CS F211: DATA STRUCTURES & ALGORITHMS (2ND SEMESTER 2024-25) STACK, QUEUE AND DEQUE ADT

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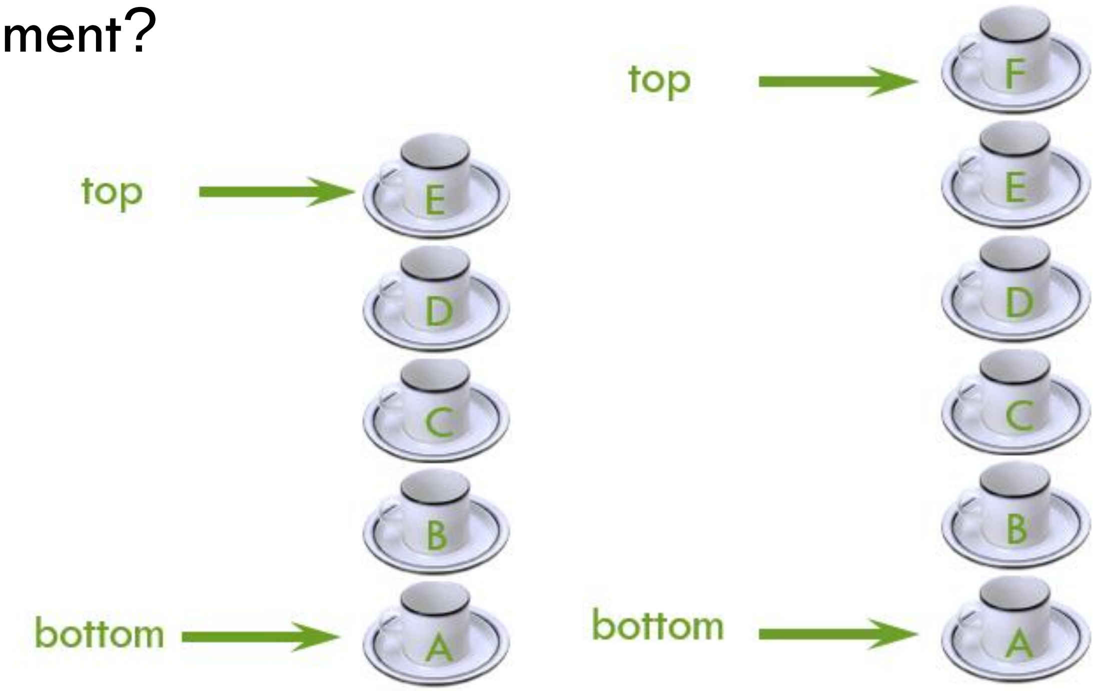
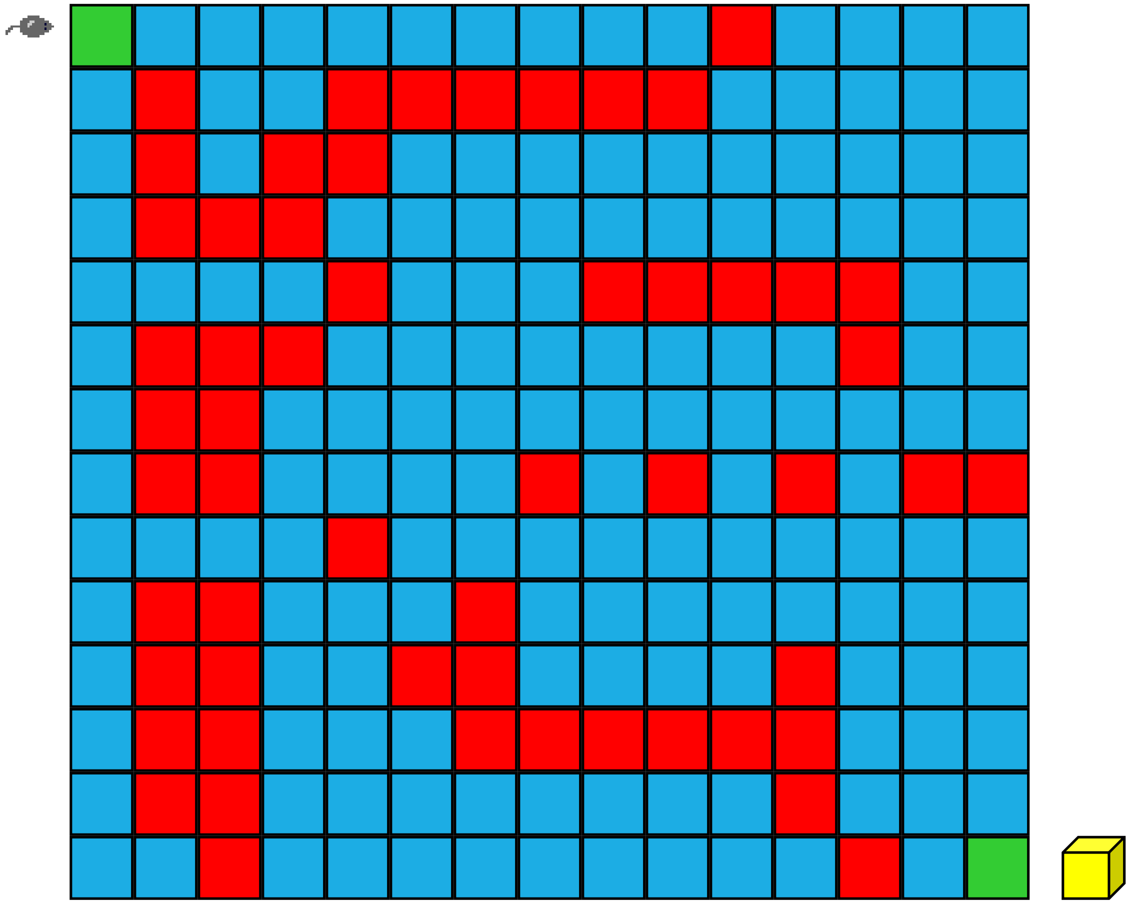
STACK ABSTRACT DATA TYPE (STACK ADT)

