**Nanyang Technological Univerisity**

**Orange Juice - ACM-ICPC Cheat Sheet**

**Basic**

**C++ Solution Template**

#**include** <bits/stdc++.h>

#**define** **GET\_BIT**(n, i) (((n) & (1 << ((i)-1))) >> ((i)-1)) *// i start from 1*

#**define** **SET\_BIT**(n, i) ((n) | (1 << ((i)-1)))

#**define** **CLR\_BIT**(n, i) ((n) & ~(1 << ((i)-1)))

#**define** **SHOW\_A**(x) {cout << #x << " = " << x << endl;}

#**define** **SHOW\_B**(x, y) {cout << #x << " = " << x << ", " << #y << " = " << y << endl;}

#**define** **SHOW\_C**(x, y, z) {cout << #x << " = " << x << ", " << #y << " = " << y << ", " << #z << " = " << z << endl;}

#**define** **REACH\_HERE** {cout << "REACH\_HERE! line: " << \_\_LINE\_\_ << endl;}

#**define** **ASSERT**(x) { **\_assert**(x); cout << #x << endl; }

**const** **double** E = 1e-8;

**const** **double** PI = acos(-1);

**using** **namespace** **std;**

**int** test = 0, pass = 0;

**void** **\_assert**(**bool** result) {

test++; pass+=result;

cout << (result ? "PASS: " : "FAIL: ");

}

**int** **main**() {

**ios::sync\_with\_stdio**(**false**);

*// int x = 0;*

*// ASSERT(x==0)*

*// ASSERT((x = SET\_BIT(x, 3))==4)*

*// ASSERT((x = CLR\_BIT(x, 3))==0)*

*// cout << "Total test: " << test << endl;*

*// cout << "Passed: " << pass << " (" << 100.0\*pass/test << "%%)" << endl;*

**return** 0;

}

Optional include list

#**include** <iostream>

#**include** <cstring>

#**include** <cmath>

#**include** <algorithm>

#**include** <climits>

#**include** <stack>

#**include** <queue>

#**include** <vector>

#**include** <set>

#**include** <map>

#**include** <list>

**C++ String**

**Input string**

get one string with no space and new-line.

string a;

cin >> a;

**read one line**

getline()

string a;

**getline**(cin, a);

**Convert to char array**

string cppstr = "this is a string";

**char** target[1024];

**strcpy**(target, cppstr.c\_str());

or

string hi = "hi";

**const** **char**[] = hi.c\_str();

**C String (Character Array)**

**Input C String**

gets()

Reads characters from the standard input (stdin) and stores them as a C string into str until a newline character or the end-of-file is reached.

**char** b[10];

**gets**(b);

cout << "[C++] You have input \"" << b << "\", "

<< ", whose length is " << strlen(b) << endl;

Note: There is a space in front of "world", which will be part of the string. However, using gets() is "unsafe", but we are not to discuss the details here.

**Convert to C++ string**

**char** arrstr[] = "this is a string";

string target = string(arr);

**Algorithm**

#**include** <algorithm>

**Permutation**

Usage

**bool** **next\_permutation** (BidirectionalIterator first, BidirectionalIterator last);

**bool** **next\_permutation** (BidirectionalIterator first, BidirectionalIterator last, Compare comp);

Example

#**include** <iostream> *// std::cout*

#**include** <algorithm> *// std::next\_permutation, std::sort*

**int** **main** () {

**int** myints[] = {1,2,3};

**std::sort** (myints,myints+3);

std::cout << "The 3! possible permutations with 3 elements:\n";

**do** {

std::cout << myints[0] << ' ' << myints[1] << ' ' << myints[2] << '\n';

} **while** ( **std::next\_permutation**(myints,myints+3) );

std::cout << "After loop: " << myints[0] << ' ' << myints[1] << ' ' << myints[2] << '\n';

**return** 0;

}

Output

The 3! possible permutations with 3 elements:

1 2 3

1 3 2

2 1 3

2 3 1

3 1 2

3 2 1

After loop: 1 2 3

**Binary Search**

Usage

**bool** **binary\_search** (ForwardIterator first, ForwardIterator last, **const** T& val, Compare comp);

*// return true if found, false if not*

**Lower Bound**

Returns an iterator pointing to the first element in the range [first,last) which does not compare less than val.

Usage

ForwardIterator **lower\_bound** (ForwardIterator first, ForwardIterator last,

**const** T& val);

ForwardIterator **lower\_bound** (ForwardIterator first, ForwardIterator last,

**const** T& val, Compare comp);

binary\_search is defined by:

**template** <**class** **ForwardIterator**, **class** **T**>

**bool** **binary\_search** (ForwardIterator first, ForwardIterator last, **const** T& val) {

first = **std::lower\_bound**(first,last,val);

**return** (first!=last && !(val<\*first));

}

**Swap**

Usage

**void** **swap** (T& a, T& b);

**void** **iter\_swap** (ForwardIterator1 a, ForwardIterator2 b);

iter\_swap example

**int** myints[]={10,20,30,40,50 }; *// myints: 10 20 30 40 50*

std::vector<**int**> **myvector** (4,99); *// myvector: 99 99 99 99*

**std::iter\_swap**(myints,myvector.begin()); *// myints: [99] 20 30 40 50*

*// myvector: [10] 99 99 99*

**std::iter\_swap**(myints+3,myvector.begin()+2); *// myints: 99 20 30 [99] 50*

*// myvector: 10 99 [40] 99*

**Heap**

// not completed

// TODO add method and example to maintain the size of vector

* make\_heap: Rearranges the elements in the range [first,last) in such a way that they form a heap. The element with the highest value is always pointed by first.
* pop\_heap: Rearranges the elements in the heap range [first,last) in such a way that the part considered a heap is shortened by one: The element with the highest value is moved to (last-1).
* push\_heap: Given a heap in the range [first,last-1), this function extends the range considered a heap to [first,last) by placing the value in (last-1) into its corresponding location within it.
* sort\_heap: Sorts the elements in the heap range [first,last) into ascending order.

Usage

**void** **make\_heap** (RandomAccessIterator first, RandomAccessIterator last, Compare comp);

**void** **pop\_heap** (RandomAccessIterator first, RandomAccessIterator last, Compare comp);

**void** **push\_heap** (RandomAccessIterator first, RandomAccessIterator last, Compare comp);

**void** **sort\_heap** (RandomAccessIterator first, RandomAccessIterator last); Compare comp);

Note: Priority queue is more recoomeneded.

**Sort**

Sorts the elements in the range [first,last) into ascending order. stable\_sort preserves the relative order of the elements with equivalent values.

Usage

**void** **sort** (RandomAccessIterator first, RandomAccessIterator last);

**void** **sort** (RandomAccessIterator first, RandomAccessIterator last, Compare comp);

**void** **stable\_sort** ( RandomAccessIterator first, RandomAccessIterator last );

**void** **stable\_sort** ( RandomAccessIterator first, RandomAccessIterator last,

Compare comp );

**Compare**

bool operator< (ele); true at bottom (for sort, true at front)

**Compare function**

Binary function that accepts two elements in the range as arguments, and returns a value convertible to bool. It should returns true if the first element is considered to be "smaller" than the second one.

Using by sort, make\_heap and etc.

**bool** **myfunction** (**int** i,**int** j) { **return** (i<j); }

**Define operator <()**

Member function

recommended // can use for priority\_queue, sort,

**struct** **Edge** {

**int** from, to, weight;

**bool** **operator**<(Edge that) **const** {

**return** weight > that.weight;

}

};

verbal version

**struct** **Edge** {

**int** from, to, weight;

**bool** **operator**<(**const** Edge& that) **const** {

**return** this->weight > that.weight;

}

};

Non-member function

**struct** **Edge** {

**int** from, to, weight;

**friend** **bool** **operator**<(Edge a, Edge b) {

**return** a.weight > b.weight;

}

};

**Define operator()()**

You can use comparison function for STL containers by passing them as the first argument of the constructor, and specifying the function type as the additional template argument. For example:

set<**int**, **bool** (\*)(**int**, **int**)> **s**(cmp);

A functor, or a function object, is an object that can behave like a function. This is done by defining operator()() of the class. In this case, implement operator()() as a comparison function:

vector<**int**> occurrences;

**struct** **cmp** {

**bool** **operator**()(**int** a, **int** b) {

**return** occurrences[a] < occurrences[b];

}

};

set<**int**, cmp> s;

priority\_queue<**int**, vector<**int**>, cmp> pq;

Used by priority\_queue.

