Contents

Chapter 1

A Better Way To Approach Competitive Programming

A Better Way To Approach Competitive Programming - GeeksforGeeks

Thisarticle helps to all those who want to begin with Competitive Programming. The only prerequisite one need is the knowledge of a programming language.

Now, Let us find a better approach to Competitive Programming. Please note:

1. One should read the proper Input and Output format because most of the beginners make mistakes of having extra print statements in the output. So please be careful to the output format. **Example** – “Please Enter Next Number :” and “Output is : .

2. Analyze the problem constraints before writing code because most of the time you have written the code that is brute force and will not run in the given time limit constraint.

Following are the some of the issues that you might face if you are a beginner.:

1. **Time Limit** : It is given in seconds. It gives you the insight about the order of the correct solution. Consider following situation.Time Limit = 1 Sec
   Let us Assume 1 sec approximately can perform 10^8 operations.
   If you write a program that is of order O(N^2) and the problem has T test cases.
   Then total order of your program becomes O(T*N^2) .
   If T <= 1000 and N <= 1000, then (ignoring hidden constants in asymptotic notations) your code may not be accepted in worst case as 1000*1000*1000 is 10^9 operations which means 10 seconds.
   To avoid TLE, always think of the worst test cases that are possible for the problem and analyze your code in that situation.

2. **Run Time Error** : It is the one of the most encountered problem by the beginners. The main reason could be :

   (a) Segmentation Fault : It is the illegal accessing of memory address. **e.g** int[] array = new int[100]; System.out.println(array[101]);
   (b) Declaration of an array of more than 10^8.
   (c) Divide & Taking Modulus with 0 .
   (d) You should know how to use GDB that will help you to correct your run time error.

3. **Compilation Error** : It is one of the errors that is frequently faced when program ming in C/C++.

4. **Wrong Answer** : Whenever you encounter WA, write a brute force code & make sure that it is perfect. Now generate test cases using random function in C++. Run your code on these test cases and match the output. Now think of the corner cases that will help you to find the problem in your algorithm.

5. **IntOverflow** : Many times unknowingly you will exceed the maximum value that can be stored in primitive type int. e.g. Constraints : 0 < num1,num2 <= 10^9

```
 #include<iostream.h>
int main()
{
   int num1, num2;
   cin >> num1 >> num2;
   int answer = num1 + num2;

   // error if num1 and num2 are large
   // numbers
   cout<< answer;
```

```
    return 0;
}
```

The above program won't run correct always because (2*10^9) it may exceed the maximum value that can be stored in INTS. i.e 10^9. So you will have to use long longint or unsigned int primitive data type for answer in such a case.

6. **Comparing Doubles** :

```
 int main()
{
    float a ;
    cin << a;
    if (a == 10)
      cout << "YES";
}
```

float and double data types don't have infinite precision . **Beware** (6/15 digit precision for them respectively). So always use a margin of (~0.0000001) in comparing. Example –


```
if (abs(a -10) < (0.0000001))
{
cout << "YES";
}
```

Other Useful Points :
Sometimes when you are stuck. Check running time of other accepted code and analyze about the order of solution is required and the amount of memory that is allowed.

1. 4 MB ~ integer array of size 10^6 (assuming int takes 4 bytes) or 2-d array of size 10^3*10^3

Standard Memory limits in most of the problem are of order of 256MB.

If you have to allocate large array, then it is NOT a good idea to do allocation inside a function as memory is allocated and released for every test case, and memory is allocated on function call stack (stack size is limited at many places). Thus if you have to make an array of large size, make it global.

I hope this article was of help to you and hope that you will now be able to attempt questions being better prepared and thereby perform better, quicker. ff

Source

Chapter 2

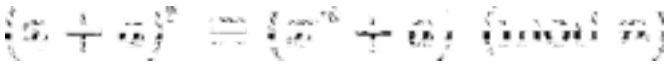
AKS Primality Test

AKS Primality Test - GeeksforGeeks

There are several primality test available to check whether the number is prime or not like **Fermat's Theorem**, **Miller-Rabin** Primality test and alot more. But problem with all of them is they all are probabilistic in nature. So, here comes one another method i.e **AKS primality test (Agrawal–Kayal–Saxena primality test)** and it is **deterministically correct** for any general number.

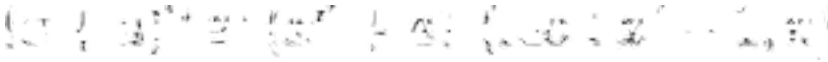
Features of AKS primality test :
1. The AKS algorithm can be used to verify the primality of any general number given. 2. The maximum running time of the algorithm can be expressed as a polynomial over the number of digits in the target number.
3. The algorithm is guaranteed to distinguish deterministically whether the target number is prime or composite.
4. The correctness of AKS is not conditional on any subsidiary unproven hypothesis.

The AKS primality test is based upon the following theorem: An integer n greater than 2 is prime if and only if the polynomial congruence relation

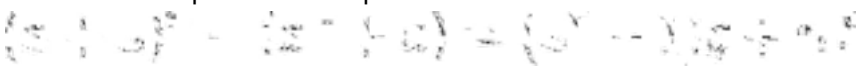


holds for some **a coprime to n**. Here x is just a formal symbol .

The AKS test evaluates the equality by making complexity dependent on the size of r . This is expressed as



which can be expressed in simpler term as



for some polynomials f and g .
This congruence can be checked in polynomial time when r is polynomial to the digits of n. The AKS algorithm evaluates this congruence for a large set of a values, whose size is polynomial to the digits of n. The proof of validity of the AKS algorithm shows that one can find r and a set of a values with the above properties such that if the congruences hold

then n is a power of a prime. The brute force approach would require the expansion of the **(x – a)^n** polynomial and a reduction (mod n) of the resulting n + 1 coefficients .

As a should be co-prime to n. So, to implement this algorithm we can check by taking a = 1, but for large values of n we should take large values of a.
***The algorithm is based on the condition* that if n is any number, then it is prime if, (x – 1)^n – (x^n – 1) is divisible by n.**

Checking for n = 3 :

(x-1)^3 – (x^3 – 1)
= (x^3 – 3x^2 + 3x – 1) – (x^3 – 1)
= -3x^2 + 3x

As all the coefficients are divisible by n i.e. 3, so 3 (n) is prime. As the number increases, size increases.
The code here is based on this condition and can check primes till 64

. Below is the implementation of above approach:

C++

```
  // C++ code to check if number is prime. This
// program demonstrates concept behind AKS
// algorithm and doesn't implement the actual
// algorithm (This works only till n = 64)
#include <bits/stdc++.h>
using namespace std;

// array used to store coefficients .
long long c[100];

// function to calculate the coefficients
```

```
// of (x - 1)^n - (x^n - 1) with the help
// of Pascal's triangle .
void coef(int n)
{
    c[0] = 1;
    for (int i = 0; i < n; c[0] = -c[0], i++) {
        c[1 + i] = 1;

        for (int j = i; j > 0; j--)
            c[j] = c[j - 1] - c[j];
    }
}

// function to check whether
// the number is prime or not
bool isPrime(int n)
```



```
{
    // Calculating all the coefficients by
    // the function coef and storing all
    // the coefficients in c array .
    coef(n);

    // subtracting c[n] and adding c[0] by 1
    // as ( x - 1 )^n - ( x^n - 1), here we
    // are subtracting c[n] by 1 and adding
    // 1 in expression.
    c[0]++, c[n]--;

    // checking all the coefficients whether
    // they are divisible by n or not.
    // if n is not prime, then loop breaks
    // and (i > 0).
    int i = n;
    while (i-- && c[i] % n == 0)
        ;

    // Return true if all coefficients are
    // divisible by n.
    return i < 0;
}

// driver program
int main()
{
    int n = 37;
    if (isPrime(n))
        cout << "Prime" << endl;
```

```
    else
        cout << "Not Prime" << endl;
    return 0;
}
```

Java

```
  // Java code to check if number is prime. This
// program demonstrates concept behind AKS
// algorithm and doesn't implement the actual
// algorithm (This works only till n = 64)

class GFG {
    // array used to store coefficients .
    static long c[] = new long[100];

    // function to calculate the coefficients
```



```
    // of (x - 1)^n - (x^n - 1) with the help
    // of Pascal's triangle .
    static void coef(int n)
    {
        c[0] = 1;
        for (int i = 0; i < n; c[0] = -c[0], i++) {
            c[1 + i] = 1;

            for (int j = i; j > 0; j--)
                c[j] = c[j - 1] - c[j];
        }
    }

    // function to check whether
    // the number is prime or not
    static boolean isPrime(int n)
    {
        // Calculating all the coefficients by
        // the function coef and storing all
        // the coefficients in c array .
        coef(n);

        // subtracting c[n] and adding c[0] by 1
        // as ( x - 1 )^n - ( x^n - 1), here we
        // are subtracting c[n] by 1 and adding
        // 1 in expression.
        c[0]++;
        c[n]--;

        // checking all the coefficients whether
```

```
        // they are divisible by n or not.
        // if n is not prime, then loop breaks
        // and (i > 0).
        int i = n;
        while ((i--) > 0 && c[i] % n == 0)
            ;

        // Return true if all coefficients are
        // divisible by n.
        return i < 0;
    }
    // Driver code
    public static void main(String[] args)
    {
        int n = 37;
        if (isPrime(n))
            System.out.println("Prime");
        else
```



```
            System.out.println("Not Prime");
    }
}

// This code is contributed by Anant Agarwal.
```