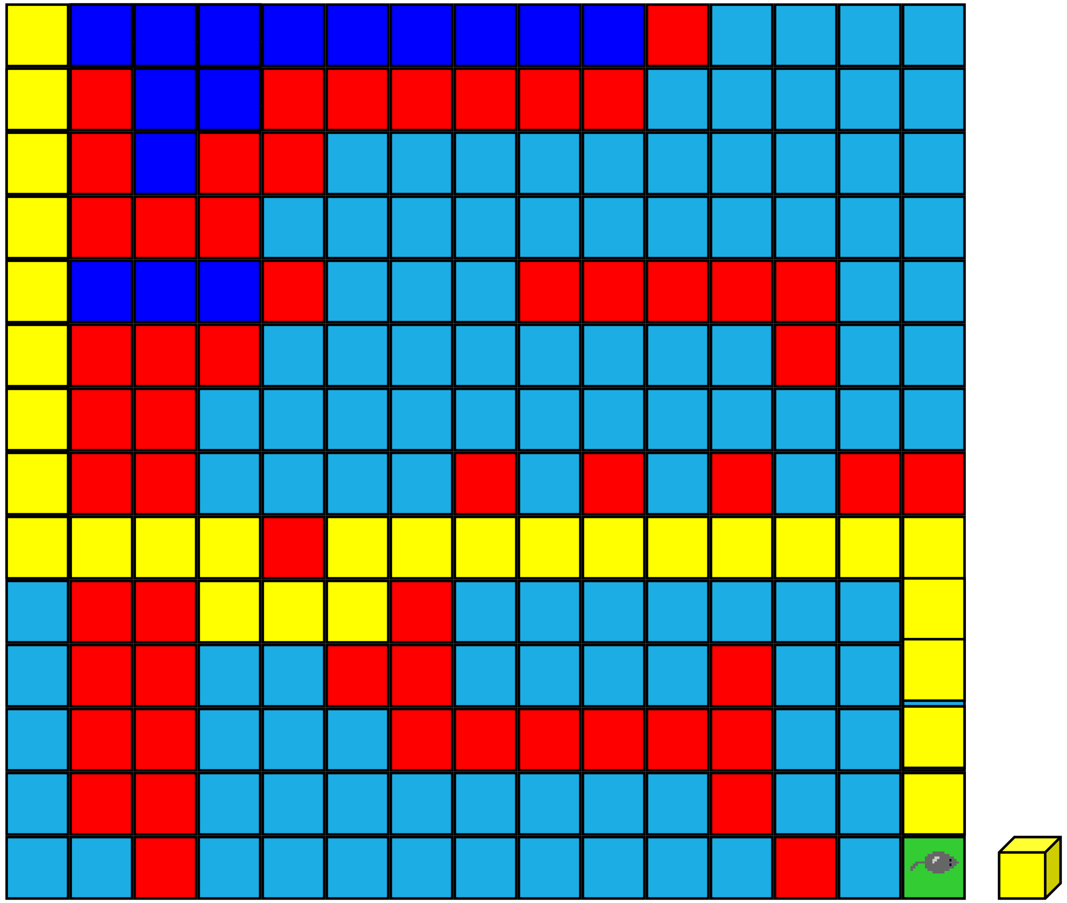
- What is a Stack?
- What type of policy does a stack implement?



Example usage: Matching parenthesis, Expression evaluation, Function call stack, Stock span, Backtracking, etc.

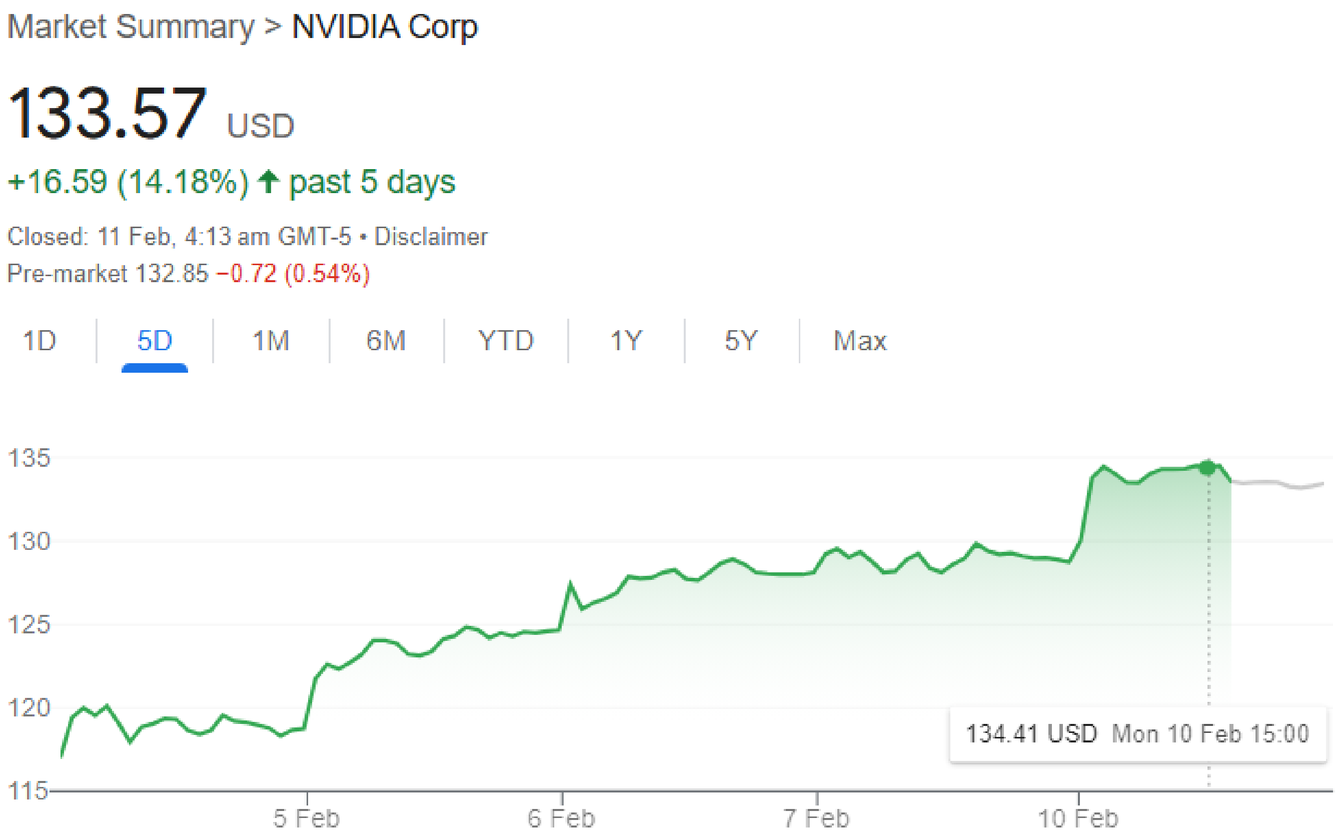
ANOTHER EX. USAGE: RAT IN A MAZE (BACKTRACKING)





STACK USAGES CONTINUED...

```
#include <iostream>
using namespace std;
void functionB() {
  cout    << "Inside Function B"   << endl;
  return;
}
void functionA() {
  cout    << "Inside Function A"   << endl;
  functionB();
  cout   << "Inside Function A"    << endl;
}
int main() {
  cout << "Inside Main function" << endl;
  functionA();
  cout <<  "Main fun finished"   <<  endl;
  return 0;
}
```