**Map**

#**include** <map>

**Define a Map**

**template** < **class** **Key**, *// map::key\_type*

**class** **T**, *// map::mapped\_type*

**class** **Compare** = less<Key>, *// map::key\_compare*

**class** **Alloc** = allocator<pair<**const** Key,T> > *// map::allocator\_type*

> **class** **map**;

**Commonly used method**

**begin**()

end()

empty()

size()

operator[] *// if not found, insert one*

insert(pair<first type, second type)

erase()

clear()

find() *// if not found, return end()*

count() *// return 1 or 0*

**Red-black Tree**

deleted...

**Hash Map**

**Unordered Map**

// TODO add interface

Unordered map is implemented as a hash table.

**template** < **class** **Key**, *// unordered\_map::key\_type*

**class** **T**, *// unordered\_map::mapped\_type*

**class** **Hash** = hash<Key>, *// unordered\_map::hasher*

**class** **Pred** = equal\_to<Key>, *// unordered\_map::key\_equal*

**class** **Alloc** = allocator< pair<**const** Key,T> > *// unordered\_map::allocator\_type*

> **class** **unordered\_map**;

**Deprecated Hash Map**

#**include** <ext/hash\_map>

\_\_gnu\_cxx::hash\_map<string, **int**> months;

months["january"] = 31;

months["february"] = 28;

**Pair**

**Vector**

**Constructor**

std::vector<**int**> **second** (4,100); *// four ints with value 100*

**Methods**

* begin(), end()
* front(), back()
* clear()
* size()
* push\_back(const value\_type& val)
* pop\_back()

**List**

List containers are implemented as doubly-linked lists.

**Methods**

* begin(), end()
* front(), back()
* clear()
* push\_front(const value\_type& val)
* push\_back(const value\_type& val)
* pop\_front(): remove the first element.
* pop\_back(): remove the last element.
* remove(const value\_type& val): remove all elements of value val.
* insert(iterator position, const value\_type& val)
* size()
* reverse()
* sort(), sort (Compare comp)

**Queue**

include <queue>

Constructor

queue<**int**> my\_queue;

queue<**int**, list<**int**> > **my\_queue** (my\_list);

*// use list<int> as container, copy my\_list into my\_queue*

Methods

**void** **queue::push**(**const** value\_type& val);

**void** **queue::pop**();

**bool** **queue::empty**() **const**;

size\_type **queue::size**() **const**;

const\_reference& **queue::front**() **const**;

**Double-ended Queue**

include <dequeue>

**Stack**

Constructor

stack<**int**, vector<**int**> > **my\_stack** (my\_data);

*// use vector<int> as container, copy my\_data into my\_stack*

**bool** **stack::empty**() **const**;

size\_type **stack::size**() **const**;

const\_reference& **stack::top**() **const**;

**void** **stack::push** (**const** value\_type& val);

**void** **stack::pop**();

**Iterator**

**Priority Queue**

*// constructor*

priority\_queue<**int**> my\_priority\_queue;

priority\_queue<**int**, vector<**int**>, greater<**int**> > two\_priority\_queue;

*// if use greater<int>, must have vector<int>*

priority\_queue<My\_type, vector<My\_type>, Comparator\_class>

**my\_priority\_queue** (my\_data.begin(), my\_data.end());

*// use Comparator\_class as comparator, use vector<My\_type> as container, copy my\_data into my\_priority\_queue*

**bool** **empty**() **const**;

*// return true if empty, false if not*

size\_type **size**() **const**;

*// return size of queue*

const\_reference :top() **const**;

*// returns a constant reference to the top element*

**void** **push**(**const** value\_type& val);

*// inserts a new element, initialize to val*

**void** **pop**();

*// removes the element on top*

**struct** **My\_type** {

**int** weight;

**int** other;

};

**struct** **My\_class\_for\_compare** {

**public:**

**bool** **operator**() (My\_type a, My\_type b) {

**return** a.weight < b.weight;

}

};

vector<My\_type> my\_vector = {(My\_type){2, 789}, (My\_type){1, 127}, (My\_type){3, 456}};

priority\_queue<My\_type, vector<My\_type>, My\_class\_for\_compare>

**one\_priority\_queue** (my\_vector.begin(), my\_vector.end());

one\_priority\_queue.push((My\_type){4, 483});

**while** (one\_priority\_queue.size() != 0) {

My\_type temp = one\_priority\_queue.**top**();

one\_priority\_queue.**pop**();

**SHOW\_B**(temp.weight, temp.other);

}

vector<**int**> my\_int = {2, 3, 1};

priority\_queue<**int**, vector<**int**>, greater<**int**> > **two\_priority\_queue** (my\_int.begin(), my\_int.end());

**while** (two\_priority\_queue.size() != 0) {

**SHOW\_A**(two\_priority\_queue.**top**());

two\_priority\_queue.**pop**();

}

*// output*

*// temp.weight = 4, temp.other = 483*

*// temp.weight = 3, temp.other = 456*

*// temp.weight = 2, temp.other = 789*

*// temp.weight = 1, temp.other = 127*

*// two\_priority\_queue.top() = 1*

*// two\_priority\_queue.top() = 2*

*// two\_priority\_queue.top() = 3*

**BigInteger & BigDecimal**

**C++ Big Integer**

**const** **int** BASE\_LENGTH = 2;

**const** **int** BASE = (**int**) pow(10, BASE\_LENGTH);

**const** **int** MAX\_LENGTH = 500;

string **int\_to\_string**(**int** i, **int** width, **bool** zero) {

string res = "";

**while** (width--) {

**if** (!zero && i == 0) **return** res;

res = (**char**)(i%10 + '0') + res;

i /= 10;

}

**return** res;

}

**struct** **bigint** {

**int** len, s[MAX\_LENGTH];

**bigint**() {

**memset**(s, 0, **sizeof**(s));

len = 1;

}

**bigint**(**unsigned** **long** **long** num) {

len = 0;

**while** (num >= BASE) {

s[len] = num % BASE;

num /= BASE;

len ++;

}

s[len++] = num;

}

**bigint**(**const** **char**\* num) {

**int** l = **strlen**(num);

len = l/BASE\_LENGTH;

**if** (l % BASE\_LENGTH) len++;

**int** index = 0;

**for** (**int** i = l - 1; i >= 0; i -= BASE\_LENGTH) {

**int** tmp = 0;

**int** k = i - BASE\_LENGTH + 1;

**if** (k < 0) k = 0;

**for** (**int** j = k; j <= i; j++) {

tmp = tmp\*10 + num[j] - '0';

}

s[index++] = tmp;

}

}

**void** **clean**() {

**while**(len > 1 && !s[len-1]) len--;

}

string **str**() **const** {

string ret = "";

**if** (len == 1 && !s[0]) **return** "0";

**for**(**int** i = 0; i < len; i++) {

**if** (i == 0) {

ret += **int\_to\_string**(s[len - i - 1], BASE\_LENGTH, **false**);

} **else** {

ret += **int\_to\_string**(s[len - i - 1], BASE\_LENGTH, **true**);

}

}

**return** ret;

}

**unsigned** **long** **long** **ll**() **const** {

**unsigned** **long** **long** ret = 0;

**for**(**int** i = len-1; i >= 0; i--) {

ret \*= BASE;

ret += s[i];

}

**return** ret;

}

bigint **operator** + (**const** bigint& b) **const** {

bigint c = b;

**while** (c.len < len) c.s[c.len++] = 0;

c.s[c.len++] = 0;

**bool** r = 0;

**for** (**int** i = 0; i < len || r; i++) {

c.s[i] += (i<len)\*s[i] + r;

r = c.s[i] >= BASE;

**if** (r) c.s[i] -= BASE;

}

c.**clean**();

**return** c;

}

bigint **operator** - (**const** bigint& b) **const** {

**if** (**operator** < (b)) **throw** "cannot do subtract";

bigint c = \*this;