Python3

```
  # Python3 code to check if
# number is prime. This
# program demonstrates concept
# behind AKS algorithm and
# doesn't implement the actual
# algorithm (This works only
# till n = 64)

# array used to
# store coefficients .
c = [0] * 100;

# function to calculate the
# coefficients of (x - 1)^n -
# (x^n - 1) with the help
# of Pascal's triangle .
def coef(n):
    c[0] = 1;
    for i in range(n):
        c[1 + i] = 1;
        for j in range(i, 0, -1):
```

```
            c[j] = c[j - 1] - c[j];
        c[0] = -c[0];

# function to check whether
# the number is prime or not
def isPrime(n):

    # Calculating all the coefficients
    # by the function coef and storing
    # all the coefficients in c array .
    coef(n);

    # subtracting c[n] and adding
    # c[0] by 1 as ( x - 1 )^n -
    # ( x^n - 1), here we are
    # subtracting c[n] by 1 and
    # adding 1 in expression.
    c[0] = c[0] + 1;
    c[n] = c[n] - 1;
```



```
    # checking all the coefficients
    # whether they are divisible by
    # n or not. if n is not prime,
    # then loop breaks and (i > 0).
    i = n;
    while (i > -1 and c[i] % n == 0):
        i = i - 1;

    # Return true if all coefficients
    # are divisible by n.
    return True if i < 0 else False;

# Driver Code
n = 37;
if (isPrime(n)):
    print("Prime");
else:
    print("Not Prime");

# This code is contributed by mits
```

C#

```
  // C# code to check if number is prime. This
// program demonstrates concept behind AKS
// algorithm and doesn't implement the actual
// algorithm (This works only till n = 64)
```

```
using System;

class GFG {

    // array used to store coefficients .
    static long []c = new long[100];

    // function to calculate the coefficients
    // of (x - 1)^n - (x^n - 1) with the help
    // of Pascal's triangle .
    static void coef(int n)
    {
        c[0] = 1;

        for (int i = 0; i < n; c[0] = -c[0], i++)
        {
            c[1 + i] = 1;

            for (int j = i; j > 0; j--)
                c[j] = c[j - 1] - c[j];
```



```
        }
    }

    // function to check whether
    // the number is prime or not
    static bool isPrime(int n)
    {

        // Calculating all the coefficients by
        // the function coef and storing all
        // the coefficients in c array .
        coef(n);

        // subtracting c[n] and adding c[0] by 1
        // as ( x - 1 )^n - ( x^n - 1), here we
        // are subtracting c[n] by 1 and adding
        // 1 in expression.
        c[0]++;
        c[n]--;

        // checking all the coefficients whether
        // they are divisible by n or not.
        // if n is not prime, then loop breaks
        // and (i > 0).
        int i = n;
        while ((i--) > 0 && c[i] % n == 0)
            ;
```

```
        // Return true if all coefficients are
        // divisible by n.
        return i < 0;
    }

    // Driver code
    public static void Main()
    {
        int n = 37;
        if (isPrime(n))
            Console.WriteLine("Prime");
        else
            Console.WriteLine("Not Prime");
    }
}

// This code is contributed by anuj_67.
```

PHP


```
 <?php
// PHP code to check if number
// is prime. This program
// demonstrates concept behind
// AKS algorithm and doesn't
// implement the actual
// algorithm (This works only
// till n = 64)

// array used to
// store coefficients .
global $c;

// function to calculate
// the coefficients
// of (x - 1)^n -
// (x^n - 1) with the help
// of Pascal's triangle .
function coef($n)
{
    $c[0] = 1;
    for ($i = 0; $i < $n; $c[0] = -$c[0], $i++)
    {
        $c[1 + $i] = 1;

        for ($j = $i; $j > 0; $j--)
```

```
            $c[$j] = $c[$j - 1] - $c[$j];
    }
}

// function to check whether
// the number is prime or not
function isPrime($n)
{
    global $c;

    // Calculating all the
    // coefficients by the
    // function coef and
    // storing all the
    // coefficients in c array .
    coef($n);

    // subtracting c[n] and
    // adding c[0] by 1 as
    // ( x - 1 )^n - ( x^n - 1),
    // here we are subtracting c[n]
    // by 1 and adding 1 in expression.
```



```
    // $c[0]++; $c[$n]--;

    // checking all the coefficients whether
    // they are divisible by n or not.
    // if n is not prime, then loop breaks
    // and (i > 0).
    $i = $n;
    while ($i-- && $c[$i] % $n == 0)

    // Return true if all
    // coefficients are
    // divisible by n.
    return $i < 0;
}

    // Driver Code
    $n = 37;
    if (isPrime($n))
        echo "Not Prime", "\n";
    else
        echo "Prime", "\n";

// This code is contributed by aj_36
?>
```

Output:

Prime

References:
https://en.wikipedia.org/wiki/AKS_primality_test
https://rosettacode.org/wiki/AKS_test_for_primes#C
https://www.youtube.com/watch?v=HvMSRWTE2mI

Improved By : jit_t, vt_m, Mithun Kumar

Source

https://www.geeksforgeeks.org/aks-primality-test/

Chapter 3

Algorithm Library | C++ Magicians STL Algorithm

Algorithm Library | C++ Magicians STL Algorithm - GeeksforGeeks

For all those who aspire to excel in competitive programming, only having a knowledge about containers of STL is of less use till one is not aware what all STL has to offer. STL has an ocean of algorithms, for all < algorithm > library functions : Refer **here**.

Some of the most used algorithms on vectors and most useful one's in Competitive Program ming are mentioned as follows :

Non-Manipulating Algorithms

1. **sort(first_iterator, last_iterator)** – To sort the given vector.
2. **reverse(first_iterator, last_iterator)** – To reverse a vector.

3. ***max_element (first_iterator, last_iterator)** – To find the maximum element of a vector.
4. ***min_element (first_iterator, last_iterator)** – To find the minimum element of a vector.
5. **accumulate(first_iterator, last_iterator, initial value of sum)** – Does the summation of vector elements

```
  // A C++ program to demonstrate working of sort(),
// reverse()
#include <algorithm>
#include <iostream>
#include <vector>
#include <numeric> //For accumulate operation
using namespace std;
```



```
int main()
{
   // Initializing vector with array values
   int arr[] = {10, 20, 5, 23 ,42 , 15};
   int n = sizeof(arr)/sizeof(arr[0]);
   vector<int> vect(arr, arr+n);

   cout << "Vector is: ";
   for (int i=0; i<n; i++)
      cout << vect[i] << " ";

   // Sorting the Vector in Ascending order
   sort(vect.begin(), vect.end());

   cout << "\nVector after sorting is: ";
   for (int i=0; i<n; i++)
     cout << vect[i] << " ";

   // Reversing the Vector
   reverse(vect.begin(), vect.end());

   cout << "\nVector after reversing is: ";
   for (int i=0; i<6; i++)
      cout << vect[i] << " ";

   cout << "\nMaximum element of vector is: ";
   cout << *max_element(vect.begin(), vect.end());

   cout << "\nMinimum element of vector is: ";
   cout << *min_element(vect.begin(), vect.end());
```

```
    // Starting the summation from 0
    cout << "\nThe summation of vector elements is: ";
    cout << accumulate(vect.begin(), vect.end(), 0);

    return 0;
}
```

Output:

```
Vector before sorting is: 10 20 5 23 42 15
Vector after sorting is: 5 10 15 20 23 42
Vector before reversing is: 5 10 15 20 23 42
Vector after reversing is: 42 23 20 15 10 5
Maximum element of vector is: 42
Minimum element of vector is: 5
The summation of vector elements is: 115
```

6. **count(first_iterator, last_iterator,x)** – To count the occurrences of x in vector. 26

7. **find(first_iterator, last_iterator, x)** – Points to last address of vector ((name_of_vector).end()) if element is not present in vector.

```
// C++ program to demonstrate working of count()
// and find()
#include <algorithm>
#include <iostream>
#include <vector>
using namespace std;

int main()
{
    // Initializing vector with array values
    int arr[] = {10, 20, 5, 23 ,42, 20, 15};
    int n = sizeof(arr)/sizeof(arr[0]);
    vector<int> vect(arr, arr+n);

    cout << "Occurrences of 20 in vector : ";

    // Counts the occurrences of 20 from 1st to
    // last element
    cout << count(vect.begin(), vect.end(), 20);

    // find() returns iterator to last address if
    // element not present
    find(vect.begin(), vect.end(),5) != vect.end()?
                    cout << "\nElement found":
                cout << "\nElement not found";

    return 0;
```

}

Output:

Occurrences of 20 in vector: 2
Element found

8. **binary_search(first_iterator, last_iterator, x)** – Tests whether x exists in sorted vector or not.
9. **lower_bound(first_iterator, last_iterator, x)** – returns an iterator pointing to the first element in the range [first,last) which has a value not less than 'x'.
10. **upper_bound(first_iterator, last_iterator, x)** – returns an iterator pointing to the first element in the range [first,last) which has a value greater than 'x'.