Market Summary > NVIDIA Corp

133.57 USD

+16.59 (14.18%) ↑ past 5 days

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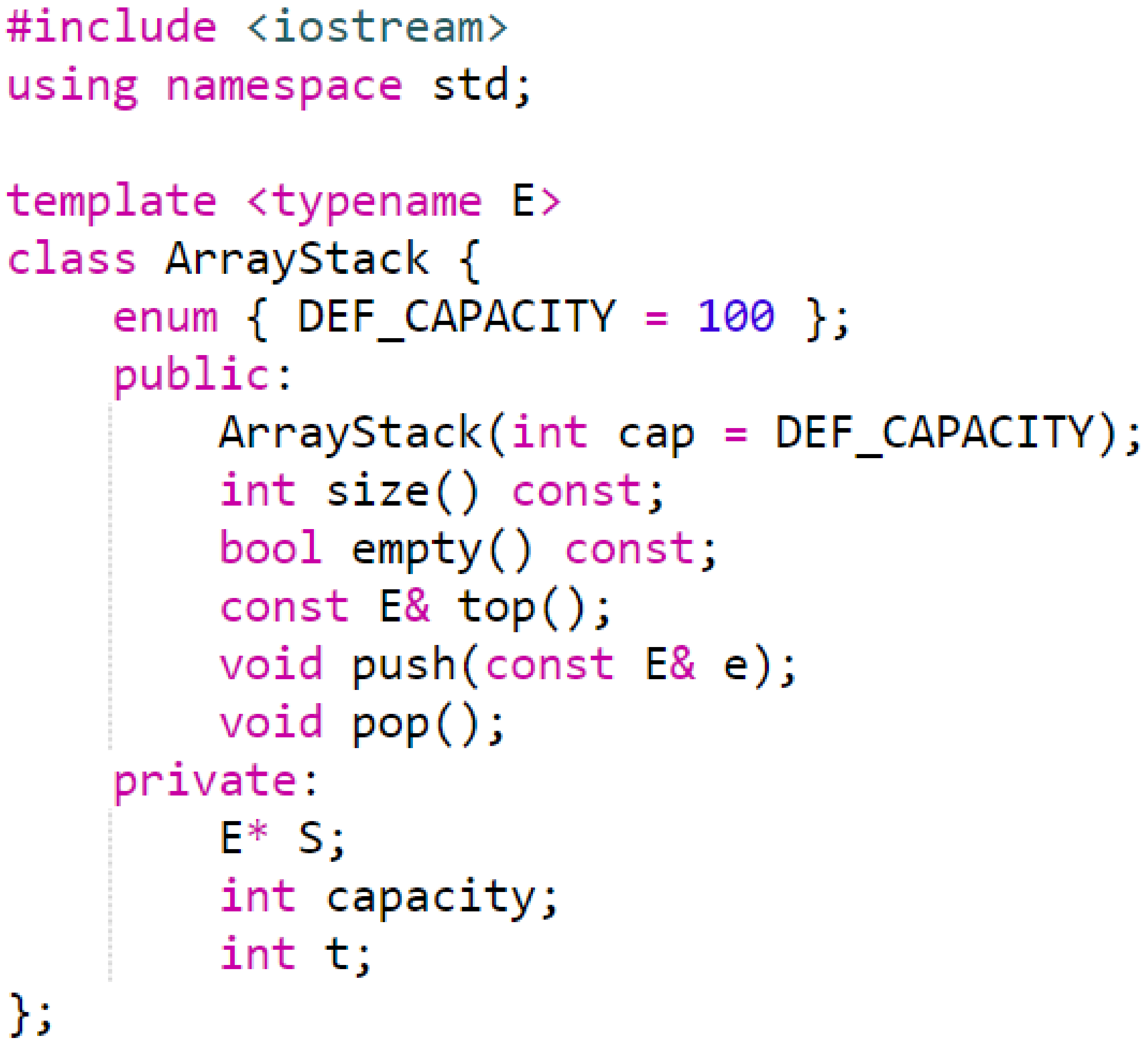
Pre-market 132.85 −0.72 (0.54%)

134.41 USD Mon 10 Feb 15:00

(Stock span: Nvidia)

STACK INTERFACE

- What is an ADT?
- Exs: Graph ADT (introductory classes), Stock trading (BST, Heaps, Hash maps, etc.)
- STACK ADT:
    - Data?
    - Operations?
    - Auxiliary operations?



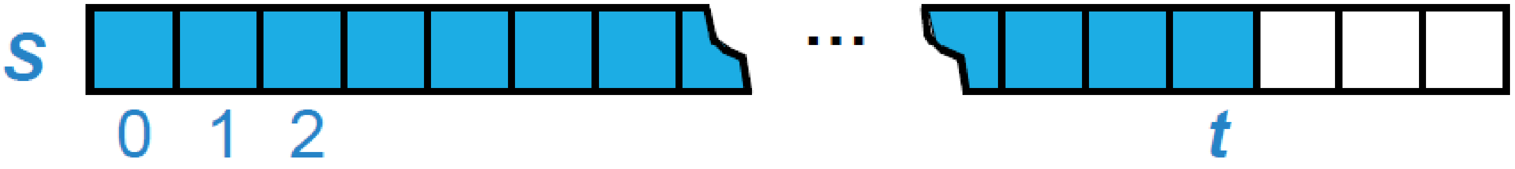
```
#include <iostream>
using namespace std;

template <typename E>
class ArrayStack {
    enum { DEF_CAPACITY = 100 };
    public:
        ArrayStack(int cap = DEF_CAPACITY);
        int size() const;
        bool empty() const;
        const E& top();
        void push(const E& e);
        void pop();
    private:
        E* S;
        int capacity;
        int t;
};
```

ARRAY-BASED STACK IMPLEMENTATION

- A simple way of implementing the Stack ADT uses an array.
- We add elements from left to right.
- A variable keeps track of the index of the top element.

```
Algorithm push(o)
    if $t = S.size() - 1$ then
        throw StackFull
    else
        $t \leftarrow t + 1$
        $S[t] \leftarrow o$
```

```
Algorithm pop()
    if empty() then
        throw StackEmpty
    else
        $t \leftarrow t - 1$
        return $S[t + 1]$
```

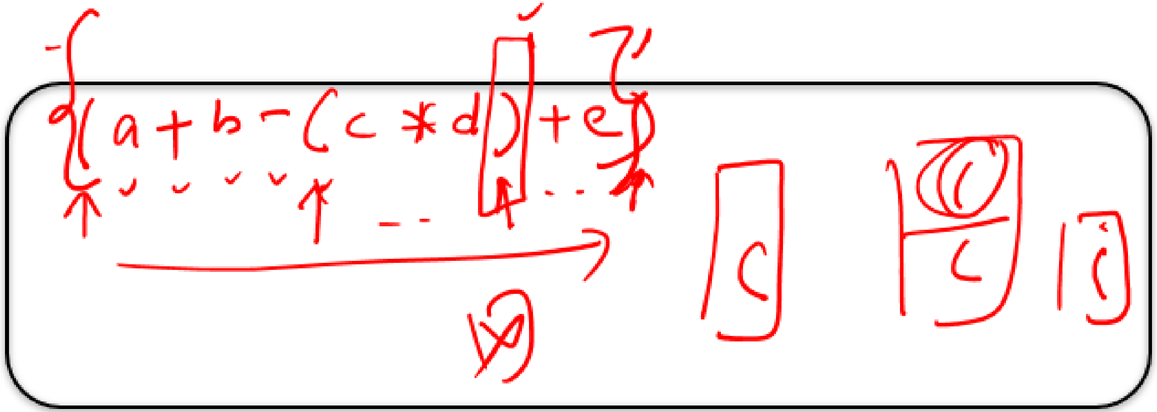


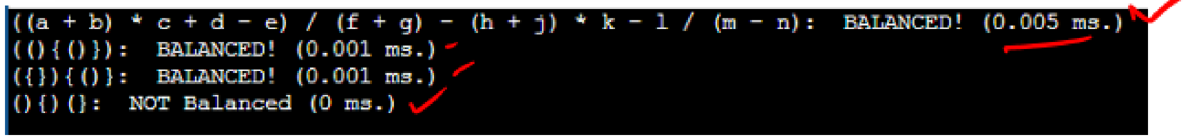
```
Algorithm size()
    return $t + 1$
```

[[ ]] {{ }} (( ))

STACK USAGE EXAMPLE-1: MATCHING PARENTHESIS

```
Let S be an empty stack
for i=0 to n-1 do
  if X[i] is an opening grouping symbol then
     S.push(X[i])
  else
    if X[i] is a closing grouping symbol then
       if S.empty() then
             return false {nothing to match with}
       if S.pop() does not match the type of X[i] then
             return false {wrong type}
if S.empty() then
   return true {every symbol matched}

else

  return false {some symbols were never matched}
```