**bool** r = 0;

**for** (**int** i = 0; i < b.len || r; i++) {

c.s[i] -= b.s[i];

r = c.s[i] < 0;

**if** (r) c.s[i] += BASE;

}

c.**clean**();

**return** c;

}

bigint **operator** \* (**const** bigint& b) **const** {

bigint c;

c.len = len + b.len;

**for**(**int** i = 0; i < len; i++)

**for**(**int** j = 0; j < b.len; j++)

c.s[i+j] += s[i] \* b.s[j];

**for**(**int** i = 0; i < c.len-1; i++){

c.s[i+1] += c.s[i] / BASE;

c.s[i] %= BASE;

}

c.**clean**();

**return** c;

}

bigint **operator** / (**const** **int** b) **const** {

bigint ret;

**int** down = 0;

**for** (**int** i = len - 1; i >= 0; i--) {

ret.s[i] = (s[i] + down \* BASE) / b;

down = s[i] + down \* BASE - ret.s[i] \* b;

}

ret.len = len;

ret.**clean**();

**return** ret;

}

**bool** **operator** < (**const** bigint& b) **const** {

**if** (len < b.len) **return** **true**;

**else** **if** (len > b.len) **return** **false**;

**for** (**int** i = 0; i < len; i++)

**if** (s[i] < b.s[i]) **return** **true**;

**else** **if** (s[i] > b.s[i]) **return** **false**;

**return** **false**;

}

**bool** **operator** == (**const** bigint& b) **const** {

**return** !(\*this<b) && !(b<(\*this));

}

**bool** **operator** > (**const** bigint& b) **const** {

**return** b < \*this;

}

};

**The Java Approach**

**BigInteger**

**import** **java. math. BigInteger**;

Constructor and Description

BigInteger(**String** val)

*// translates the decimal String representation of a BigInteger into a BigInteger.*

BigInteger(**String** val, **int** radix)

*// translates the String representation of a BigInteger in the specified radix into a BigInteger.*

*//Modifier and Type Method and Description*

**BigInteger** abs()

*// returns a BigInteger whose value is the absolute value of this BigInteger.*

**BigInteger** add(**BigInteger** val)

*// returns a BigInteger whose value is (this + val).*

**BigInteger** subtract(**BigInteger** val)

**BigInteger** multiply(**BigInteger** val)

**BigInteger** divide(**BigInteger** val)

**BigInteger** pow(**int** exponent)

*// returns a BigInteger whose value is (thisexponent).*

**BigInteger** and(**BigInteger** val)

*// returns a BigInteger whose value is (this & val).*

**BigInteger** or(**BigInteger** val)

**BigInteger** not()

**BigInteger** shiftLeft(**int** n)

*// returns a BigInteger whose value is (this << n).*

**BigInteger** shiftRight(**int** n)

**BigInteger** mod(**BigInteger** m)

*// returns a BigInteger whose value is (this mod m).*

**BigInteger** remainder(**BigInteger** val)

*// returns a BigInteger whose value is (this % val).*

**BigInteger** gcd(**BigInteger** val)

*// returns a BigInteger whose value is the greatest common divisor of abs(this) and abs(val).*

**BigInteger** max(**BigInteger** val)

*// returns the maximum of this BigInteger and val.*

**BigInteger** min(**BigInteger** val)

**int** compareTo(**BigInteger** val)

*// compares this BigInteger with the specified BigInteger.*

**String** toString(**int** radix)

*// returns the String representation of this BigInteger in the given radix.*

**static** **BigInteger** valueOf(**long** val)

*// returns a BigInteger whose value is equal to that of the specified long.*

**long** longValue()

*// converts this BigInteger to a long.*

**BigDecimal**

*// constructor*

BigDecimal(**BigInteger** val)

*// Translates a BigInteger into a BigDecimal.*

BigDecimal(**BigInteger** unscaledVal, **int** scale)

*// Translates a BigInteger unscaled value and an int scale into a BigDecimal.*

BigDecimal(**BigInteger** unscaledVal, **int** scale, **MathContext** mc)

*// Translates a BigInteger unscaled value and an int scale into a BigDecimal, with rounding according to the context settings.*

BigDecimal(**BigInteger** val, **MathContext** mc)

*// Translates a BigInteger into a BigDecimal rounding according to the context settings.*

BigDecimal(**char**[] in)

*// Translates a character array representation of a BigDecimal into a BigDecimal, accepting the same sequence of characters as the BigDecimal(String) constructor.*

BigDecimal(**char**[] in, **int** offset, **int** len)

*// Translates a character array representation of a BigDecimal into a BigDecimal, accepting the same sequence of characters as the BigDecimal(String) constructor, while allowing a sub-array to be specified.*

BigDecimal(**char**[] in, **int** offset, **int** len, **MathContext** mc)

*// Translates a character array representation of a BigDecimal into a BigDecimal, accepting the same sequence of characters as the BigDecimal(String) constructor, while allowing a sub-array to be specified and with rounding according to the context settings.*

BigDecimal(**char**[] in, **MathContext** mc)

*// Translates a character array representation of a BigDecimal into a BigDecimal, accepting the same sequence of characters as the BigDecimal(String) constructor and with rounding according to the context settings.*

BigDecimal(**double** val)

*// Translates a double into a BigDecimal which is the exact decimal representation of the double's binary floating-point value.*

BigDecimal(**double** val, **MathContext** mc)

*// Translates a double into a BigDecimal, with rounding according to the context settings.*

BigDecimal(**int** val)

*// Translates an int into a BigDecimal.*

BigDecimal(**int** val, **MathContext** mc)

*// Translates an int into a BigDecimal, with rounding according to the context settings.*

BigDecimal(**long** val)

*// Translates a long into a BigDecimal.*

BigDecimal(**long** val, **MathContext** mc)

*// Translates a long into a BigDecimal, with rounding according to the context settings.*

BigDecimal(**String** val)

*// Translates the string representation of a BigDecimal into a BigDecimal.*

BigDecimal(**String** val, **MathContext** mc)

*// Translates the string representation of a BigDecimal into a BigDecimal, accepting the same strings as the BigDecimal(String) constructor, with rounding according to the context settings.*

**BigDecimal** abs()

*// Returns a BigDecimal whose value is the absolute value of this BigDecimal, and whose scale is this.scale().*

**BigDecimal** abs(**MathContext** mc)

*// Returns a BigDecimal whose value is the absolute value of this BigDecimal, with rounding according to the context settings.*

**BigDecimal** add(**BigDecimal** augend)

*// Returns a BigDecimal whose value is (this + augend), and whose scale is max(this.scale(), augend.scale()).*

**BigDecimal** add(**BigDecimal** augend, **MathContext** mc)

*// Returns a BigDecimal whose value is (this + augend), with rounding according to the context settings.*

**byte** byteValueExact()

*// Converts this BigDecimal to a byte, checking for lost information.*

**int** compareTo(**BigDecimal** val)

*// Compares this BigDecimal with the specified BigDecimal.*

**BigDecimal** divide(**BigDecimal** divisor)

*// Returns a BigDecimal whose value is (this / divisor), and whose preferred scale is (this.scale() - divisor.scale()); if the exact quotient cannot be represented (because it has a non-terminating decimal expansion) an ArithmeticException is thrown.*

**BigDecimal** divide(**BigDecimal** divisor, **int** roundingMode)

*// Returns a BigDecimal whose value is (this / divisor), and whose scale is this.scale().*

**BigDecimal** divide(**BigDecimal** divisor, **int** scale, **int** roundingMode)

*// Returns a BigDecimal whose value is (this / divisor), and whose scale is as specified.*

**BigDecimal** divide(**BigDecimal** divisor, **int** scale, **RoundingMode** roundingMode)

*// Returns a BigDecimal whose value is (this / divisor), and whose scale is as specified.*

**BigDecimal** divide(**BigDecimal** divisor, **MathContext** mc)

*// Returns a BigDecimal whose value is (this / divisor), with rounding according to the context settings.*

**BigDecimal** divide(**BigDecimal** divisor, **RoundingMode** roundingMode)

*// Returns a BigDecimal whose value is (this / divisor), and whose scale is this.scale().*