// C++ program to demonstrate working of lower_bound()
// and upper_bound().


```
#include <algorithm>
#include <iostream>
#include <vector>
using namespace std;

int main()
{
   // Initializing vector with array values
   int arr[] = {5, 10, 15, 20, 20, 23, 42, 45};
   int n = sizeof(arr)/sizeof(arr[0]);
   vector<int> vect(arr, arr+n);

   // Sort the array to make sure that lower_bound()
   // and upper_bound() work.
   sort(vect.begin(), vect.end());

   // Returns the first occurrence of 20
   auto q = lower_bound(vect.begin(), vect.end(), 20);

   // Returns the last occurrence of 20
   auto p = upper_bound(vect.begin(), vect.end(), 20);

   cout << "The lower bound is at position: ";
   cout << q-vect.begin() << endl;

   cout << "The upper bound is at position: ";
   cout << p-vect.begin() << endl;

   return 0;
```

```
}
```

Output:

```
The lower bound is at position: 3
The upper bound is at position: 5
```

Some Manipulating Algorithms

11. **arr.erase(position to be deleted)** – This erases selected element in vector and shifts and resizes the vector elements accordingly.
12. **arr.erase(unique(arr.begin(),arr.end()),arr.end())** – This erases the duplicate occurrences in sorted vector in a single line.

```
  // C++ program to demonstrate working of erase()
#include <algorithm>
#include <iostream>
#include <vector>
```



```
using namespace std;

int main()
{
   // Initializing vector with array values
   int arr[] = {5, 10, 15, 20, 20, 23, 42, 45};
   int n = sizeof(arr)/sizeof(arr[0]);
   vector<int> vect(arr, arr+n);

   cout << "Vector is :";
   for (int i=0; i<6; i++)
      cout << vect[i]<<" ";

   // Delete second element of vector
   vect.erase(vect.begin()+1);

   cout << "\nVector after erasing the element: ";
   for (int i=0; i<5; i++)
      cout << vect[i] << " ";

   // sorting to enable use of unique()
   sort(vect.begin(), vect.end());

   cout << "\nVector before removing duplicate "
           " occurrences: ";
   for (int i=0; i<5; i++)
      cout << vect[i] << " ";
```

```
    // Deletes the duplicate occurrences
    vect.erase(unique(vect.begin(),vect.end()),vect.end());
    cout << "\nVector after deleting duplicates: ";
    for (int i=0; i< vect.size(); i++)
        cout << vect[i] << " ";

    return 0;
}
```

Output:

```
Vector before erasing the element:5 20 5 23 20 20
Vector after erasing the element: 5 5 23 20 20
Vector before removing duplicate occurrences: 5 5 20 20 23 Vector
after deleting duplicates: 5 20 23
```

13. **next_permutation(first_iterator, last_iterator)** – This modified the vector to its next permutation.

14. **prev_permutation(first_iterator, last_iterator)** – This modified the vector to its previous permutation.

```
  // C++ program to demonstrate working of next_permutation() // and
prev_permutation()
#include <algorithm>
#include <iostream>
#include <vector>
using namespace std;

int main()
{
    // Initializing vector with array values
    int arr[] = {5, 10, 15, 20, 20, 23, 42, 45};
    int n = sizeof(arr)/sizeof(arr[0]);
    vector<int> vect(arr, arr+n);

    cout << "Given Vector is:\n";
    for (int i=0; i<n; i++)
        cout << vect[i] << " ";

    // modifies vector to its next permutation order
    next_permutation(vect.begin(), vect.end());
    cout << "\nVector after performing next permutation:\n";     for (int
i=0; i<n; i++)
        cout << vect[i] << " ";

    prev_permutation(vect.begin(), vect.end());
```

```
    cout << "\nVector after performing prev permutation:\n";     for (int
i=0; i<n; i++)
        cout << vect[i] << " ";

    return 0;
}
```

Output:

```
Given Vector is:
5 10 15 20 20 23 42 45
Vector after performing next permutation:
5 10 15 20 20 23 45 42
Vector after performing prev permutation:
5 10 15 20 20 23 42 45
```

14. **distance(first_iterator,desired_position)** – It returns the distance of desired po sition from the first iterator.This function is very useful while finding the index.


```
  // C++ program to demonstrate working of distance()
#include <algorithm>
#include <iostream>
#include <vector>
using namespace std;

int main()
{
    // Initializing vector with array values
    int arr[] = {5, 10, 15, 20, 20, 23, 42, 45};
    int n = sizeof(arr)/sizeof(arr[0]);
    vector<int> vect(arr, arr+n);

    // Return distance of first to maximum element
    cout << "Distance between first to max element: ";
    cout << distance(vect.begin(),
                max_element(vect.begin(), vect.end()));     return 0;
}
```

Output:

```
Distance between first to max element: 7
```

More – STL Articles

Source

https://www.geeksforgeeks.org/c-magicians-stl-algorithms/

Chapter 4

Array algorithms in C++ STL (all_of, any_of, none_of, copy_n and iota)

Array algorithms in C++ STL (all_of, any_of, none_of, copy_n and iota) - GeeksforGeeks

From C++11 onwards, some new and interesting algorithms are added in STL of C++. These algorithms operate on an array and are useful in saving time during coding and hence useful in competitive programming as well.

all_of()

This function operates on whole range of array elements and can save time to run a loop to check each elements one by one. It checks for a given property on every element and returns true when each element in range satisfies specified property, else returns false.

```
  // C++ code to demonstrate working of all_of()
#include<iostream>
#include<algorithm> // for all_of()
```

```
using namespace std;
int main()
{
   // Initializing array
   int ar[6] =  {1, 2, 3, 4, 5, -6};

   // Checking if all elements are positive
   all_of(ar, ar+6, [](int x) { return x>0; })?
        cout << "All are positive elements" :
        cout << "All are not positive elements";

   return 0;
```



```
}
```

Output:

All are not positive elements

In the above code, -6 being a negative element negates the condition and returns false.

any_of()

This function checks for a given range if there's even one element satisfying a given property mentioned in function. Returns true if at least one element satisfies the property else returns false.

```
  // C++ code to demonstrate working of any_of()
#include<iostream>
#include<algorithm> // for any_of()
using namespace std;
int main()
{
   // Initializing array
   int ar[6] =  {1, 2, 3, 4, 5, -6};

   // Checking if any element is negative
   any_of(ar, ar+6, [](int x){ return x<0; })?
        cout << "There exists a negative element" :
        cout << "All are positive elements";

   return 0;

}
```

Output:

There exists a negative element

In above code, -6 makes the condition positive.

none_of()

This function returns true if none of elements satisfies the given condition else returns false.

```
  // C++ code to demonstrate working of none_of()
#include<iostream>
```



```
#include<algorithm> // for none_of()
using namespace std;
int main()
{
    // Initializing array
    int ar[6] =  {1, 2, 3, 4, 5, 6};

    // Checking if no element is negative
    none_of(ar, ar+6, [](int x){ return x<0; })?
         cout << "No negative elements" :
         cout << "There are negative elements";

    return 0;
}
```

Output:

No negative elements

Since all elements are positive, the function returns true.

copy_n()

copy_n() copies one array elements to new array. This type of copy creates a deep copy of array. This function takes 3 arguments, source array name, size of array and the target array name.

```
  // C++ code to demonstrate working of copy_n()
#include<iostream>
#include<algorithm> // for copy_n()
using namespace std;
int main()
```

```
{
   // Initializing array
   int ar[6] =  {1, 2, 3, 4, 5, 6};

   // Declaring second array
   int ar1[6];

   // Using copy_n() to copy contents
   copy_n(ar, 6, ar1);

   // Displaying the copied array
   cout << "The new array after copying is : ";
   for (int i=0; i<6 ; i++)
      cout << ar1[i] << " ";
```



```
   return 0;

}
```

Output:

The new array after copying is : 1 2 3 4 5 6

In the above code, the elements of ar are copied in ar1 using copy_n()

iota()

This function is used to assign continuous values to array. This function accepts 3 arguments, the array name, size, and the starting number.

```
  // C++ code to demonstrate working of iota()
#include<iostream>
#include<numeric> // for iota()
using namespace std;
int main()
{
   // Initializing array with 0 values
   int ar[6] =  {0};

   // Using iota() to assign values
   iota(ar, ar+6, 20);

   // Displaying the new array
   cout << "The new array after assigning values is : ";     for (int
i=0; i<6 ; i++)
      cout << ar[i] << " ";
```

```
    return 0;
}
```

Output:

```
The new array after assigning values is : 20 21 22 23 24 25
```

In the above code, continuous values are assigned to array using iota(). **Improved By :** mohitw16

Source

https://www.geeksforgeeks.org/useful-array-algorithms-in-c-stl/

Chapter 5

Array range queries over range queries

Array range queries over range queries - GeeksforGeeks

Given an array of size n and a give set of commands of size m. The commands are enumerated from 1 to m. These commands can be of the following two types of commands:

1. **Type 1 [l r (1 <= l <= r <= n)] :** Increase all elements of the array by one, whose indices belongs to the range [l, r]. In these queries of the index is inclusive in the range.
2. **Type 2 [l r (1 <= l <= r <= m)] :** Execute all the commands whose indices are in the range [l, r]. In these queries of the index is inclusive in the range. It's guaranteed that r is strictly less than the enumeration/number of the current command.

Note : The array indexing is from 1 as per the problem statement.

Example 1

```
Input : 5 5
        1 1 2
        1 4 5
        2 1 2
```

2 1 3
2 3 4
Output : 7 7 0 7 7

Explanation of Example 1 :
Our array initially is of size 5 whose each element has been initialized to 0. So now the question states that we have 5 queries for the above example.