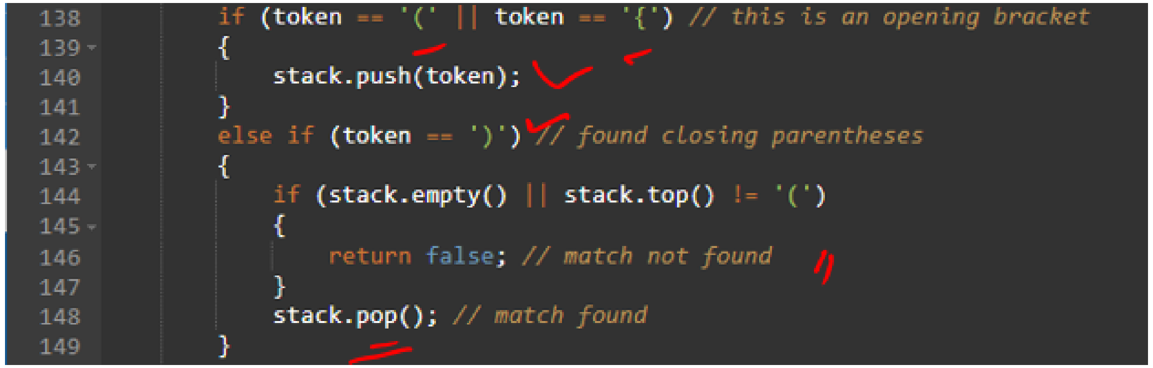




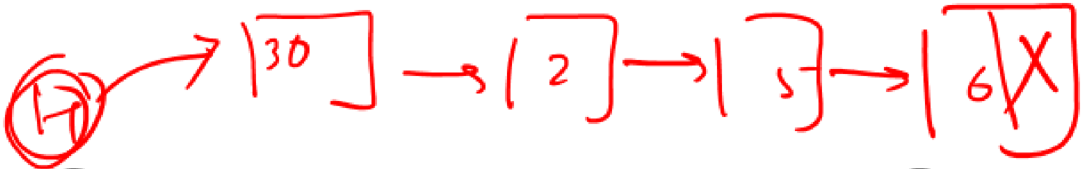
```
((a + b) * c + d - e) / (f + g) - (h + j) * k - l / (m - n):  BALANCED!  (0.005 ms.)
(){()}):  BALANCED!  (0.001 ms.)
({}){()}:  BALANCED!  (0.001 ms.)
(){}(}:  NOT Balanced  (0 ms.)
```

(Output)

Lab-6 (Next week's Lab)



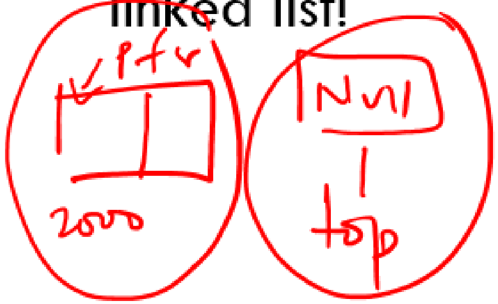
```
        if (token == '(' || token == '{') // this is an opening bracket
        {
            stack.push(token);
        }
        else if (token == ')') // found closing parentheses
        {
            if (stack.empty() || stack.top() != '(')
            {
                return false; // match not found
            }
            stack.pop(); // match found
        }
```



LINKED LIST-BASED STACK IMPLEMENTATION

LIFO

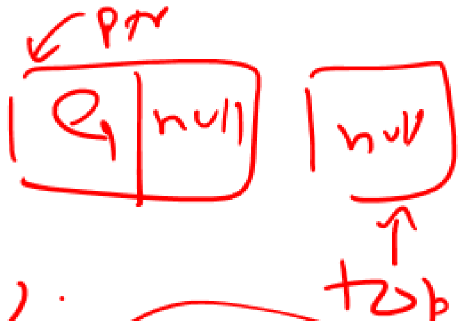
- Let us see how to do push into and pop from an empty stack implemented using a linked list!



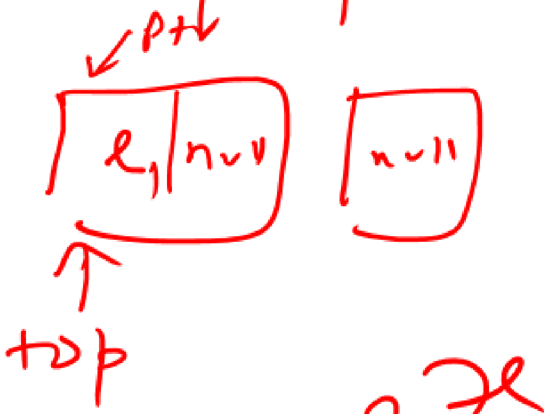
Node * top = null;

ptr -> data = e1;

ptr -> next = *top;



*top = ptr

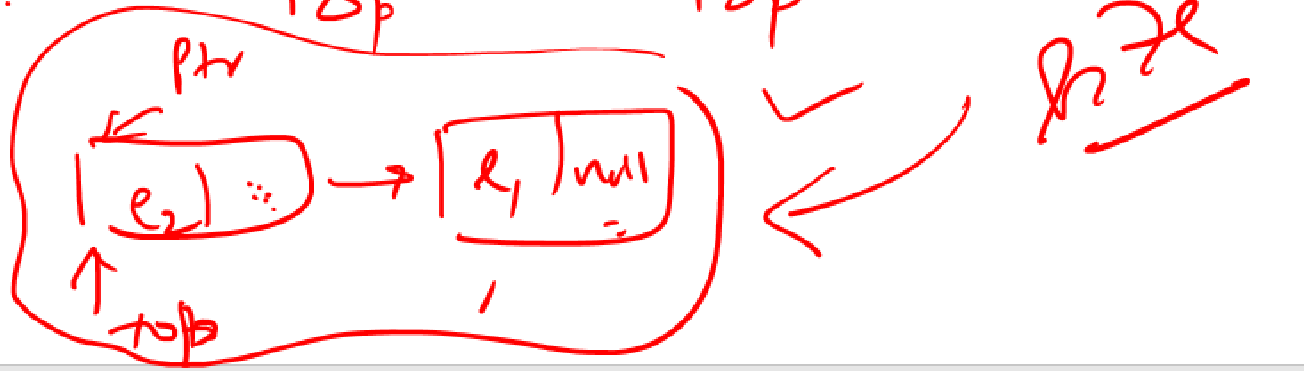


func Node * ptr = new Node();