**BigDecimal**[] divideAndRemainder(**BigDecimal** divisor)

*// Returns a two-element BigDecimal array containing the result of divideToIntegralValue followed by the result of remainder on the two operands.*

**BigDecimal**[] divideAndRemainder(**BigDecimal** divisor, **MathContext** mc)

*//Returns a two-element BigDecimal array containing the result of divideToIntegralValue followed by the result of remainder on the two operands calculated with rounding according to the context settings.*

**BigDecimal** divideToIntegralValue(**BigDecimal** divisor)

*// Returns a BigDecimal whose value is the integer part of the quotient (this / divisor) rounded down.*

**BigDecimal** divideToIntegralValue(**BigDecimal** divisor, **MathContext** mc)

*// Returns a BigDecimal whose value is the integer part of (this / divisor).*

**double** doubleValue()

*// Converts this BigDecimal to a double.*

**boolean** equals(**Object** x)

*// Compares this BigDecimal with the specified Object for equality.*

**float** floatValue()

*// Converts this BigDecimal to a float.*

**int** hashCode()

*// Returns the hash code for this BigDecimal.*

**int** intValue()

*// Converts this BigDecimal to an int.*

**int** intValueExact()

*// Converts this BigDecimal to an int, checking for lost information.*

**long** longValue()

*// Converts this BigDecimal to a long.*

**long** longValueExact()

*// Converts this BigDecimal to a long, checking for lost information.*

**BigDecimal** max(**BigDecimal** val)

*// Returns the maximum of this BigDecimal and val.*

**BigDecimal** min(**BigDecimal** val)

*// Returns the minimum of this BigDecimal and val.*

**BigDecimal** movePointLeft(**int** n)

*// Returns a BigDecimal which is equivalent to this one with the decimal point moved n places to the left.*

**BigDecimal** movePointRight(**int** n)

*// Returns a BigDecimal which is equivalent to this one with the decimal point moved n places to the right.*

**BigDecimal** multiply(**BigDecimal** multiplicand)

*// Returns a BigDecimal whose value is (this × multiplicand), and whose scale is (this.scale() + multiplicand.scale()).*

**BigDecimal** multiply(**BigDecimal** multiplicand, **MathContext** mc)

*// Returns a BigDecimal whose value is (this × multiplicand), with rounding according to the context settings.*

**BigDecimal** negate()

*// Returns a BigDecimal whose value is (-this), and whose scale is this.scale().*

**BigDecimal** negate(**MathContext** mc)

*// Returns a BigDecimal whose value is (-this), with rounding according to the context settings.*

**BigDecimal** plus()

*// Returns a BigDecimal whose value is (+this), and whose scale is this.scale().*

**BigDecimal** plus(**MathContext** mc)

*// Returns a BigDecimal whose value is (+this), with rounding according to the context settings.*

**BigDecimal** pow(**int** n)

*// Returns a BigDecimal whose value is (thisn), The power is computed exactly, to unlimited precision.*

**BigDecimal** pow(**int** n, **MathContext** mc)

*// Returns a BigDecimal whose value is (thisn).*

**int** precision()

*// Returns the precision of this BigDecimal.*

**BigDecimal** remainder(**BigDecimal** divisor)

*// Returns a BigDecimal whose value is (this % divisor).*

**BigDecimal** remainder(**BigDecimal** divisor, **MathContext** mc)

*// Returns a BigDecimal whose value is (this % divisor), with rounding according to the context settings.*

**BigDecimal** round(**MathContext** mc)

*// Returns a BigDecimal rounded according to the MathContext settings.*

**int** scale()

*// Returns the scale of this BigDecimal.*

**BigDecimal** scaleByPowerOfTen(**int** n)

*// Returns a BigDecimal whose numerical value is equal to (this \* 10n).*

**BigDecimal** setScale(**int** newScale)

*// Returns a BigDecimal whose scale is the specified value, and whose value is numerically equal to this BigDecimal's.*

**BigDecimal** setScale(**int** newScale, **int** roundingMode)

*// Returns a BigDecimal whose scale is the specified value, and whose unscaled value is determined by multiplying or dividing this BigDecimal's unscaled value by the appropriate power of ten to maintain its overall value.*

**BigDecimal** setScale(**int** newScale, **RoundingMode** roundingMode)

*// Returns a BigDecimal whose scale is the specified value, and whose unscaled value is determined by multiplying or dividing this BigDecimal's unscaled value by the appropriate power of ten to maintain its overall value.*

**short** shortValueExact()

*// Converts this BigDecimal to a short, checking for lost information.*

**int** signum()

*// Returns the signum function of this BigDecimal.*

**BigDecimal** stripTrailingZeros()

*// Returns a BigDecimal which is numerically equal to this one but with any trailing zeros removed from the representation.*

**BigDecimal** subtract(**BigDecimal** subtrahend)

*// Returns a BigDecimal whose value is (this - subtrahend), and whose scale is max(this.scale(), subtrahend.scale()).*

**BigDecimal** subtract(**BigDecimal** subtrahend, **MathContext** mc)

*// Returns a BigDecimal whose value is (this - subtrahend), with rounding according to the context settings.*

**BigInteger** toBigInteger()

*// Converts this BigDecimal to a BigInteger.*

**BigInteger** toBigIntegerExact()

*// Converts this BigDecimal to a BigInteger, checking for lost information.*

**String** toEngineeringString()

*// Returns a string representation of this BigDecimal, using engineering notation if an exponent is needed.*

**String** toPlainString()

*// Returns a string representation of this BigDecimal without an exponent field.*

**String** toString()

*// Returns the string representation of this BigDecimal, using scientific notation if an exponent is needed.*

**BigDecimal** ulp()

*// Returns the size of an ulp, a unit in the last place, of this BigDecimal.*

**BigInteger** unscaledValue()

*// Returns a BigInteger whose value is the unscaled value of this BigDecimal.*

**static** **BigDecimal** valueOf(**double** val)

*// Translates a double into a BigDecimal, using the double's canonical string representation provided by the Double.toString(double) method.*

**static** **BigDecimal** valueOf(**long** val)

*// Translates a long value into a BigDecimal with a scale of zero.*

**static** **BigDecimal** valueOf(**long** unscaledVal, **int** scale)

*// Translates a long unscaled value and an int scale into a BigDecimal.*

**Tree**

**Tree Traversal**

**Trie**

**后缀数组**

**Binary Indexed Tree**

**Segment Tree**

**const** **int** MAX = 100000;

**struct** **node** {

**int** left, right;

**int** color;

**bool** cover;

};

node nodes[3\*MAX];

**void** **build\_tree**(**int** left, **int** right, **int** u) {

nodes[u].left = left;

nodes[u].right = right;

nodes[u].color = 1;

nodes[u].cover = **true**;

**if** (left == right) **return**;

**int** mid = (left + right)/2;

**build\_tree**(left, mid, 2\*u);

**build\_tree**(mid+1, right, 2\*u + 1);

}

**void** **get\_down**(**int** u) {

**int** value = nodes[u].color;

nodes[u].cover = **false**;

nodes[2\*u].color = value;

nodes[2\*u].cover = **true**;

nodes[2\*u + 1].color = value;

nodes[2\*u + 1].cover = **true**;

}

**void** **update**(**int** left, **int** right, **int** value, **int** u) {

**if** (left <= nodes[u].left && nodes[u].right <= right) {

nodes[u].color = value;

nodes[u].cover = **true**;

**return**;

}

**if** (nodes[u].color == value) **return**; *// optimize purpose*

*//SHOW(u);*

**if** (nodes[u].cover) **get\_down**(u);

**if** (left <= nodes[2\*u].right) {

**update**(left, right, value, 2\*u);

}

**if** (right >= nodes[2\*u+1].left) {

**update**(left, right, value, 2\*u + 1);

}

nodes[u].color = nodes[2\*u].color | nodes[2\*u+1].color;

}

**void** **query**(**int** left, **int** right, **int** &sum, **int** u) {

**if** (nodes[u].cover) {

sum |= nodes[u].color;

**return**;

}

**if** (left <= nodes[u].left && nodes[u].right <= right) {

sum |= nodes[u].color;