1. Query 1 is of type 1 : As stated above we will simply increment the array indices by 1 the given indices are 1 and 2 so after the execution of the first our array turns down to be 1 1 0 0 0 .
2. Query 2 is of type 1 : As stated above we will simply increment the array indices by 1 the given indices are 4 and 5 so after the execution of the first our array turns down to be 1 1 0 1 1 .
3. Query 3 is of type 2 : As stated in the definition of this type of query we will execute the queries stated in the range i.e. we will operate the queries instead of the array. The range given is 1 and 2 so we will execute queries 1 and 2 again i.e. we will use repetitive approach for the type 2 queries so we will execute query 1 again and our array will be 2 2 0 1 1. Now when we execute the query we will execute query 2 and our resultant array will be 2 2 0 2 2 .
4. Query 4 is of type 2 : As stated in the definition of this type of query we will execute the queries stated in the range i.e. we will operate the queries instead of the array. The range given is 1 and 3 so we will execute queries 1, 2 and 3 again i.e. using repetitive approach queries 1, 2 and 3 will be executed. After the execution of the query 1 again the array will be 3 3 0 2 2 . After the execution of the query 2 again the array will be 3 3 0 3 3 . Now due to query 3 inclusive in the range we will execute query 3 the resultant array will be 4 4 0 4 4 . As explained above.
5. Query 5 is of type 2 : The last query will execute the 3rd and 4th query which has been explained above. After the execution of the 3rd query our array will be 5 5 0 5 5 . And after the execution of the 4th query i.e. execution of query 1, 2 and 3 our array will be 7 7 0 7 7 The above is the desired result

Example 2

Input : 1 2
1 1 1
1 1 1
Output : 2

Explanation of the example 2:
Our array initially is of size 1 whose each element has been initialized to 0. So now the question states that we have 2 queries for the above example.

1. Query 1 is of type 1 : As stated above we will simply increment the array indices by 1 the given indices are 1 and 1 so after the execution of the first our array turns down to be 1 .
2. Query 2 is of type 1 : As stated above we will simply increment the array indices by 1 the given indices are 1 and 1 so after the execution of the first our array turns down to be 2 . This gives us the desired result

Method 1 :
This method is the brute force method where by simple recursion is applied on the type 2 queries and for type 1 queries simple increment in the array index is performed.


```
 // CPP program to perform range queries over range
// queries.
#include <bits/stdc++.h>
using namespace std;

// Function to execute type 1 query
void type1(int arr[], int start, int limit)
{
    // incrementing the array by 1 for type
    // 1 queries
    for (int i = start; i <= limit; i++)
        arr[i]++;
}

// Function to execute type 2 query
void type2(int arr[], int query[][3], int start, int limit) {
    for (int i = start; i <= limit; i++) {

        // If the query is of type 1 function
        // call to type 1 query
        if (query[i][0] == 1)
            type1(arr, query[i][1], query[i][2]);

        // If the query is of type 2 recursive call
        // to type 2 query
        else if (query[i][0] == 2)
            type2(arr, query, query[i][1], query[i][2]);            }
}

// Driver code
int main()
{
    // Input size of array amd number of queries
    int n = 5, m = 5;
    int arr[n + 1];
```

```
    for (int i = 1; i <= n; i++)
        arr[i] = 0;

    // Build query matrix
    int temp[15] = { 1, 1, 2, 1, 4, 5, 2,
                     1, 2, 2, 1, 3, 2, 3, 4 };
    int query[5][3];
    int j = 0;
    for (int i = 1; i <= m; i++) {
        query[i][0] = temp[j++];
        query[i][1] = temp[j++];
```



```
        query[i][2] = temp[j++];
    }

    // Perform queries
    for (int i = 1; i <= m; i++)
        if (query[i][0] == 1)
            type1(arr, query[i][1], query[i][2]);
        else if (query[i][0] == 2)
            type2(arr, query, query[i][1], query[i][2]);
    // printing the result
    for (int i = 1; i <= n; i++)
        cout << arr[i] << " ";

    return 0;
}
```

Output:

7 7 0 7 7

The Time complexity of the above code is **O(2 ^ m)**

Method 2 :
In this method we use an extra array for creating the record array to find the number of time a particular query is being executed and after creating the record array we simply execute the queries of type 1 and the contains of the record array is simply added to the main array the and this would give us the resultant array.

```
  // CPP program to perform range queries over range
// queries.
#include <bits/stdc++.h>
using namespace std;

// Function to create the record array
void record_sum(int record[], int l, int r,
                int n, int adder)
```

```
{
    for (int i = l; i <= r; i++)
        record[i] += adder;
}

// Driver Code
int main()
{
    int n = 5, m = 5;
    int arr[n];
```



```
    // Build query matrix
    memset(arr, 0, sizeof arr);
    int query[5][3] = { { 1, 1, 2 }, { 1, 4, 5 },
                        { 2, 1, 2 }, { 2, 1, 3 },
                        { 2, 3, 4 } };
    int record[m];
    memset(record, 0, sizeof record);

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

        // If query is of type 2 then function
        // call to record_sum
        if (query[i][0] == 2)
            record_sum(record, query[i][1] - 1,
              query[i][2] - 1, m, record[i] + 1);

        // If query is of type 1 then simply add
        // 1 to the record array
        else
            record_sum(record, i, i, m, 1);

    }

    // for type 1 queries adding the contains of
    // record array to the main array record array
    for (int i = 0; i < m; i++) {
        if (query[i][0] == 1)
            record_sum(arr, query[i][1] - 1,
                query[i][2] - 1, n, record[i]);
    }

    // printing the array
    for (int i = 0; i < n; i++)
        cout << arr[i] << ' ';

    return 0;
```

}

Output :

7 7 0 7 7

The Time complexity of the above code is **O(n^2)**

Method 3 :
This method has been made more efficient by applying square root decomposition to the record array.


```
  // CPP program to perform range queries over range
// queries.
#include <bits/stdc++.h>
#define max 10000
using namespace std;

// For prefix sum array
void update(int arr[], int l)
{
    arr[l] += arr[l - 1];
}

// This function is used to apply square root
// decomposition in the record array
void record_func(int block_size, int block[],
         int record[], int l, int r, int value)
{
    // traversing first block in range
    while (l < r && l % block_size != 0 && l != 0) {
        record[l] += value;
        l++;
    }
    // traversing completely overlapped blocks in range
    while (l + block_size <= r + 1) {
        block[l / block_size] += value;
        l += block_size;
    }
    // traversing last block in range
    while (l <= r) {
        record[l] += value;
        l++;
    }
}
// Function to print the resultant array
void print(int arr[], int n)
```

```
{
   for (int i = 0; i < n; i++)
      cout << arr[i] << " ";
}

// Driver code
int main()
{
   int n = 5, m = 5;
   int arr[n], record[m];
   int block_size = sqrt(m);
   int block[max];
   int command[5][3] = { { 1, 1, 2 }, { 1, 4, 5 },
```



```
                         { 2, 1, 2 }, { 2, 1, 3 },
                         { 2, 3, 4 } };
   memset(arr, 0, sizeof arr);
   memset(record, 0, sizeof record);
   memset(block, 0, sizeof block);

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

      // If query is of type 2 then function
      // call to record_func
      if (command[i][0] == 2) {
         int x = i / (block_size);
         record_func(block_size, block, record,
                     command[i][1] - 1, command[i][2] - 1,
                     (block[x] + record[i] + 1));
      }
      // If query is of type 1 then simply add
      // 1 to the record array
      else
         record[i]++;
   }

   // Merging the value of the block in the record array     for (int i =
0; i < m; i++) {
      int check = (i / block_size);
      record[i] += block[check];
   }

   for (int i = 0; i < m; i++) {
      // If query is of type 1 then the array
      // elements are over-written by the record
      //  array
      if (command[i][0] == 1) {
         arr[command[i][1] - 1] += record[i];
```

```
        if ((command[i][2] - 1) < n - 1)
            arr[(command[i][2])] -= record[i];                }
    }

    // The prefix sum of the array
    for (int i = 1; i < n; i++)
        update(arr, i);

    // Printing the resultant array
    print(arr, n);
    return 0;
}
```