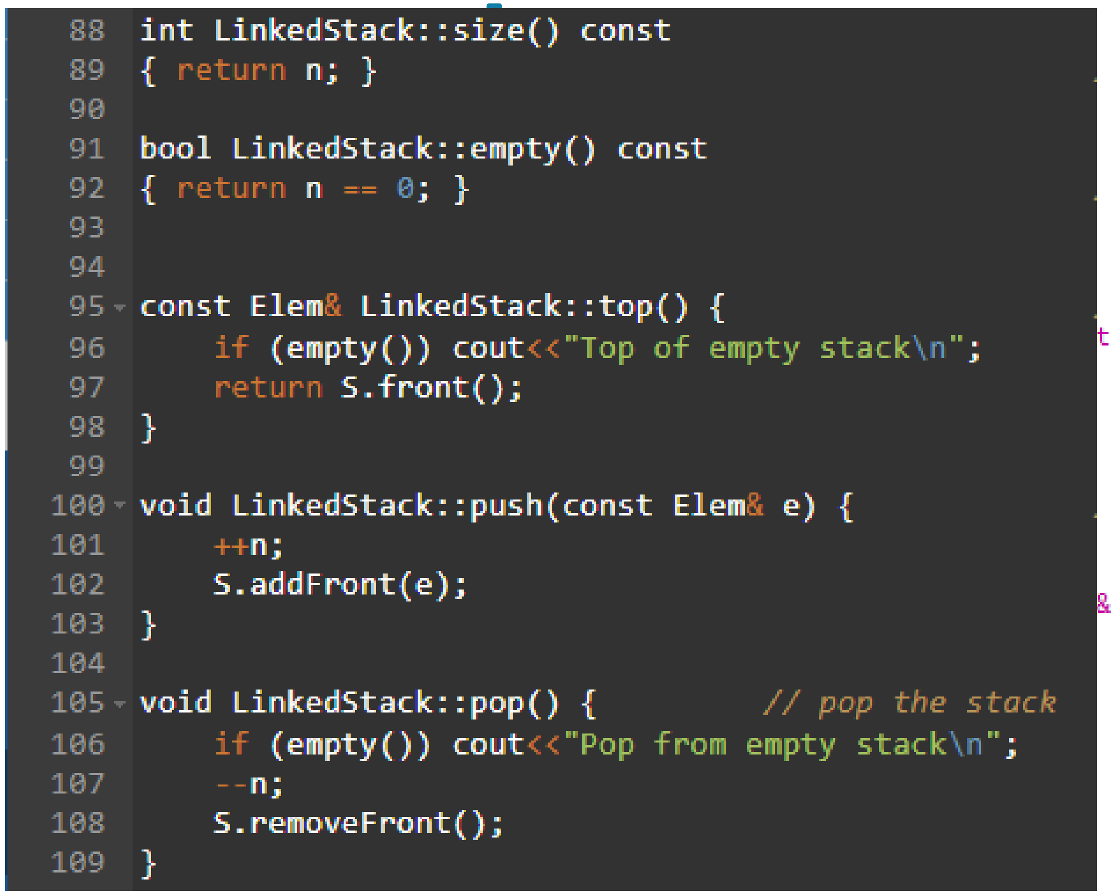
delete
return data;

Node * tmp = top;
data = tmp -> data;
top = tmp -> next;

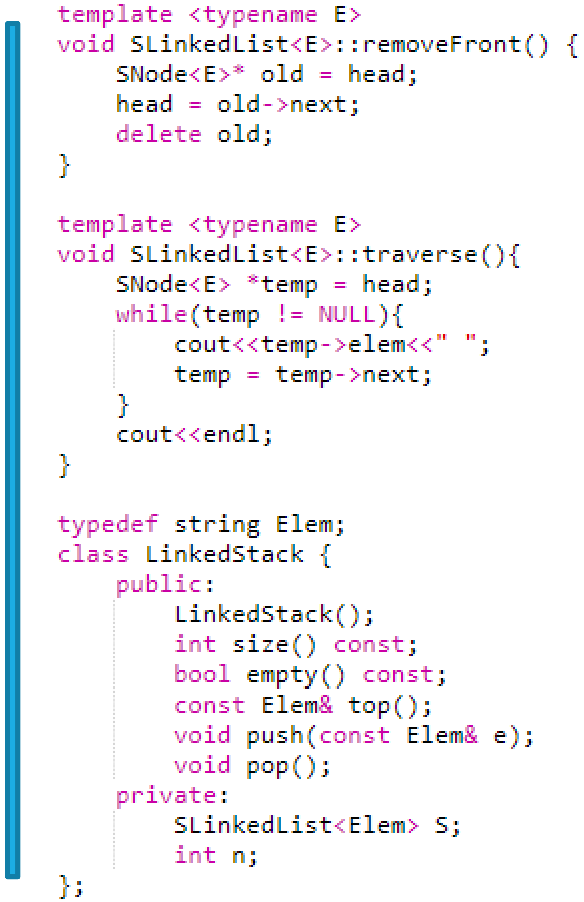
pop



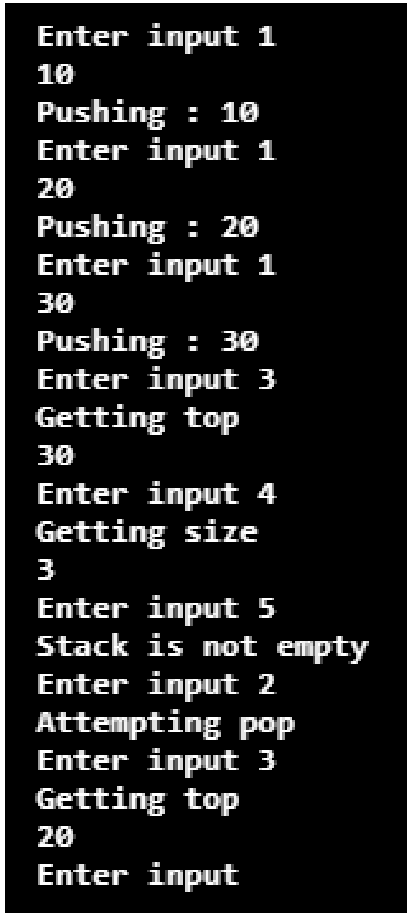
IMPLEMENTING A STACK WITH A GENERIC LINKED LIST



```
int LinkedStack::size() const
{ return n; }

bool LinkedStack::empty() const
{ return n == 0; }


const Elem& LinkedStack::top() {
    if (empty()) cout<<"Top of empty stack\n";
    return S.front();
}

void LinkedStack::push(const Elem& e) {
    ++n;
    S.addFront(e);
}

void LinkedStack::pop() {          // pop the stack
    if (empty()) cout<<"Pop from empty stack\n";
    --n;
    S.removeFront();
}
```

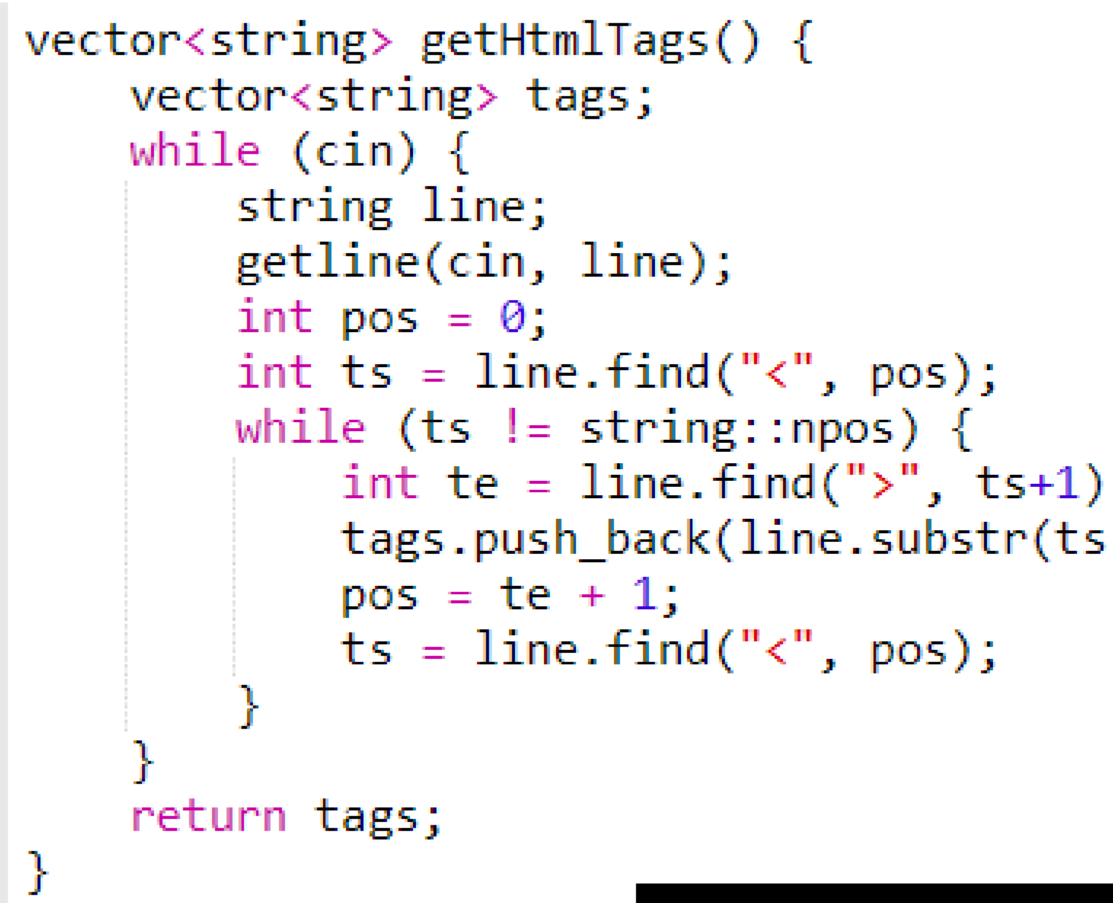


```
template <typename E>
void SLinkedList<E>::removeFront() {
    SNode<E>* old = head;
    head = old->next;
    delete old;
}

template <typename E>
void SLinkedList<E>::traverse(){
    SNode<E> *temp = head;
    while(temp != NULL){
        cout<<temp->elem<<" ";
        temp = temp->next;
    }
    cout<<endl;
}

typedef string Elem;
class LinkedStack {
    public:
        LinkedStack();
        int size() const;
        bool empty() const;
        const Elem& top();
        void push(const Elem& e);
        void pop();
    private:
        SLinkedList<Elem> S;
        int n;
};
```