**return**;

}

**if** (left <= nodes[2\*u].right) {

**query**(left, right, sum, 2\*u);

}

**if** (right >= nodes[2\*u+1].left) {

**query**(left, right, sum, 2\*u + 1);

}

}

*// only for this question*

**int** **bit\_count**(**int** sum) {

**int** ans = 0;

**while** (sum) {

**if** (sum%2) ans++;

sum = sum >> 1;

}

**return** ans;

}

**int** **main**() {

**int** L, T, O;

cin >> L >> T >> O;

**build\_tree**(1, L, 1);

**while** (O--) {

**char** op;

**int** a, b, c;

cin >> op;

**if** (op == 'C') {

cin >> a >> b >> c;

**if** (a > b) **swap**(a, b);

**update**(a, b, 1<<(c-1), 1);

} **else** {

cin >> a >> b;

**if** (a > b) **swap**(a, b);

**int** sum = 0;

**query**(a, b, sum, 1);

cout << **bit\_count**(sum) << endl;

}

}

**return** 0;

}

**Range Minimum Query RMQ**

place holder

**String**

**KMP**

**Longest palindromic substring (Manacher's algorithm)**

**Graph**

**Union-find Set**

**int** father[n];

**int** **get\_father**(**int** a) {

**if** (father[a] != a)

**return** father[a] = **get\_father**(father[a]);

**return** a;

}

**void** **init**() {

**for** (**int** i = 0; i < n; i++)

father[i] = i;

}

**Union-find Set - application**

place holder

**Minimium Spanning Tree**

**Prim's**

graph[][], time complexity: O(V^2)

**void** **mst\_prim**() {

**int** n\_node, n\_edge;

*////////////////////////////////////////*

*// read data*

*////////////////////////////////////////*

**int** graph[n\_node][n\_node];

**int** min\_dis[n\_node];

**for** (**int** i = 0; i < n\_node; i++)

min\_dis[i] = INT\_MAX; *// initialize*

*////////////////////////////////////////*

*// read graph[][]*

*////////////////////////////////////////*

**int** cur = 0; *// the node just added*

**for** (**int** i = 1; i < n\_node; i++) { *// total need pick n-1 edges*

min\_dis[cur] = -1; *// add cur*

**for** (**int** j = 0; j < n\_node; j++) *// for all node*

**if** (graph[cur][j] < min\_dis[j]) *// if can reach from new node and nearer*

min\_dis[j] = graph[cur][j]; *// update the distance*

**int** next = -1; *// the node to add*

**int** cur\_min\_dis = INT\_MAX; *// current distance of nearest node*

**for** (**int** j = 0; j < n\_node; j++) *// check all node*

**if** (min\_dis[j] >= 0 && min\_dis[j] < cur\_min\_dis) { *// if j node is nearer*

next = j; *// record*

cur\_min\_dis = min\_dis[j];

}

*// add edge: cur->next*

cur = next; *// next node to add*

}

}

vector graph[], time complexity: (V + E)log(V)

**struct** **Edge** {

**int** from;

**int** to;

**int** length;

**bool** **operator**< (Edge b) **const** {

**return** this->length > b.length;

}

};

**void** **mst\_prim**() {

**int** n\_node;

**int** n\_edge;

*////////////////////////////////////////////*

*// cin >> n\_node >> n\_edge;*

*////////////////////////////////////////////*

vector<Edge> graph[n\_node];

*////////////////////////////////////////////*

*// read graph*

*////////////////////////////////////////////*

priority\_queue<Edge> discovered;

**int** added[n\_node];

**memset**(added, 0, **sizeof**(added));

**int** to\_add = n\_node;

Edge temp = {0, 0, 0};

discovered.**push**(temp); *// 0 is first node*

**while** (to\_add--) {

Edge cur = discovered.**top**();

discovered.**pop**();

**while** (added[cur.to] == 1) {

cur = discovered.**top**();

discovered.**pop**();

}

*// cur is the edge to add*

added[cur.to] = 1;

**for** (**int** i = 0; i < graph[cur.to].**size**(); i++) {

Edge& next = graph[cur.to][i];

**if** (to != next.to && added[next.to] == 0) {

discovered.**push**(next);

}

}

}

*// should directly maintain the min distance for each node to current tree*

*// use heapfy...*

}

**Kruskal**

Elog(E) + Elog(V)

**struct** **Edge** {

**int** from;

**int** to;

**int** length;

**bool** **operator**< (Edge b) **const** {

**return** this->length < b.length;

}

};

**int** **get\_father**(**int** father[], **int** a) {

**if** (father[a] != a)

**return** father[a] = **get\_father**(father, father[a]);

**return** a;

}

**void** **solve**() {

**int** n\_node, n\_edge;

*/////////////////////////////////////////////////////*

*// initialize n\_edge*

*/////////////////////////////////////////////////////*

Edge e[n\_edge];

*/////////////////////////////////////////////////////*

*// initialize edge e*

*/////////////////////////////////////////////////////*

**int** father[n\_node];

**for** (**int** i = 0; i < n\_node; i++)

father[i] = i; *// initialize*

**sort**(e, e + n\_edge);

**int** to\_add = n\_node - 1;

**for** (**int** cur = 0; to\_add; cur++) {

**int** fromSfather = **get\_father**(father, e[cur].from);

**int** toSfather = **get\_father**(father, e[cur].to);

**if** (fromSfather != toSfather) {

father[fromSfather] = toSfather;

to\_add--;

*// add edge e[cur]*

}

}

}

**Shortest Path**

**任意两点**

for ()

for ()

for ()

**Bellman–Ford**

Bellman–Ford algorithm is O(VE). Can be applied to situations when there is a maximun number of vertices in shortest path.

for (n times of relax)

for (each node)

relax each node

**SPFA**

**Dijkstra**

Dijkstra is good for graphs non-negative edges.

O(V^2)

**Bipartite Graph 二分图**

1. A graph is bipartite if and only if it does not contain an odd cycle.
2. A graph is bipartite if and only if it is 2-colorable, (i.e. its chromatic number is less than or equal to 2).
3. The spectrum of a graph is symmetric if and only if it's a bipartite graph.

**Hungarian algorithm 匈牙利算法**

O(E \* V)

**int** n\_node;

**int** graph[405][405];

**int** match[405];

**int** visited[405];

**bool** **augment**(**int** cur) {

**for** (**int** i = 0; i < n\_node; i++) { *// for all node*

**if** (graph[cur][i] > 0 && visited[i] == 0) { *// if have edge and not visited*

visited[i] = 1; *// mark visited*

**if** (match[i] == -1 || **augment**(match[i])) { *// if not matched, or its previous can find other match*

match[i] = cur; *// match it*

**return** **true**;

}

}

}

**return** **false**; *// cannot find any match*

}

**int** **match**() {

**memset**(graph, 0, **sizeof**(graph));

*////////////////////////////////////////////////*

*// initialize n\_node, graph*

*////////////////////////////////////////////////*

**int** n\_match = 0;

**memset**(match, -1, **sizeof**(match));

**for** (**int** i = 0; i < n\_node; i++) { *// for each node, find an augmented path*

**memset**(visited, 0, **sizeof**(visited)); *// each node only visit once*

**if** (**augment**(i)) *// if found*

n\_match++; *// maximum matching ++*

}

}

**Maximum Flow Problem 最大流**

**Dinic**

**int** graph[250][250];

**int** level[250];

**int** n\_node;

**int** **mark\_level**(**int** start, **int** end) {

**memset**(level, -1, **sizeof**(level));

queue<**int**> to\_visit;

level[start] = 0;

to\_visit.**push**(start);

**while** (!to\_visit.**empty**()) {

**int** cur = to\_visit.**front**();

to\_visit.**pop**();

**for** (**int** i = 0; i < n\_node; ++i) {

**if** (graph[cur][i] != 0 && level[i] == -1) {

level[i] = level[cur] + 1;

to\_visit.**push**(i);

}

}

}

**if** (level[end] == -1)

**return** 0; *// cannot reach the sink*

**return** 1; *// can reach the sink*

}

**int** **augment**(**int** cur, **int** end, **int** min\_flow) {

**if** (cur == end)

**return** min\_flow;

**int** augmented\_flow = 0;

**for** (**int** i = 0; i < n\_node; ++i) {

**if** ((level[i] == level[cur] + 1 && graph[cur][i] > 0) &&

(augmented\_flow = **augment**(i, end, **min**(graph[cur][i], min\_flow)))

