memmove(s,ct,n)`
compare `n` chars of `cs` with `ct`	`memcmp(cs,ct,n)`
pointer to first `c` in first `n` chars of `cs`	`memchr(cs,c,n)`
put `c` into first `n` chars of `cs`	`memset(s,c,n)`

C Reference Card (ANSI)

Input/Output <stdio.h>

Standard I/O

standard input stream	stdin
standard output stream	stdout
standard error stream	stderr
end of file	EOF
get a character	getchar()
print a character	putchar(*chr*)
print formatted data	printf("*format*",arg_1,...)
print to string s	sprintf(s,"*format*",arg_1,...)
read formatted data	scanf("*format*",&$name_1$,...)
read from string s	sscanf(s,"*format*",&$name_1$,...)
read line to string s (< max chars)	gets(s,max)
print string s	puts(s)

File I/O

declare file pointer	FILE *fp
pointer to named file	fopen("*name*","*mode*")
modes: r (read), w (write), a (append)	
get a character	getc(*fp*)
write a character	putc(*chr*,*fp*)
write to file	fprintf(*fp*,"*format*",arg_1,...)
read from file	fscanf(*fp*,"*format*",arg_1,...)
close file	fclose(*fp*)
non-zero if error	ferror(*fp*)
non-zero if EOF	feof(*fp*)
read line to string s (< max chars)	fgets(s,max,*fp*)
write string s	fputs(s,*fp*)

Codes for Formatted I/O: "%-+ 0*w.pmc*"

-	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 unamed arg, update pointer	va_arg(*name*,*type*)
call before exiting function	va_end(*name*)

Standard Utility Functions <stdlib.h>

absolute value of int n	abs(n)
absolute value of long n	labs(n)
quotient and remainder of ints n,d	div(n,d)
returns structure with div_t.quot and div_t.rem	
quotient and remainder of longs n,d	ldiv(n,d)
returns structure with ldiv_t.quot and ldiv_t.rem	
pseudo-random integer [0,RAND_MAX]	rand()
set random seed to n	srand(n)
terminate program execution	exit(status)
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	malloc(size), calloc(nobj,size)
change size of object	realloc(pts,size)
deallocate space	free(ptr)

Array Functions

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

Time and Date Functions <time.h>

processor time used by program	clock()
Example. clock()/CLOCKS_PER_SEC is time in seconds	
current calendar time	time()
$time_2$-$time_1$ in seconds (double)	difftime($time_2$,$time_1$)
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	sin(x), cos(x), tan(x)
inverse trig functions	asin(x), acos(x), atan(x)
arctan(y/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	
FLT_DIG	decimal digits of precision	(6)
FLT_EPSILON	smallest x so $1.0 + x \neq 1.0$	(10^{-5})
FLT_MANT_DIG	number of digits in mantissa	
FLT_MAX	maximum floating point number	(10^{37})
FLT_MAX_EXP	maximum exponent	
FLT_MIN	minimum floating point number	(10^{-37})
FLT_MIN_EXP	minimum exponent	
DBL_DIG	decimal digits of precision	(10)
DBL_EPSILON	smallest x so $1.0 + x \neq 1.0$	(10^{-9})
DBL_MANT_DIG	number of digits in mantissa	
DBL_MAX	max double floating point number	(10^{37})
DBL_MAX_EXP	maximum exponent	
DBL_MIN	min double floating point number	(10^{-37})
DBL_MIN_EXP	minimum exponent	

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