Output :
7 7 0 7 7

Method 4 :
This method has been made more efficient by applying Binary Indexed Tree or Fenwick Treeby creating two binary indexed tree for query 1 and query 2 respectively.

```
  // CPP program to perform range queries over range
// queries.
#include <bits/stdc++.h>
using namespace std;

// Updates a node in Binary Index Tree (BITree) at given index // in
BITree.  The given value 'val' is added to BITree[i] and // all of its
ancestors in tree.
void updateBIT(int BITree[], int n, int index, int val)
{
    // index in BITree[] is 1 more than the index in arr[]     index =
index + 1;

    // Traverse all ancestors and add 'val'
    while (index <= n) {

        // Add 'val' to current node of BI Tree
        BITree[index] = (val + BITree[index]);

        // Update index to that of parent in update View
        index = (index + (index & (-index)));
    }
    return;
}

// Constructs and returns a Binary Indexed Tree for given // array of
```

```
size n.
int* constructBITree(int n)
{
    // Create and initialize BITree[] as 0
    int* BITree = new int[n + 1];
    for (int i = 1; i <= n; i++)
        BITree[i] = 0;

    return BITree;
}

// Returns sum of arr[0..index]. This function assumes
// that the array is preprocessed and partial sums of
// array elements are stored in BITree[]
```



```
int getSum(int BITree[], int index)
{
    int sum = 0;
    // index in BITree[] is 1 more than the index in arr[]     index =
index + 1;

    // Traverse ancestors of BITree[index]
    while (index > 0) {

        // Add element of BITree to sum
        sum = (sum + BITree[index]);

        // Move index to parent node in getSum View
        index -= index & (-index);
    }
    return sum;
}

// Function to update the BITree
void update(int BITree[], int l, int r, int n, int val)
{
    updateBIT(BITree, n, l, val);
    updateBIT(BITree, n, r + 1, -val);
    return;
}

// Driver code
int main()
{
    int n = 5, m = 5;
    int temp[15] = { 1, 1, 2, 1, 4, 5, 2, 1, 2,
                     2, 1, 3, 2, 3, 4 };
    int q[5][3];
```

```
    int j = 0;
    for (int i = 1; i <= m; i++) {
        q[i][0] = temp[j++];
        q[i][1] = temp[j++];
        q[i][2] = temp[j++];
    }

    // BITree for query of type 2
    int* BITree = constructBITree(m);

    // BITree for query of type 1
    int* BITree2 = constructBITree(n);

    // Input the queries in a 2D matrix
    for (int i = 1; i <= m; i++)
```



```
        cin >> q[i][0] >> q[i][1] >> q[i][2];

     // If query is of type 2 then function call
     // to update with BITree
    for (int i = m; i >= 1; i--)
        if (q[i][0] == 2)
            update(BITree, q[i][1] - 1, q[i][2] - 1, m, 1);
    for (int i = m; i >= 1; i--) {
        if (q[i][0] == 2) {
            long int val = getSum(BITree, i - 1);
            update(BITree, q[i][1] - 1, q[i][2] - 1, m, val);        }
    }

    // If query is of type 1 then function call
    // to update with BITree2
    for (int i = m; i >= 1; i--) {
        if (q[i][0] == 1) {
            long int val = getSum(BITree, i - 1);
            update(BITree2, q[i][1] - 1, q[i][2] - 1,
                   n, (val + 1));
        }
    }

    for (int i = 1; i <= n; i++)
        cout << (getSum(BITree2, i - 1)) << " ";

    return 0;
}
```

Output :

7 7 0 7 7

The Time complexity of Method 3 and Method 4 is **O(log n)** .

Source

https://www.geeksforgeeks.org/array-range-queries-range-queries/

Chapter 6

Array with GCD of any of its subset belongs to the given array

Array with GCD of any of its subset belongs to the given array - GeeksforGeeks Given a set of N elements such that N  , task is to generate an array such that the GCD of any subset of the generated array lies in the given set of elements. The generated array should **not be more than thrice the length of the set of the GCD**.

Prerequisite : GCD of an Array | Subset of Array

Examples :

Input : 3
1 2 7
Output : 1 1 2 1 7

Input : 4
2 4 6 12
Output : 4 6 12

Input : 5

2 5 6 7 11
Output : No array can be build

Explanation :
Calculate the GCD of an array or in this case a set. Now, first sort the given set of GCD. If the GCD of this set is equal to the minimum number of the given set, then just by putting this GCD between each number. But, if this GCD is not the minimum element of the given

set, then unfortunately “no array can be build”.

C++

```
  // C++ implementation to generate the
// required array
#include <bits/stdc++.h>
using namespace std;

// Function to return gcd of a and b
int gcd(int a, int b)
{
    if (a == 0)
       return b;
    return gcd(b % a, a);
}

// Function to find gcd of
// array of numbers
int findGCD(vector<int> arr, int n)
{
    int result = arr[0];
    for (int i = 1; i < n; i++)
        result = gcd(arr[i], result);
    return result;
}

// Function to generate the array
// with required constraints.
void compute(vector<int> arr, int n)
{
    vector<int> answer;

    // computing GCD of the given set
    int GCD_of_array = findGCD(arr, n);

    // Solution exists if GCD of array is equal
    // to the minimum element of the array
    if(GCD_of_array == arr[0])
    {
```

```
        answer.push_back(arr[0]);
        for(int i = 1; i < n; i++)
        {
            answer.push_back(arr[0]);
            answer.push_back(arr[i]);
        }

        // Printing the built array
```



```
        for (int i = 0; i < answer.size(); i++)
            cout << answer[i] << " ";
    }
    else
        cout << "No array can be build";
}

// Driver function
int main()
{

    // Taking in the input and initializing
    // the set STL set in cpp has a property
    // that it maintains the elements in
    // sorted order, thus we do not need
    // to sort them externally
    int n = 3;
    int input[]= {2, 5, 6, 7, 11};
    set<int> GCD(input, input + n);
    vector<int> arr;
    set<int>::iterator it;

    for(it = GCD.begin(); it!= GCD.end(); ++it)
        arr.push_back(*it);

    // Calling the computing function.
    compute(arr,n);

    return 0;
}
```

Java

```
  // Java implementation
// to generate the
// required array
import java.io.*;
import java.util.*;
```

```
class GFG
{
// Function to return
// gcd of a and b
static int gcd(int a,
               int b)
{
   if (a == 0)
   return b;
```



```
   return gcd(b % a, a);
}

// Function to find gcd
// of array of numbers
public static int findGCD(ArrayList<Integer>
                          arr, int n)
{
   int result = arr.get(0);
   for (int i = 1; i < n; i++)
      result = gcd(arr.get(i),
                   result);
   return result;
}

// Function to generate
// the array with required
// constraints.
public static void compute(ArrayList<Integer>
                           arr, int n)
{
   ArrayList<Integer> answer =
                   new ArrayList<Integer>();

   // computing GCD of
   // the given set
   int GCD_of_array = findGCD(arr, n);

   // Solution exists if GCD
   // of array is equal to the
   // minimum element of the array
   if(GCD_of_array == arr.get(0))
   {
      answer.add(arr.get(0));
      for(int i = 1; i < n; i++)
      {
         answer.add(arr.get(0));
         answer.add(arr.get(i));
```

```
        }

        // Printing the
        // built array
        for (int i = 0;
                i < answer.size(); i++)
            System.out.print(answer.get(i) + " ");
    }
    else
        System.out.print("No array " +
```



```
                    "can be build");
}

// Driver Code
public static void main(String args[])
{

    // Taking in the input and
    // initializing the set STL
    // set in cpp has a property
    // that it maintains the
    // elements in sorted order,
    // thus we do not need to
    // sort them externally
    int n = 3;
    Integer input[]= {2, 5, 6, 7, 11};
    HashSet<Integer> GCD = new HashSet<Integer>
                    (Arrays.asList(input));
    ArrayList<Integer> arr =
                new ArrayList<Integer>();

    for (int v : GCD)
        arr.add(v);

    // Calling the
    // computing function.
    compute(arr, n);
}
}

// This code is contributed by
// Manish Shaw(manishshaw1)
```

C#

```
  // C# implementation
// to generate the
```

```
// required array
using System;
using System.Collections.Generic;

class GFG
{
   // Function to return
   // gcd of a and b
   static int gcd(int a, int b)
   {
      if (a == 0)
```



```
      return b;
      return gcd(b % a, a);
   }

   // Function to find gcd
   // of array of numbers
   static int findGCD(List<int> arr,
                      int n)
   {
      int result = arr[0];
      for (int i = 1; i < n; i++)
         result = gcd(arr[i],
                      result);
      return result;
   }

   // Function to generate
   // the array with required
   // constraints.
   static void compute(List<int> arr,
                       int n)
   {
      List<int> answer = new List<int>();

      // computing GCD of
      // the given set
      int GCD_of_array = findGCD(arr, n);

      // Solution exists if GCD
      // of array is equal to the
      // minimum element of the array
      if(GCD_of_array == arr[0])
      {
         answer.Add(arr[0]);
         for(int i = 1; i < n; i++)
         {
```

```
            answer.Add(arr[0]);
            answer.Add(arr[i]);
        }

        // Printing the
        // built array
        for (int i = 0; i < answer.Count; i++)
            Console.Write(answer[i] + " ");
    }
    else
        Console.Write("No array " +
                "can be build");
```



```
    }

    // Driver Code
    static void Main()
    {

        // Taking in the input and
        // initializing the set STL
        // set in cpp has a property
        // that it maintains the
        // elements in sorted order,
        // thus we do not need to
        // sort them externally
        int n = 3;
        int []input= new int[]{2, 5, 6, 7, 11};
        HashSet<int> GCD = new HashSet<int>(input);
        List<int> arr = new List<int>();

        foreach (int b in GCD)
            arr.Add(b);

        // Calling the
        // computing function.
        compute(arr, n);
    }
}

// This code is contributed by
// Manish Shaw(manishshaw1)
```

Output:

```
No array can be build
```

Time Complexity : O(nlog(n)), where n is the size of array given.

Improved By : manishshaw1

Source

https://www.geeksforgeeks.org/array-gcd-subset-belongs-given-array/ 52

Chapter 7

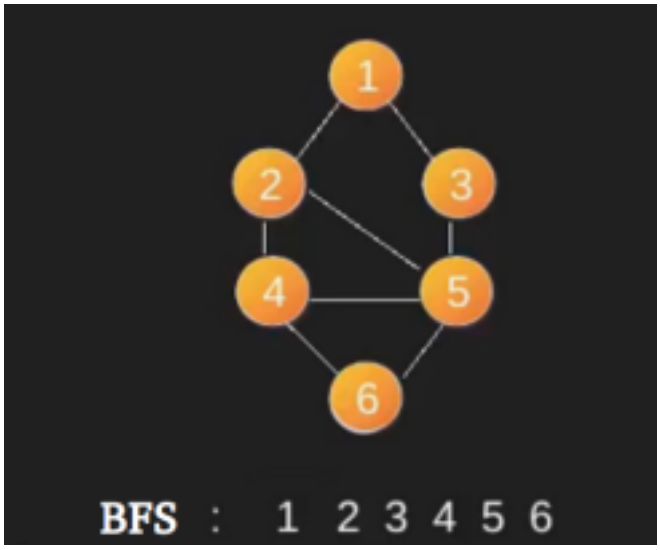
BFS using STL for competitive coding

BFS using STL for competitive coding - GeeksforGeeks

A STL based simple implementation of BFS using queue and vector in STL. The adjacency list is represented using vectors of vector.