) {

graph[cur][i] -= augmented\_flow;

graph[i][cur] += augmented\_flow;

**return** augmented\_flow;

}

}

**return** 0;

}

**int** **dinic**(**int** start, **int** end) {

**int** ans = 0;

**int** temp = 0;

**while** (**mark\_level**(start, end))

**while** (temp = **augment**(start, end, INT\_MAX))

ans += temp;

**return** ans;

}

**Minimum-Cost Maximum-Flow**

*// have not tested*

**int** n\_node;

**int** n\_edge;

**int** cost[405][405]; *// cost[i][j] = -cost[j][i]*

**int** residual[405][405];

**bool** **bellman\_ford**(**int**& flow\_sum, **int**&cost\_sum) { *// 0: start, n\_node - 1: end*

**int** min\_cost[405]; **for** (**int** i = 0; i < n\_node; i++) min\_cost[i] = INT\_MAX; min\_cost[0] = 0;

**int** pre\_node[405]; pre\_node[0] = 0;

**int** max\_flow[405];

**int** in\_queue[405]; **memset**(in\_queue, 0, **sizeof**(in\_queue));

queue<**int**> q;

q.**push**(0);

**while** (q.**size**()) {

**int** cur = q.**front**(); q.**pop**();

in\_queue[cur] = 0;

**for** (**int** i = 0; i < n\_node; i++) {

**if** (residual[cur][i] > 0 && min\_cost[i] > min\_cost[cur] + cost[cur][i]) {

min\_cost[i] = min\_cost[cur] + cost[cur][i];

pre\_node[i] = cur;

max\_flow[i] = **min**(max\_flow[cur], residual[cur][i]);

**if** (in\_queue[i] == 0) {

in\_queue[i] = 1;

q.**push**(i);

}

}

}

}

**if** (min\_cost[n\_node - 1] == INT\_MAX)

**return** **false**;

flow\_sum += max\_flow[n\_node - 1];

cost\_sum += max\_flow[n\_node - 1] \* min\_cost[n\_node - 1];

**for** (**int** cur = n\_node - 1; cur != 0; cur = pre\_node[cur]) {

residual[pre\_node[cur]][cur] -= max\_flow[n\_node - 1];

residual[cur][pre\_node[cur]] += max\_flow[n\_node - 1];

}

**return** **true**;

}

**void** **min\_cost\_max\_flow**() {

**int** flow\_sum = 0;

**int** cost\_sum = 0;

**while** (**bellman\_ford**(flow\_sum, cost\_sum));

cout << flow\_sum << " " << cost\_sum << endl;

}

**强连通分量 图的 割点, 桥, 双连通分支**https://www.byvoid.com/blog/biconnect

### **[点连通度与边连通度]**

在一个无向连通图中，如果有一个顶点集合，删除这个顶点集合，以及这个集合中所有顶点相关联的边以后，原图变成多个连通块，就称这个点集为**割点集合**。一个图的**点连通度**的定义为，最小割点集合中的顶点数。

类似的，如果有一个边集合，删除这个边集合以后，原图变成多个连通块，就称这个点集为**割边集合**。一个图的**边连通度**的定义为，最小割边集合中的边数。

### **[双连通图、割点与桥]**

如果一个无向连通图的点连通度大于1，则称该图是**点双连通的(point biconnected)**，简称**双连通**或**重连通**。一个图有割点，当且仅当这个图的点连通度为1，则割点集合的唯一元素被称为**割点(cut point)**，又叫**关节点(articulation point)**。

如果一个无向连通图的边连通度大于1，则称该图是**边双连通的(edge biconnected)**，简称双连通或重连通。一个图有桥，当且仅当这个图的边连通度为1，则割边集合的唯一元素被称为**桥(bridge)**，又叫**关节边(articulation edge)。**

可以看出，点双连通与边双连通都可以简称为双连通，它们之间是有着某种联系的，下文中提到的双连通，均既可指点双连通，又可指边双连通。

### **[双连通分支]**

在图G的所有子图G'中，如果G'是双连通的，则称G'为**双连通子图**。如果一个双连通子图G'它不是任何一个双连通子图的真子集，则G'为**极大双连通子图**。**双连通分支(biconnected component)**，或**重连通分支**，就是图的极大双连通子图。特殊的，点双连通分支又叫做**块**。

### **[求割点与桥]**

该算法是R.Tarjan发明的。对图深度优先搜索，定义DFS(u)为u在搜索树（以下简称为树）中被遍历到的次序号。定义Low(u)为u或u的子树中能通过非父子边追溯到的最早的节点，即DFS序号最小的节点。根据定义，则有：

Low(u)=Min { DFS(u) DFS(v) (u,v)为后向边(返祖边) 等价于 DFS(v)<DFS(u)且v不为u的父亲节点 Low(v) (u,v)为树枝边(父子边) }

一个顶点u是割点，当且仅当满足(1)或(2) (1) u为树根，且u有多于一个子树。 (2) u不为树根，且满足存在(u,v)为树枝边(或称父子边，即u为v在搜索树中的父亲)，使得DFS(u)<=Low(v)。

一条无向边(u,v)是桥，当且仅当(u,v)为树枝边，且满足DFS(u)<Low(v)。

### **[求双连通分支]**

下面要分开讨论点双连通分支与边双连通分支的求法。

对于点双连通分支，实际上在求割点的过程中就能顺便把每个点双连通分支求出。建立一个栈，存储当前双连通分支，在搜索图时，每找到一条树枝边或后向边(非横叉边)，就把这条边加入栈中。如果遇到某时满足DFS(u)<=Low(v)，说明u是一个割点，同时把边从栈顶一个个取出，直到遇到了边(u,v)，取出的这些边与其关联的点，组成一个点双连通分支。割点可以属于多个点双连通分支，其余点和每条边只属于且属于一个点双连通分支。

对于边双连通分支，求法更为简单。只需在求出所有的桥以后，把桥边删除，原图变成了多个连通块，则每个连通块就是一个边双连通分支。桥不属于任何一个边双连通分支，其余的边和每个顶点都属于且只属于一个边双连通分支。

### **[构造双连通图]**

一个有桥的连通图，如何把它通过加边变成边双连通图？方法为首先求出所有的桥，然后删除这些桥边，剩下的每个连通块都是一个双连通子图。把每个双连通子图收缩为一个顶点，再把桥边加回来，最后的这个图一定是一棵树，边连通度为1。

统计出树中度为1的节点的个数，即为叶节点的个数，记为leaf。则至少在树上添加(leaf+1)/2条边，就能使树达到边二连通，所以至少添加的边数就是(leaf+1)/2。具体方法为，首先把两个最近公共祖先最远的两个叶节点之间连接一条边，这样可以把这两个点到祖先的路径上所有点收缩到一起，因为一个形成的环一定是双连通的。然后再找两个最近公共祖先最远的两个叶节点，这样一对一对找完，恰好是(leaf+1)/2次，把所有点收缩到了一起。

**拓扑排序**

place holder

**Euler Cycle/Path, Hamilton Cycle/Path**

place holder

**Mathematics**

**class/struct Matrix**

**operator**+

**operator**\*

Square matrix

**struct** **Matrix** {

*// int height;*

*// int width;*

**long** **long** value[32][32];

Matrix **operator**\* (**const** Matrix& that);

Matrix **operator**+ (**const** Matrix& that);

Matrix **mirror**();

**void** **show**() {

cout << endl;

**for** (**int** i = 0; i < n; i++) {

**for** (**int** j = 0; j < n; j++)

cout << this->value[i][j] << " ";

cout << endl;

}

}

};

**void** **mod\_it**(Matrix& temp) {

**for** (**int** i = 0; i < n; i++)

**for** (**int** j = 0; j < n; j++)

temp.value[i][j] %= m;

}

Matrix Matrix::**operator**\* (**const** Matrix& that) {

Matrix temp;

**for** (**int** i = 0; i < n; i++) {

**for** (**int** j = 0; j < n; j++) {

temp.value[i][j] = 0;

**for** (**int** k = 0; k < n; k++)

temp.value[i][j] += this->value[i][k] \* that.value[k][j];