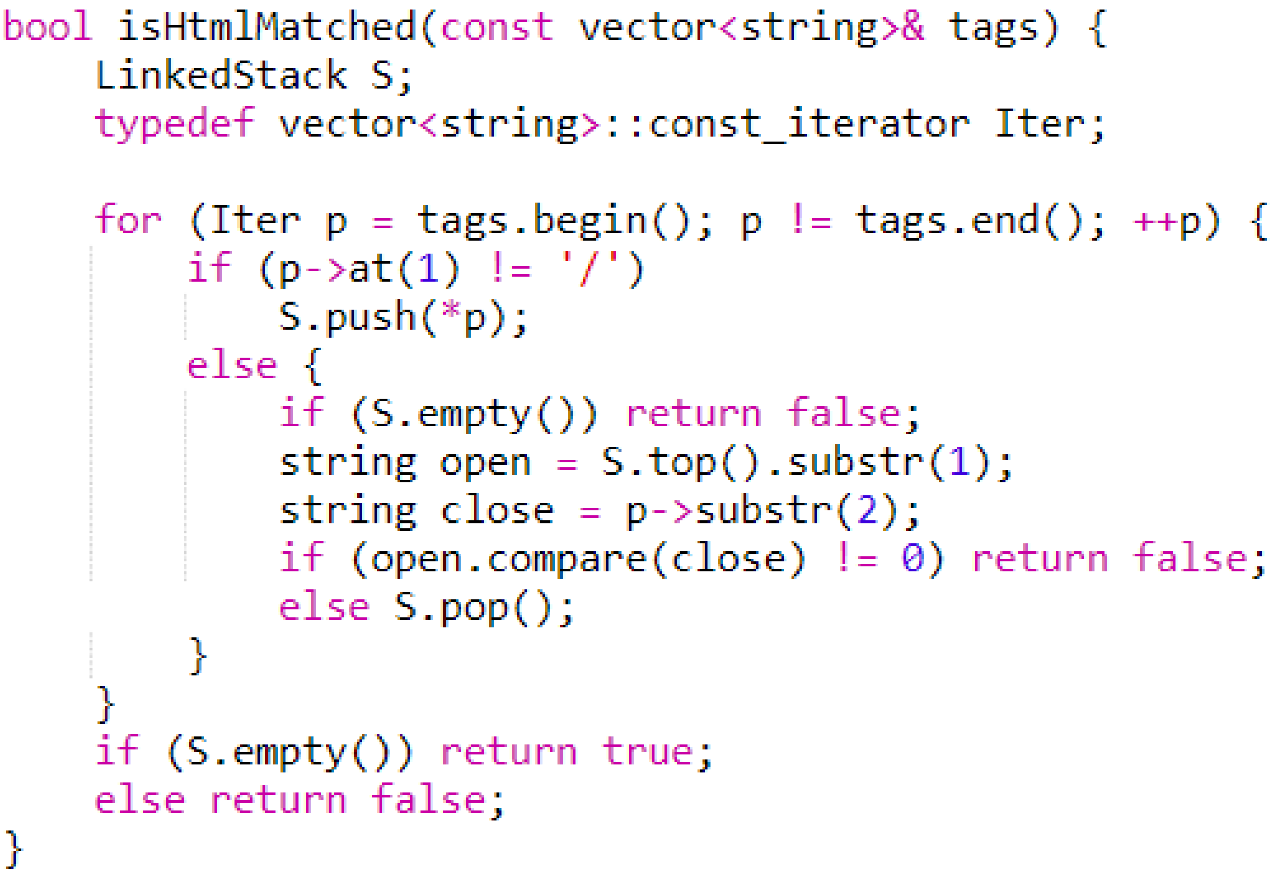


```
Enter input 1
10
Pushing : 10
Enter input 1
20
Pushing : 20
Enter input 1
30
Pushing : 30
Enter input 3
Getting top
30
Enter input 4
Getting size
3
Enter input 5
Stack is not empty
Enter input 2
Attempting pop
Enter input 3
Getting top
20
Enter input
```

EX-2: MATCHING TAGS

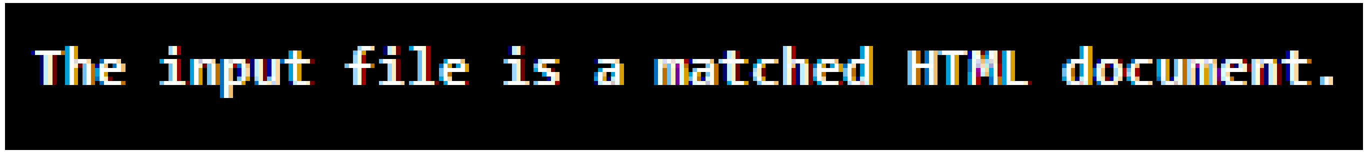


```
vector<string> getHtmlTags() {
    vector<string> tags;
    while (cin) {
        string line;
        getline(cin, line);
        int pos = 0;
        int ts = line.find("<", pos);
        while (ts != string::npos) {
            int te = line.find(">", ts+1)
            tags.push_back(line.substr(ts
            pos = te + 1;
            ts = line.find("<", pos);
        }
    }
    return tags;
}
```



```
bool isHtmlMatched(const vector<string>& tags) {
    LinkedStack S;
    typedef vector<string>::const_iterator Iter;

    for (Iter p = tags.begin(); p != tags.end(); ++p) {
        if (p->at(1) != '/')
            S.push(*p);
        else {
            if (S.empty()) return false;
            string open = S.top().substr(1);
            string close = p->substr(2);
            if (open.compare(close) != 0) return false;
            else S.pop();
        }
    }
    if (S.empty()) return true;
    else return false;
}
```