In BFS, we start with a node.
1) Create a queue and enqueue source into it.
   Mark source as visited.
2) While queue is not empty, do following
   a) Dequeue a vertex from queue. Let this
      be f.
   b) Print f
   c) Enqueue all not yet visited adjacent
      of f and mark them visited.

Below is an example BFS starting from source vertex 1. Note that there can be multple BFSs possible for a graph (even from a particular vertex).



For more details of BFS, refer this post .

The code here is simplified such that it could be used in competitive coding.

```
  // A Quick implementation of BFS using
// vectors and queue
#include <bits/stdc++.h>
#define pb push_back

using namespace std;

vector<bool> v;
vector<vector<int> > g;

void edge(int a, int b)
{
    g[a].pb(b);

    // for undirected graph add this line
```

```
    // g[b].pb(a);
}

void bfs(int u)
{
    queue<int> q;

    q.push(u);
    v[u] = true;

    while (!q.empty()) {
```



```
        int f = q.front();
        q.pop();

        cout << f << " ";

        // Enqueue all adjacent of f and mark them visited          for (auto
i = g[f].begin(); i != g[f].end(); i++) {             if (!v[*i]) {
                q.push(*i);
                v[*i] = true;
            }
        }
    }
}

// Driver code
int main()
{
    int n, e;
    cin >> n >> e;

    v.assign(n, false);
    g.assign(n, vector<int>());

    int a, b;
    for (int i = 0; i < e; i++) {
        cin >> a >> b;
        edge(a, b);
    }

    for (int i = 0; i < n; i++) {
        if (!v[i])
            bfs(i);
    }

    return 0;
```

}

Input:
8 10
0 1
0 2
0 3
0 4
1 5
2 5
3 6

4 6
5 7
6 7

Output:
0 1 2 3 4 5 6 7

Source

https://www.geeksforgeeks.org/bfs-using-stl-competitive-coding/

Chapter 8

Bit Tricks for Competitive Programming

Bit Tricks for Competitive Programming - GeeksforGeeks

In competitive programming or in general some problems seems difficult but can be solved very easily with little bit magic. We have discussed some tricks in below previous post.

Bitwise Hacks for Competitive Programming

We have considered below facts in this article –

- 0 based indexing of bits from left to right.
- Setting i-th bit means, turning i-th bit to 1
- Clearing i-th bit means, turning i-th bit to 0

1) Clear all bits from LSB to ith bit

```
mask = ~((1 << i+1 ) - 1);
x &= mask;
```

Logic: To clear all bits from LSB to i-th bit, we have to AND x with mask having LSB to i-th bit 0. To obtain such mask, first left shift 1 i times. Now if we minus 1 from that, all the bits from 0 to i-1 become 1 and remaining bits become 0. Now we can simply take complement of mask to get all first i bits to 0 and remaining to 1.
Example
x = 29 (00011101) and we want to clear LSB to 3rd bit, total 4 bits
mask -> 1 << 4 -> 16(00010000)
mask -> 16 – 1 -> 15(00001111)
mask -> ~mask -> 11110000
x & mask -> 16 (00010000)

2) Clearing all bits from MSB to i-th bit


```
mask = (1 << i) - 1;
x &= mask;
```

Logic: To clear all bits from MSB to i-th bit, we have to AND x with mask having MSB to i-th bit 0. To obtain such mask, first left shift 1 i times. Now if we minus 1 from that, all the bits from 0 to i-1 become 1 and remaining bits become 0.
Example
x = 215 (11010111) and we want to clear MSB to 4th bit, total 4 bits
mask -> 1 << 4 -> 16(00010000)
mask -> 16 – 1 -> 15(00001111)
x & mask -> 7(00000111)

3) Divide by 2

```
x >>= 1;
```

Logic: When we do arithmetic right shift, every bit is shifted to right and blank position is substituted with sign bit of number, 0 in case of positive and 1 in case of negative number. Since every bit is a power of 2, with each shift we are reducing the value of each bit by factor of 2 which is equivalent to division of x by 2.
Example
x = 18(00010010)
x >> 1 = 9 (00001001)

4) Multiplying by 2

```
x <<= 1;
```

Logic: When we do arithmetic left shift, every bit is shifted to left and blank position is substituted with 0 . Since every bit is a power of 2, with each shift we are increasing the value of each bit by a factor of 2 which is equivalent to multiplication of x by 2. Example
x = 18(00010010)
x << 1 = 36 (00100100)

5) Upper case English alphabet to lower case

```
ch |= ' ';
```

Logic: The bit representation of upper case and lower case English alphabets are –

A -> 01000001 a -> 01100001

B -> 01000010 b -> 01100010
C -> 01000011 c -> 01100011
. .
. .
Z -> 01011010 z -> 01111010

As we can see if we set 5th bit of upper case characters, it will be converted into lower case character. We have to prepare a mask having 5th bit 1 and other 0 (00100000). This mask is bit representation of space character (‘ ‘). The character ‘ch’ then ORed with mask.

Example

ch = ‘A’ (01000001)
mask = ‘ ‘ (00100000)
ch | mask = ‘a’ (01100001)
Please refer Case conversion (Lower to Upper and Vice Versa) for

details. **6) Lower case English alphabet to upper case**

```
ch &= '_' ;
```

Logic: The bit representation of upper case and lower case English alphabets are –

A -> 01000001 a -> 01100001
B -> 01000010 b -> 01100010
C -> 01000011 c -> 01100011
. .
. .
Z -> 01011010 z -> 01111010

As we can see if we clear 5th bit of lower case characters, it will be converted into upper case character. We have to prepare a mask having 5th bit 0 and other 1 (10111111). This mask is bit representation of underscore character (‘_‘). The character ‘ch’ then AND with mask.
Example
ch = ‘a’ (01100001)
mask = ‘_ ‘ (11011111)
ch | mask = ‘A’ (01000001)
Please refer Case conversion (Lower to Upper and Vice Versa) for

details. **7) Count set bits in integer**

```
 int countSetBits(int x)
{
   int count = 0;
   while (x)
   {
```



```
      x &= (x-1);
      count++;
   }
   return count;
}
```

Logic: This is**Brian Kernighan’s** algorithm.

8) Find log base 2 of 32 bit integer

```
 int log2(int x)
{
   int res = 0;
   while (x >>= 1)
      res++;
   return res;
}
```

Logic: We right shift x repeatedly until it becomes 0, meanwhile we keep count on the shift operation. This count value is the log2(x).

9) Checking if given 32 bit integer is power of 2

```
 int isPowerof2(int x)
{
   return (x && !(x & x-1));
}
```

Logic: All the power of 2 have only single bit set e.g. 16 (00010000). If we minus 1 from this, all the bits from LSB to set bit get toggled, i.e., 16-1 = 15 (00001111). Now if we AND x with (x-1) and the result is 0 then we can say that x is power of 2 otherwise not. We have to take extra care when x = 0.

Example
x = 16(000100000)
x – 1 = 15(00001111)
x & (x-1) = 0
so 16 is power of 2

Please refer this article for more bit hacks.

Source

https://www.geeksforgeeks.org/bit-tricks-competitive-programming/ 60

Chapter 9

Bits manipulation (Important tactics)

Bits manipulation (Important tactics) - GeeksforGeeks

Prerequisites : Bitwise operators in C, Bitwise Hacks for Competitive Programming, Bit Tricks for Competitive Programming

1. Compute XOR from 1 to n (direct method) :

```
// Direct XOR of all numbers from 1 to n
int computeXOR(int n)
{
    if (n % 4 == 0)
        return n;
    if (n % 4 == 1)
        return 1;
    if (n % 4 == 2)
        return n + 1;
    else
        return 0;
}
```

Input: 6
Output: 7

Refer Compute XOR from 1 to n for details.

2. We can quickly calculate the total number of combinations with numbers smaller than or equal to with a number whose sum and XOR are equal. Instead of using looping (Brute force method), we can directly find it by a mathematical trick i.e.


```
// Refer Equal Sum and XOR for details.
Answer = pow(2, count of zero bits)
```

3. How to know if a number is a power of 2?

```
//  Function to check if x is power of 2
bool isPowerOfTwo(int x)
{
    // First x in the below expression is
    // for  the case when x is 0
    return x && (!(x & (x - 1)));
}
```

Refer check if a number is power of twofor details.

4. Find XOR of all subsets of a set. We can do it in O(1) time. The answer is always 0 if given set has more than one elements. For set with single element, the answer is value of single element. Refer XOR of the XOR's of all subsets for details.

5. We can quickly find number of leading, trailing zeroes and number of 1's in a binary code of an integer in C++ using GCC. It can be done by using inbuilt function i.e.

```
Number of leading zeroes: builtin_clz(x)
Number of trailing zeroes : builtin_ctz(x)
Number of 1-bits: __builtin_popcount(x)
```

ReferGCC inbuilt functions for details.

6. Convert binary code directly into an integer in C++.

```
// Conversion into Binary code//
#include <iostream>
using namespace std;

int main()
{
   auto number = 0b011;
   cout << number;
   return 0;
}
```

Output: 3

7. The Quickest way to swap two numbers:


```
a ^= b;
b ^= a;
a ^= b;
```

Refer swap two numbersfor details.