}

}

**mod\_it**(temp);

**return** temp;

}

Matrix Matrix::**operator**+ (**const** Matrix& that) {

Matrix temp;

**for** (**int** i = 0; i < n; i++)

**for** (**int** j = 0; j < n; j++)

temp.value[i][j] = this->value[i][j] + that.value[i][j];

**mod\_it**(temp);

**return** temp;

}

Matrix **Matrix::mirror**() {

Matrix temp;

**for** (**int** i = 0; i < n; i++)

**for** (**int** j = 0; j < n; j++)

temp.value[i][j] = this->value[i][j];

**return** temp;

}

**欧拉函数 ?**

**欧几里得算法 / gcd**

see next section

**扩展欧几里得算法**

http://www.cnblogs.com/frog112111/archive/2012/08/19/2646012.html

对于不完全为 0 的非负整数 a, b, 必然存在整数对 (x, y), 使得 gcd(a, b) = ax + by

suppose: a > b, we want to get (x1, y1)

(i) if b == 0, then gcd(a, b) = a = ax + 0, then x1 = 1, y1 = 0

(ii) if b != 0:

(1): a \* x1 + b \* y1 = gcd(a, b)

(2): b \* x2 + (a % b) \* y2 = gcd(b, a % b)

(1) == (2)

so: a \* x1 + b \* y1 = b \* x2 + (a % b) \* y2

so: a \* x1 + b \* y1 = b \* x2 + (a - (int)(a / b) \* b) \* y2

so: a \* x1 + b \* y1 = a \* y2 + b \* (x2 - (int)(a / b) \* y2)

so: x1 = y2, y1 = x2 - (int)(a / b) \* y2, can get (x1, y1) from (x2, y2)

next:

(1): b \* x2 + (a % b) \* y2 = gcd(b, a % b)

(2): (a % b) \* x3 + b % (a % b) \* y3 = gcd(a % b, b % (a % b))

so: can get (x2, y2) from (x3, y3)

next: ... until in gcd(a, b), b == 0, then xi = 1, yi = 0, go back ...

**long** **long** ansx, ansy, ansd;

**void** **euclidean**(**long** **long** a, **long** **long** b) {

**if** (b == 0) {

ansx = 1;

ansy = 0;

ansd = a;

} **else** {

**euclidean**(b, a % b);

**long** **long** temp = ansx;

ansx = ansy;

ansy = temp - a / b \* ansy;

}

}

**int** **main**(**int** argc, **char** **const** \*argv[]) {

**long** **long** a, b, c;

cin >> a >> b >> c;

ansx = 0;

ansy = 0;

ansd = 0;

**euclidean**(a, b);

*// now (ansx, ansy) is the answer (x, y) for a \* x1 + b \* y1 = gcd(a, b)*

*// ansd is the a when b == 0, which is just gcd(a, b)*

}

**求解不定方程**

for: p \* a + q \* b = c

if c % gcd(a, b) == 0, then 有整数解 (p, q), else NO

if we get (p0, q0) for p0 \* a + q0 \* b = gcd(a, b)

then: for p \* a + q \* b = gcd(a, b) (k is any integer)

p = p0 + b / gcd(a, b) \* k

q = q0 - a / gcd(a, b) \* k

then: for p \* a + q \* b = c = c / gcd(a, b) \* gcd(a, b) (k is any integer)

p = (p0 + b / gcd(a, b) \* k) \* c / gcd(a, b)

q = (q0 - a / gcd(a, b) \* k) \* c / gcd(a, b)

*// after get ansx, ansy, ansd*

*// test if c % ansd == 0*

*// ansx = (ansx + b / gcd(a, b) \* k) \* c / gcd(a, b)*

*// ansy = (ansy - a / gcd(a, b) \* k) \* c / gcd(a, b)*

*// smallest: ansx % (b / gcd(a, b) + b / gcd(a, b)) % (b / gcd(a, b))*

**求解模线性方程（线性同余方程）**

(a \* x) % n = b % n, x = ?

same as: a \* x + n \* y= b

so: one answer for a \* x + n \* y= b is: x \* b / gcd(a, n)

so: one answer for (a \* x) % n = b % n is: x0 = (x \* b / gcd(a, n)) % n

other answer xi = (x0 + i \* (n / gcd(a, n))) % n, i = 0...gcd(a, n)-1

smallest answer is x0 % (n / gcd(a, n) + gcd(a, n)) % gcd(a, n)

**求解模的逆元**

(a \* x) % n = 1, x = ?

if gcd(a, n) != 1, then NO answer

else:

same as: a \* x + n \* y = 1

can get only one answer x

*// after get ansx, ansy, ansd*

*// if ansd != 1, then NO answer*

*// smallest ansx = (ansx % (n / gcd(a, n)) + (n / gcd(a, n))) % (n / gcd(a, n))*

**中国剩余定理**

**最小公倍数**

a \* b / gcd(a, b)

**分解质因数**

**long** **long** x;

cin >> x;

**for** (**long** **long** factor = 2; x != 1; factor++) {

**if** (x % factor == 0)

cout << factor << " is a prime factor" << endl;

**while** (x % factor == 0)

x = x / factor;

}

**因数个数**

n = p1 ^ x1 \* p2 ^ x2 \* ... \* pn ^ xn

total = (x1 + 1) \* (x2 + 1) \* ... \* (xn + 1)

**素数判定**

大于 3 的质数可以被表示为 6n - 1 或 6n + 1

**bool** **is\_prime**(**int** n) {

**if** (n == 1 || n % 2 == 0)

**return** **false**;

**int** t = **sqrt**(n);

**for** (**int** i = 3; i <= t; i += 2)

**if** (n % i == 0)

**return** **false**;

**return** **true**;

}

**进制转换**

**void** **convert\_dec\_to\_base**(**int** n, **const** **int** base) {

**if** (n == 0)

cout << 0 << endl;

**while** (n != 0) {

**int** e = n % base;

cout << e << " "; *// printing in reverse order*

n /= base;

} cout << endl;

}

**int** **convert\_base\_to\_dec**(**const** **int** s[], **const** **int** len, **const** **int** base) {

**int** result = 0;

**for** (**int** i = 0; i < len; i++)

result = result \* base + s[i];

**return** result;

}

**A / C**

C(n, k) = C(n-1, k) + C(n-1, k-1) C(n, k) = C(n, n-k)

**博弈论**

place holder

**Geometry**

**template class for Point?**

**struct** **point** {

**int** x, y;

**double** **length**() {

**return** **sqrt**(x\*x + y\*y);

}

**long** **operator**\* (**const** point& b) {

**return** x\*b.y - y\*b.x;

}

**long** **cross\_product**(**const** point& b) {

**return** x \* b.x + y \* b.y;

}

**bool** **at\_right\_of**(**const** point& a, **const** point& b) **const** {

*// a: relative point, b: base*

point vec\_self = {x - b.x, y - b.y};

point vec\_that = {a.x - b.x, a.y - b.y};

**long** product = vec\_self \* vec\_that;

**if** (product>0) **return** **true**;

**if** (product==0 && vec\_self.**length**()>vec\_that.**length**()) **return** **true**;

**return** **false**;

}

**double** **to\_point**(**const** point& b) **const** {

**return** **sqrt**(**pow**(x-b.x,2) + **pow**(y-b.y,2));

}

**double** **to\_segment**(**const** point& a, **const** point& b) **const** {

**double** len\_ab = a.**to\_point**(b);

**if** (**abs**(len\_ab)<E) **return** **to\_point**(a);

**double** r = ((a.y-y)\*(a.y-b.y) - (a.x-x)\*(a.x-b.x))/**pow**(len\_ab,2);

**if** (r>1 || r<0) **return** **min**(**to\_point**(a), **to\_point**(b));

*// projection of p is on extension of AB*

r = ((a.y - y)\*(b.y - y) - (a.x - x)\*(b.y - a.y))/**pow**(len\_ab,2);

**return** **fabs**(r\*len\_ab);

}

**double** **to\_segment\_v2**(**const** point& a, **const** point& b) **const** {

point vec\_ab = {b.x - a.x, b.y - a.y};

point vec\_ia = {x - a.x, y - a.y};

point vec\_ib = {x - b.x, y - b.y};