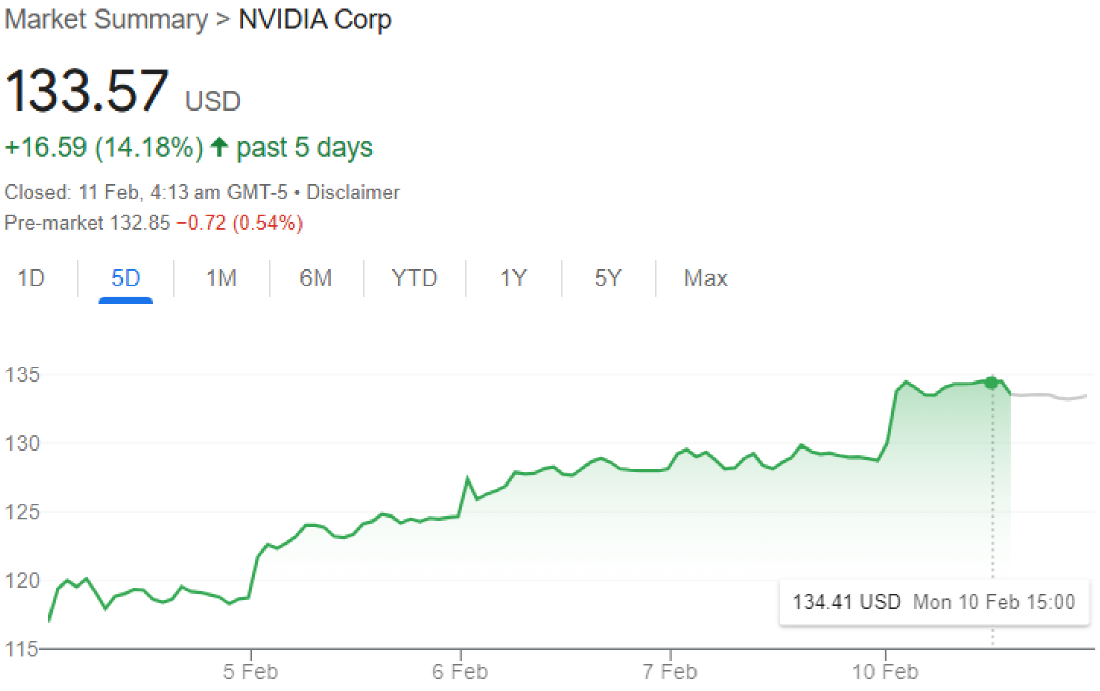
Lab6: Next week



```
The input file is a matched HTML document.
```

STACK USAGE EXAMPLE-3: STOCK SPAN

- Stock span can be defined as the number of consecutive days before the current day where the price of the stock was equal to or less than the current price.



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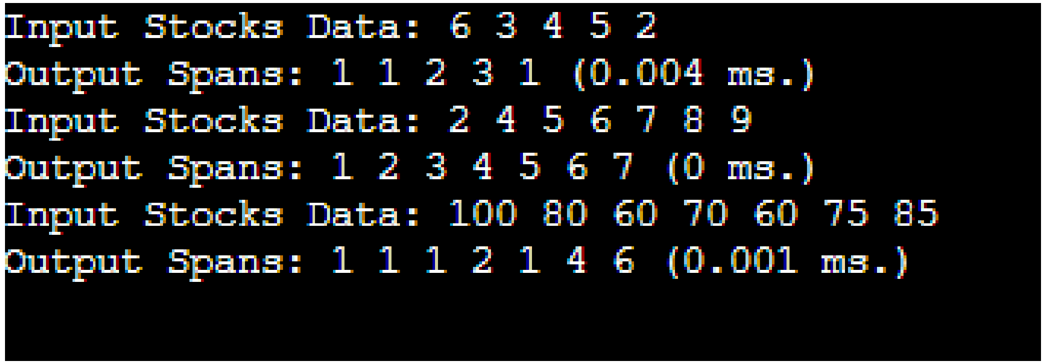
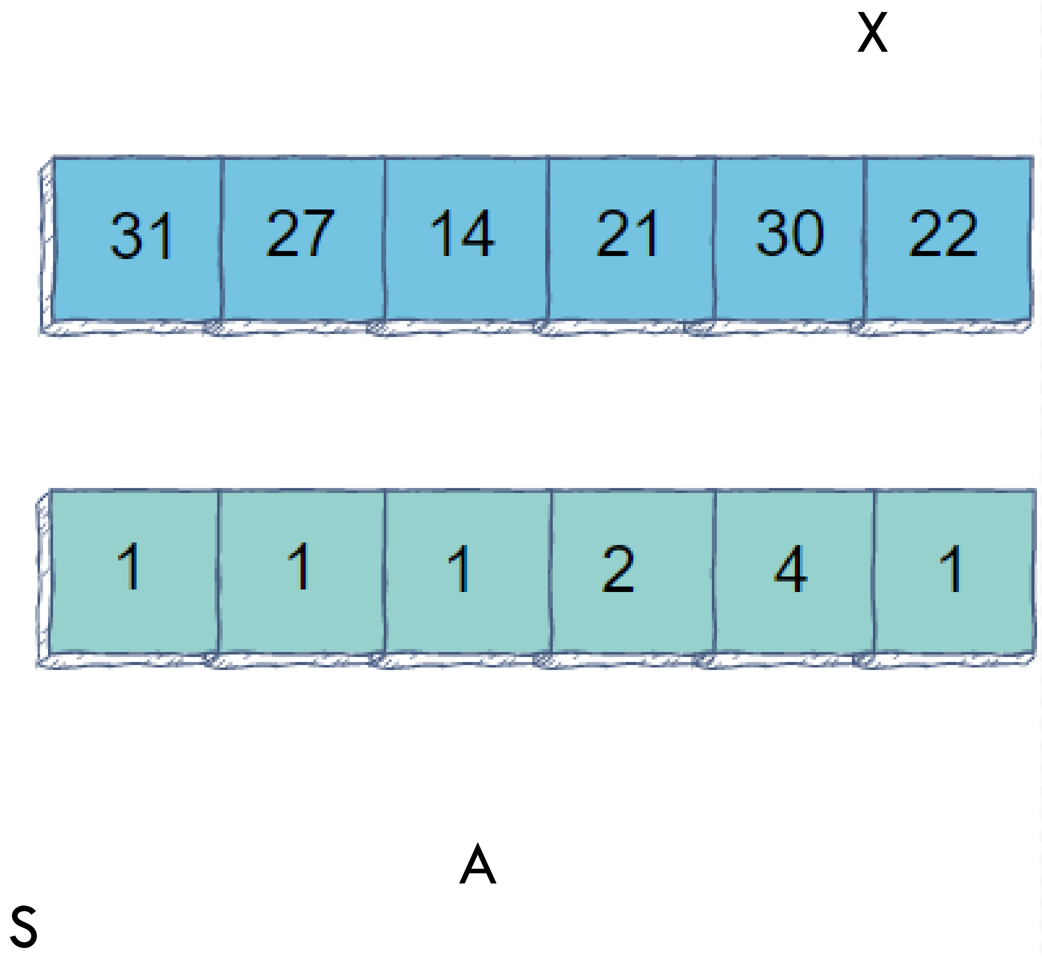
(Stock span: Nvidia)



```
Input Stocks Data: 6 3 4 5 2
Output Spans: 1 1 2 3 1 (0.004 ms.)
Input Stocks Data: 2 4 5 6 7 8 9
Output Spans: 1 2 3 4 5 6 7 (0 ms.)
Input Stocks Data: 100 80 60 70 60 75 85
Output Spans: 1 1 1 2 1 4 6 (0.001 ms.)
```