8. Simple approach to flip the bits of a number: It can be done by a simple way, just simply subtract the number from the value obtained when all the bits are equal to 1 . For example:

Number : Given Number

Value : A number with all bits set in given number.
Flipped number = Value – Number.

Example :
Number = 23,
Binary form: 10111;
After flipping digits number will be: 01000;
Value: 11111 = 31;

9. We can find the most significant set bit in O(1) time for a fixed size integer. For example below cocde is for 32 bit integer.

```
 int setBitNumber(int n)
{
   // Below steps set bits after
   // MSB (including MSB)

   // Suppose n is 273 (binary
   // is 100010001). It does following
   // 100010001 | 010001000 = 110011001
   n |= n>>1;

   // This makes sure 4 bits
   // (From MSB and including MSB)
   // are set. It does following
   // 110011001 | 001100110 = 111111111
   n |= n>>2;

   n |= n>>4;
   n |= n>>8;
   n |= n>>16;

   // Increment n by 1 so that
   // there is only one set bit
   // which is just before original
   // MSB. n now becomes 1000000000
```



```
   n = n + 1;

   // Return original MSB after shifting.
   // n now becomes 100000000
   return (n >> 1);
}
```

Refer Find most significant set bit of a number for details.

10. We can quickly check if bits in a number are in alternate pattern (like 101010). We compute n ^ (n >> 1). If n has an alternate pattern, then n ^ (n >> 1) operation will produce a number having set bits only. '^'

is a bitwise XOR operation. Refer check if a number has bits in alternate pattern for details.

Source

https://www.geeksforgeeks.org/bits-manipulation-important-tactics/ 64

Chapter 10

Bitwise Hacks for Competitive Programming

It is recommended to refer Interesting facts about Bitwise Operators as a prerequisite. **1. How to set a bit in the number 'num' :**

If we want to set a bit at nth position in number 'num' ,it can be done using 'OR' operator(|).

- First we left shift '1' to n position via (1<<n)
- Then, use 'OR' operator to set bit at that position.'OR' operator is used because it will set the bit even if the bit is unset previously in binary representation of number 'num'.

```
 #include<iostream>
using namespace std;
// num is the number and pos is the position
// at which we want to set the bit.
void set(int & num,int pos)
{
    // First step is shift '1', second
    // step is bitwise OR
    num |= (1 << pos);
}
int main()
{
    int num = 4, pos = 1;
    set(num, pos);
    cout << (int)(num) << endl;
    return 0;
}
```


Output:

6

We have passed the parameter by 'call by reference' to make permanent changes in the number.

2. How to unset/clear a bit at n'th position in the number 'num' :

Suppose we want to unset a bit at nth position in number 'num' then we have to do this with the help of 'AND' (&) operator.

- First we left shift '1' to n position via (1<<n) than we use bitwise NOT operator '~' to unset this shifted '1'.
- Now after clearing this left shifted '1' i.e making it to '0' we will 'AND'(&) with the number 'num' that will unset bit at nth position position.

```
 #include <iostream>
```

```
using namespace std;
// First step is to get a number that  has all 1's except the given position. void unset(int
&num,int pos)
{
   //Second step is to bitwise and this  number with given number     num &=
(~(1 << pos));
}
int main()
{
   int num = 7;
   int  pos = 1;
   unset(num, pos);
   cout << num << endl;
   return 0;
}
```

Output:

5

3. Toggling a bit at nth position :

Toggling means to turn bit ‘on’(1) if it was ‘off’(0) and to turn ‘off’(0) if it was ‘on’(1) previously.We will be using ‘XOR’ operator here which is this ‘^’. The reason behind ‘XOR’ operator is because of its properties.

- Properties of ‘XOR’ operator.
  - 1^1 = 0
  - 0^0 = 0

  - 1^0 = 1
  - 0^1 = 1
- If two bits are different then ‘XOR’ operator returns a set bit(1) else it returns an unset bit(0).

```
 #include <iostream>
using namespace std;
// First step is to shift 1,Second step is to XOR with given number void
toggle(int &num,int pos)
{
   num ^= (1 << pos);
}
int main()
{
   int num = 4;
   int pos = 1;
   toggle(num, pos);
```

```
    cout << num << endl;
    return 0;
}
```

Output:

6

4. Checking if bit at nth position is set or unset:

It is quite easily doable using ‘AND’ operator.

- Left shift ‘1’ to given position and then ‘AND’(‘&’).

```
 #include <iostream>
using namespace std;

bool at_position(int num,int pos)
{
    bool bit = num & (1<<pos);
    return bit;
}

int main()
{
    int num = 5;
    int pos = 0;
    bool bit = at_position(num, pos);
    cout << bit << endl;
    return 0;
}
```


Output:

1

Observe that we have first left shifted ‘1’ and then used ‘AND’ operator to get bit at that position. So if there is ‘1’ at position ‘pos’ in ‘num’, then after ‘AND’ our variable ‘bit’ will store ‘1’ else if there is ‘0’ at position ‘pos’ in the number ‘num’ than after ‘AND’ our variable bit will store ‘0’.

Some more quick hacks:

- **Inverting every bit of a number/1’s complement:**

  If we want to invert every bit of a number i.e change bit ‘0’ to ‘1’ and bit ‘1’ to ‘0’.We can do this with the help of ‘~’ operator. For example : if number is num=00101100 (binary representation) so ‘~num’ will be ‘11010011’.

This is also the '1s complement of number'.

```
 #include <iostream>
using namespace std;
int main()
{
   int num = 4;

   // Inverting every bit of number num
   cout << (~num);
   return 0;
}
```

Output:
-5

- **Two's complement of the number:** 2's complement of a number is 1's complement + 1.

So formally we can have 2's complement by finding 1s complement and adding 1 to the result i.e (~num+1) or what else we can do is using '-' operator.

```
 #include <iostream>
using namespace std;
int main()
{
   int num = 4;
   int twos_complement = -num;
   cout << "This is two's complement " << twos_complement << endl;     cout
<< "This is also two's complement " << (~num+1) << endl;     return 0;
}
```


Output:

```
This is two's complement -4
This is also two's complement -4
```

- **Stripping off the lowest set bit :**

In many situations we want to strip off the lowest set bit for example in Binary Indexed tree data structure, counting number of set bit in a number.

We do something like this:

X = X & (X-1)

But how does it even work ?

Let us see this by taking an example, let X = 1100.

(X-1) inverts all the bits till it encounter lowest set ‘1’ and it also invert that lowest set ‘1’.

X-1 becomes 1011. After ‘ANDing’ X with X-1 we get lowest set bit stripped.

```
 #include <iostream>
using namespace std;
void strip_last_set_bit(int &num)
{
   num = num & (num-1);
}
int main()
{
   int num = 7;
   strip_last_set_bit(num);
   cout << num << endl;
   return 0;
}
```

Output:

6

- **Getting lowest set bit of a number:**

This is done by using expression ‘X &(-X)’Let us see this by taking an example:Let X = 00101100. So ~X(1’s complement) will be ‘11010011’ and 2’s complement will be (~X+1 or -X) i.e ‘11010100’.So if we ‘AND’ original number ‘X’ with its two’s complement which is ‘-X’, we get lowest set bit.


```
00101100
& 11010100
----------
00000100
```

```
#include <iostream>
using namespace std;
int lowest_set_bit(int num)
{
   int ret = num & (-num);
   return ret;
}
```

```
int main()
{
    int num = 10;
    int ans = lowest_set_bit(num);
    cout << ans << endl;
    return 0;
}
```

Output:

2

Bit Tricks for Competitive Programming

Refer BitWise Operators Articles for more articles on Bit Hacks.

Improved By : jit_t

Source

https://www.geeksforgeeks.org/bitwise-hacks-for-competitive-programming/ 70

Chapter 11

Burst Balloon to maximize coins

Burst Balloon to maximize coins - GeeksforGeeks

We have been given N balloons, each with a number of coins associated with it. On bursting a balloon i, the number of coins gained is equal to A[i-1]*A[i]*A[i+1]. Also, balloons i-1 and i+1 now become adjacent. Find the maximum possible profit earned after bursting all the balloons. Assume an extra 1 at each boundary.

Examples:

Input : 5, 10
Output : 60
Explanation - First Burst 5, Coins = 1*5*10
Then burst 10, Coins+= 1*10*1
Total = 60

Input : 1, 2, 3, 4, 5
Output : 110

A recursive solution is discussed here. We can solve this problem using dynamic program ming.
First, consider a sub-array from indices Left to Right(inclusive).
If we assume the balloon at index Last to be the last balloon to be burst in this sub-array, we would say the coined gained to be-A[left-1]*A[last]*A[right+1].
Also, the total Coin Gained would be this value, plus dp[left][last – 1] + dp[last + 1][right], where dp[i][j] means maximum coin gained for sub-array with indices i, j. Therefore, for each value of Left and Right, we need find and choose a value of Last with maximum coin gained, and update the dp array.
Our Answer is the value at dp[1][N].