**if** (vec\_ia.**cross\_product**(ba) < 0 ||　vec\_ib.**cross\_product**(ba) > 0)

**return** **min**(**to\_point**(a), **to\_point**(b));

**return** **abs**(vec\_ab \* vec\_ia) / vec\_ab.**length**();

} *// same meaning with v1, need test*

};

**向量点乘 叉乘**

a = (x1, y1) b = (x2, y2) i ... |i| = 1, vertical to a-b surface

**dot product**

a dot b = x1 \* x2 + y1 \* y2 = |a| \* |b| \* cos(angle)

if = 0: 90 degree

a dot b / |b| = a project to b

**cross product**

a x b = x1 \* y2 - x2 \* y1 = |a| \* |b| \* sin(angle) \* i

if < 0: b is at left of a

if = 0: a, b in a line

if 0: b is at right of a

a x b = area of 平行四边形 a x b x c = area of 平行六面体, c = (x3, y3)

**直线公式**

(x, y) = (x1, y1) + k \* ((x2, y2) - (x1, y1))

**Convex Hull**

**Gift Wrapping**

place holder

**QuickHull**

place holder

**Graham scan**

O(VlogV)

**struct** **Point** {

**long** x;

**long** y;

**bool** **at\_right\_of**(Point& that, Point& base) {

Point vec\_self = {this->x - base.x, this->y - base.y};

Point vec\_that = {that.x - base.x, that.y - base.y};

**long** product = vec\_self \* vec\_that;

**if** (product > 0)

**return** **true**; *// "this" is at right of "that"*

**if** (product == 0 && vec\_self.**length**() > vec\_that.**length**())

**return** **true**; *// "this" is at right of "that"*

**return** **false**; *// "this" is NOT at right of "that"*

};

**long** **operator**\* (Point& that) {

**return** this->x \* that.y - this->y \* that.x;

};

**double** **distance\_to**(Point& that) {

**long** x\_diff = this->x - that.x;

**long** y\_diff = this->y - that.y;

**return** **sqrt**(x\_diff \* x\_diff + y\_diff \* y\_diff);

};

**double** **length**() {

**return** **sqrt**(this->x \* this->x + this->y \* this->y);

}

};

Point p[1005];

**int** my\_stack[1005];

**int** n, l, my\_stack\_top = -1;

**bool** **compare**(Point p1, Point p2) {

**return** p1.**at\_right\_of**(p2, p[0]);

}

**void** **push**(**int** index) {

my\_stack[++my\_stack\_top] = index;

}

**int** **pop**() {

**int** temp = my\_stack[my\_stack\_top--];

**return** temp;

}

**void** **graham\_scan**() {

**push**(0);

**push**(1);

**int** pre;

**int** prepre;

**for** (**int** i = 2; i < n; i++) {

pre = my\_stack\_top;

prepre = my\_stack\_top - 1;

**while** (p[i].**at\_right\_of**(p[my\_stack[pre]], p[my\_stack[prepre]])) {

**pop**();

**if** (my\_stack\_top == 0)

**break**;

pre = my\_stack\_top;

prepre = my\_stack\_top - 1;

}

**push**(i);

}

**int** last = my\_stack\_top;

**if** (p[0].**at\_right\_of**(p[my\_stack[last]], p[my\_stack[pre]]))

**pop**();

}

**int** **main**(**int** argc, **char** **const** \*argv[]) {

cin >> n >> l;

**int** minimun = 0;

**for** (**int** i = 0; i < n; ++i) {

**int** temp\_x, temp\_y;

cin >> temp\_x >> temp\_y;

p[i] = {temp\_x, temp\_y};

**if** ((p[i].y < p[minimun].y) || (p[i].y == p[minimun].y && p[i].x < p[minimun].x))

minimun = i;

}

Point temp = {p[minimun].x, p[minimun].y}; *// swap lowest and most left point to p[0]*

p[minimun] = p[0];

p[0] = temp;

**sort**(p + 1, p + n, compare); *// use p[0] as base, sort according to polar angle*

**graham\_scan**();

*// now all points in the stack is on Convex Hull // size of stack = 1 + stack\_top*

**for** (**int** i = 0; i <= my\_stack\_top; i++)

cout << "point " << my\_stack[i] << " is on Convex Hull" << endl;

}

**Tricks / 分析方法**

**Recursive**

**Hanoi**

**void** **hanoi**(**int** n, **char** x, **char** y, **char** z) { *// 将 x 上编号 1 至 n 的圆盘移到 z, y 作辅助塔*

**if** (n == 1)

**printf**("%d from %c to %c\n", n, x, z); *// 将编号为 n 的圆盘从 x 移到 z*

**else** {

**hanoi**(n-1, x, z, y); *// 将 x 上编号 1 至 n-1 的圆盘移到 y, z 作辅助塔*

**printf**("%d from %c to %c\n", n, x, z); *// 将编号为 n 的圆盘从 x 移到 z*

**hanoi**(n-1, y, x, z); *// 将 y 上编号 1 至 n-1 的圆盘移到 z, x 作辅助塔*

}

}

**Dynamic Programming**

**树上的**

**Divide and Conquer**

**迭代加深搜索 (binary increase/decrease)**

**int** up\_limit = ;

**int** down\_limit = ;

**int** cur, pre;

**while** (**true**) {

cur = (down\_limit + up\_limit) / 2;

**bool** ok = **search**();

**if** (ok)

up\_limit = cur;

**else**

down\_limit = cur;

pre = cur;

cur = (down\_limit + up\_limit) / 2;

**if** (pre == cur)

**return** up\_limit;

}

**双向 BFS**

**从终点开始搜**

**Brute Force**

**子集生成**

**Userful Code Snippets**

**cantor\_expansion / reverse\_cantor\_expansion**

for hashing, or ...

**long** **long** **factorial**(**int** n) {

**if** (n == 0)

**return** 1;

**long** **long** ans = n;

**for** (**int** i = 1; i < n; i++)

ans = ans \* i;

**return** ans;

}

**long** **long** **cantor\_expansion**(**int** permutation[], **int** n) {

*// input: (m-th permutation of n numbers, n)*

*// return: m*

**int** used[n + 1];

**memset**(used, n, **sizeof**(used));

**long** **long** ans = 0;

**for** (**int** i = 0; i < n; i++) {

**int** temp = 0;

used[permutation[i]] = 1;

**for** (**int** j = 1; j < permutation[i]; j++)

**if** (used[j] != 1)

temp += 1;

ans += **factorial**(n - 1 - i) \* temp;

}

**return** ans + 1;

}

**void** **reverse\_cantor\_expansion**(**int** n, **long** **long** m) {

*// m-th permutation of n numbers*

**int** ans[n + 1], used[n + 1];

**memset**(ans, -1, **sizeof** (ans));

**memset**(used, 0, **sizeof** (used));

m = m - 1;

**for** (**int** i = n - 1; i >= 0; i--) {

**long** **long** fac = **factorial**(i);

**int** temp = m / fac + 1;

m = m - (temp - 1) \* fac;

**for** (**int** j = 1; j <= temp; j++)

**if** (used[j] == 1)

temp++;

ans[n - i] = temp;

used[temp] = 1;

}

**for** (**int** i = 1; i < n + 1; i++)

cout << ans[i] << " ";

cout << "\n";

}

**Fast Exponention**

To calculate n ^ p % M

**int** **power\_modulo**(**int** n, **int** p, **int** M) {

**int** result = 1;

**while** (p > 0) {

**if** (p % 2 == 1)

result = (result\*n) % M;

p /= 2;

n = (n\*n) % M;

}

**return** result;

}

**质数表**

**int** is\_prime[UP\_LIMIT + 1];

**for** (**int** i = 1; i <= UP\_LIMIT; i++) *// init to 1*

is\_prime[i] = 1;

**for** (**int** i = 4; i <= UP\_LIMIT; i += 2) *// even number is not*

is\_prime[i] = 0;

**for** (**int** k = 3; k\*k <= UP\_LIMIT; k++) *// start from 9, end at sqrt*

**if** (is\_prime[k])

**for**(**int** i = k\*k; i <= UP\_LIMIT; i += 2\*k) *// every two is not*

is\_prime[i] = 0;