Python3

```
 # Python program burst balloon problem.
```



```
def getMax(A):
    N = len(A)
    A = [1] + A + [1]# Add Bordering Balloons
    dp = [[0 for x in range(N + 2)] for y in range(N + 2)]# Declare DP Array
    for length in range(1, N + 1):
        for left in range(1, N-length + 2):
            right = left + length -1

            # For a sub-array from indices left, right
            # This innermost loop finds the last balloon burst            for last in
range(left, right + 1):
                dp[left][right] = max(dp[left][right], \
                                      dp[left][last-1] + \
                                      A[left-1]*A[last]*A[right + 1] + \                                      dp[last
+ 1][right])     return(dp[1][N])

# Driver code
A = [1, 2, 3, 4, 5]
print(getMax(A))
```

Output:

110

Source

https://www.geeksforgeeks.org/burst-balloon-to-maximize-coins/

Chapter 12

C qsort() vs C++ sort()

C qsort() vs C++ sort() - GeeksforGeeks

Standard C library provides qsort function that can be used for sorting an array. Following is the prototype of qsort() function.

```
// Sort an array of any type. The parameters are, base
// address of array, size of array and pointer to
// comparator function
void qsort (void* base, size_t num, size_t size,
                    int (*comparator)(const void*, const void*));
```

It requires a pointer to the array, the number of elements in the array, the size of each element and a comparator function. We have discussed qsort comparator in detail here.

C++ Standard Library provides a similar function sort() that originated in the STL. We have discussed C++ sort here. Following are prototypes of C++ sort() function.

```
// To sort in default or ascending order.
template
void sort(T first, T last);

// To sort according to the order specified
// by comp.
template
void sort(T first, T last, Compare comp);
```

The order of equal elements is not guaranteed to be preserved. C++ provides std::stable_sort that can be used to preserve order.

Comparison to qsort and sort()
1. Implementation details:

As the name suggests, qsort function uses QuickSort algorithm to sort the given array, although the C standard does not require it to implement quicksort.

C++ sort function uses introsort which is a hybrid algorithm. Different implementations use different algorithms. The GNU Standard C++ library, for example, uses a 3-part hybrid sorting algorithm: introsort is performed first (introsort itself being a hybrid of quicksort and heap sort) followed by an insertion sort on the result.

2. Complexity :
The C standard doesn't talk about its complexity of qsort. The new C++11 standard requires that the complexity of sort to be O(Nlog(N)) in the worst case. Previous versions of C++ such as C++03 allow possible worst case scenario of O(N^2). Only average complexity was required to be O(N log N).

3. Running time:
STL's sort ran faster than C's qsort, because C++'s templates generate optimized code for a particular data type and a particular comparison function.

STL's sort runs 20% to 50% faster than the hand-coded quicksort and 250% to 1000% faster than the C qsort library function. C might be the fastest language but qsort is very slow.

When we tried to sort one million integers on C++14, Time taken by C qsort() was 0.247883 sec and time taken by C++ sort() was only 0.086125 sec

```
// C++ program to demonstrate performance of
// C qsort and C++ sort() algorithm
#include <bits/stdc++.h>
using namespace std;

// Number of elements to be sorted
```

```
#define N 1000000

// A comparator function used by qsort
int compare(const void * a, const void * b)
{
   return ( *(int*)a - *(int*)b );
}

// Driver program to test above functions
int main()
{
   int arr[N], dupArr[N];

   // seed for random input
   srand(time(NULL));

   // to measure time taken by qsort and sort
   clock_t begin, end;
   double time_spent;
```



```
   // generate random input
   for (int i = 0; i < N; i++)
      dupArr[i] = arr[i] = rand()%100000;

   begin = clock();
   qsort(arr, N, sizeof(int), compare);
   end = clock();

   // calculate time taken by C qsort function
   time_spent = (double)(end - begin) / CLOCKS_PER_SEC;

   cout << "Time taken by C qsort() - "
        << time_spent << endl;

   time_spent = 0.0;

   begin = clock();
   sort(dupArr, dupArr + N);
   end = clock();

   // calculate time taken by C++ sort
   time_spent = (double)(end - begin) / CLOCKS_PER_SEC;

   cout << "Time taken by C++ sort() - "
        << time_spent << endl;

   return 0;
```

}

Output :

Time taken by C qsort() - 0.247883
Time taken by C++ sort() - 0.086125

C++ sort() is blazingly faster than qsort() on equivalent data due to inlining. sort() on a container of integers will be compiled to use std::less::operator() by default, which will be inlined and sort() will be comparing the integers directly. On the other hand, qsort() will be making an indirect call through a function pointer for every comparison which compilers fails to optimize.

4. Flexibility:
STL's sort works for all data types and for different data containers like C arrays, C++ vectors, C++ deques, etc and other containers that can be written by the user. This kind of flexibility is rather difficult to achieve in C.

5. Safety:
Compared to qsort, the templated sort is more type-safe since it does not require access to data items through unsafe void pointers, as qsort does.

References:
http://theory.stanford.edu/~amitp/rants/c++-vs-c
https://en.wikipedia.org/wiki/Sort_(C%2B%2B)

Source

https://www.geeksforgeeks.org/c-qsort-vs-c-sort/

Chapter 13

C++ tricks for competitive programming (for C++ 11)

C++ tricks for competitive programming (for C++ 11) - GeeksforGeeks We have discussed some tricks in below post. In this post, some more tricks are discussed. Writing C/C++ code efficiently in Competitive programming

Although practice is the only way that ensures increased performance in programming con tests but having some tricks up your sleeve ensures an upper edge and fast debugging.

1) Checking if the number is even or odd without using the % operator: Although this trick is not much better than using % operator but is sometimes efficient (with large numbers). Use & operator:

```
 if (num & 1)
  cout << "ODD";
else
  cout << "EVEN";
```

Example:
num = 5
Binary: “101 & 1” will be 001, so true
num = 4
Binary: “100 & 1” will be 000, so false.

2) Fast Multiplication or Division by 2
Multiplying by 2 means shifting all the bits to left and dividing by 2 means shifting to the right.

Example : 2 (Binary 10): shifting left 4 (Binary 100) and right 1 (Binary 1)

```
 n = n << 1;   // Multiply n with 2
n = n >> 1;   // Divide n by 2
```


3) Swapping of 2 numbers using XOR:
This method is fast and doesn’t require the use of 3rd variable.

```
 // A quick way to swap a and b
a ^= b;
b ^= a;
a ^= b;
```

4) Avoiding use of strlen():

```
 //  Use of strlen() can be avoided by:
for (i=0; s[i]; i++)
```

```
{
}
// loop breaks when the character array ends.
```

5) Use of emplace_back() (Discussed here, here and here)
Instead of push_back() in STL emplace_back can be used because it is much faster and in stead of allocating memory somewhere else and then appending it directly allocates memory in the container.

6) Inbuilt GCD function: C++ has inbuilt GCD function and there is no need to explicitly code it. Syntax: __gcd(x, y);

7) Using Inline functions: We can create inline functions and use them without having to code them up during the contest. Examples: (a) function for sieve, (b) function for palindrome.

8) Maximum size of the array: We must be knowing that the maximum size of array declared inside the main function is of the order of 10^6 but if you declare array globally then you can declare its size upto 10^7.

9) Calculating the most significant digit: To calculate the most significant digit of any number log can be directly used to calculate it.

Suppose the number is N then
Let double K = log10(N);
now K = K - floor(K);
int X = pow(10, K);
X will be the most significant digit.

10) Calculating the number of digits directly: To calculate number of digits in a number, instead of looping you can efficiently use log :

Number of digits in N =floor(log10(N)) + 1;

11) Efficient trick to know if a number is a power of 2 sing the normal technique of division the complexity comes out to be O(logN), but it can be solved using O(v) where v are the number of digits of number in binary form.

```
  /* Function to check if x is power of 2*/
bool isPowerOfTwo (int x)
{
  /* First x in the below expression is
    for the case when x is 0 */
  return x && (!(x&(x-1)));
}
```

12) C++11 has in built algorithms for following:

```
// are all of the elements positive?
all_of(first, first+n, ispositive());

// is there at least one positive element?
any_of(first, first+n, ispositive());

// are none of the elements positive?
none_of(first, first+n, ispositive());
```

Please refer Array algorithms in C++ STL (all_of, any_of, none_of, copy_n and itoa) for details.

13) Copy Algorithm: used to copy elements from one container to another.

```
int source[5] = {0, 12, 34, 50, 80};
int target[5];
// copy 5 elements from source to target
copy_n(source, 5, target);
```

Please refer Array algorithms in C++ STL (all_of, any_of, none_of, copy_n and itoa) for details.

14) The Iota Algorithm The algorithm iota() creates a range of sequentially increasing values, as if by assigning an initial value to *first, then incrementing that value using prefix ++. In the following listing, iota() assigns the consecutive values {10, 11, 12, 13, 14} to the array arr, and {‘a’, ‘b’, ‘c’} to the char array c[].

```
int a[5] = {0};
char c[3] = {0};

// changes a to {10, 11, 12, 13, 14}
iota(a, a+5, 10);
iota(c, c+3, 'a'); // {'a', 'b', 'c'}
```


Please refer Array algorithms in C++ STL (all_of, any_of, none_of, copy_n and itoa) for details.

15) Initialization in Binary form: In C++ 11 assignments can also be made in binary form.

```
// C++ code to demonstrate working of
// "binary" numbers
#include<iostream>
using namespace std;
```

```
int main()
{
   auto number = 0b011;
   cout << number;
   return 0;
}
```

Output :

3

16) Use of “and” Though not a very productive one, this tip helps you to just use conditional operator and instead of typing &.

```
  // C++ code to demonstrate working of "and"
#include<iostream>
using namespace std;
int main()
{
   int a = 10;
   if (a < 20 and a > 5)
     cout << "Yes";
   return 0;
}
```

Output :

Yes

Improved By : bugsanderrors

Source

https://www.geeksforgeeks.org/c-tricks-competitive-programming-c-11/ 80