Lab 6: Next week's lab

COMPUTING STOCK SPAN CONTINUED…



31	27	14	21	30	22

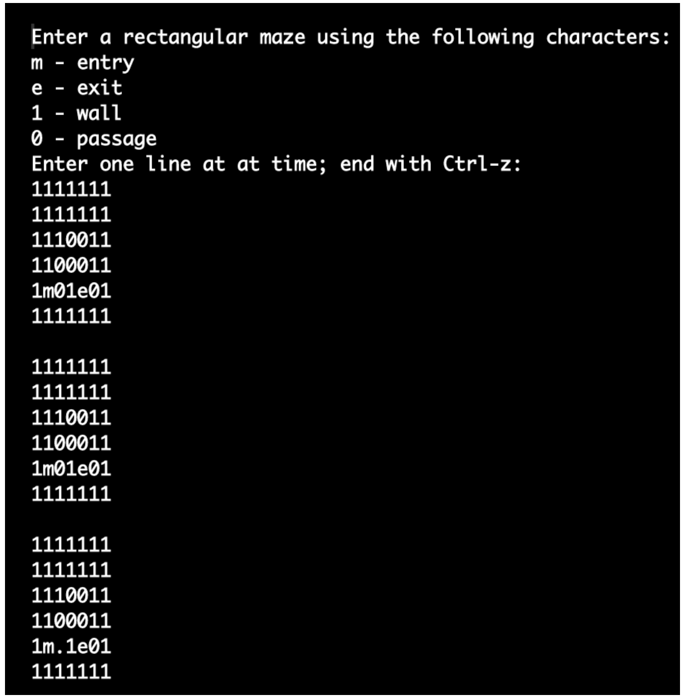
1	1	1	2	4	1

```
STOCK_SPAN(prices):
  n = length(prices)
  span = array of size n  // To store the stock spans
  stack = empty stack     // Stack to store indices

  for i from 0 to n-1:
    while stack is not empty AND prices[stack.top()] <= prices[i]:
      stack.pop()

    if stack is empty:
      span[i] = i + 1  // Span is from the beginning
    else:
      span[i] = i - stack.top() // Span is difference of indices

    stack.push(i) // Push the current index

  return span
```

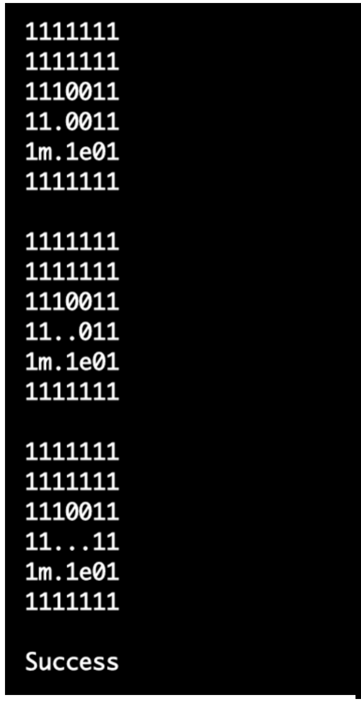
STACK USAGE EX-4: BACKTRACKING

```
1 1 1 1 1    1 1 1 1 1
1 1 0 0 1    1 1 0 0 1
1 0 0 0 1    1 0 1 0 1
m 0 1 e 0    m 0 1 e 0
```

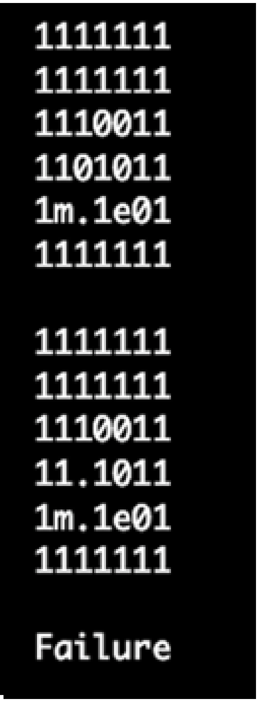
Chakravyuha from Mahabharata



```
Enter a rectangular maze using the following characters:
m - entry
e - exit
1 - wall
0 - passage
Enter one line at at time; end with Ctrl-z:
1111111
1111111
1110011
1100011
1m01e01
1111111

1111111
1111111
1110011
1100011
1m01e01
1111111

1111111
1111111
1110011
1100011
1m.1e01
1111111
```



```
1111111
1111111
1110011
11.0011
1m.1e01
1111111

1111111
1111111
1110011
11..011
1m.1e01
1111111

1111111
1111111
1110011
11...11
1m.1e01
1111111

Success
```



```
1111111
1111111
1110011
1101011
1m.1e01
1111111

1111111
1111111
1110011
11.1011
1m.1e01
1111111

Failure
```

Lab 6: Next week’s Lab

(3, 4, 5)

STACK STL IN C++ (REVERSING A VECTOR)

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

It is a container adaptor. Why?

```
#include <vector>
stack<int, vector<int>> myStack;
stack<int, list<int>> myStack;
stack<int, deque<int>> myStack;
```

Which one is default?

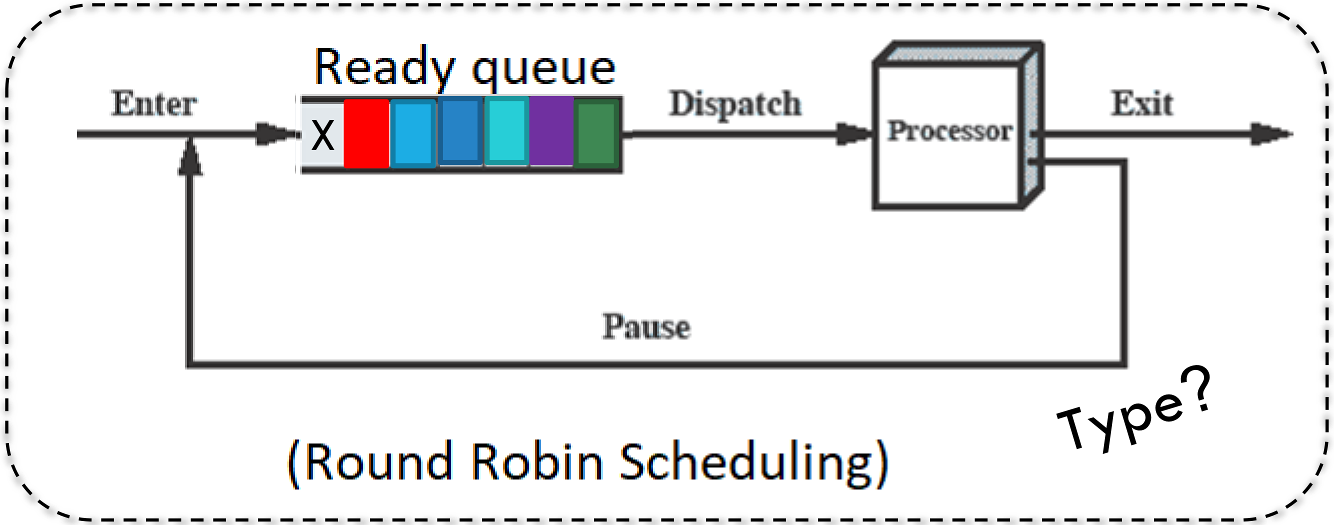
```
vector<int> rever(const vector<int>& inputVector) {
  stack<int> myStack;
  vector<int> reversedVector;
  for (int element : inputVector) {
   myStack.push(element);
  }
  while (!myStack.empty()) {
    reversedVector.push_back(myStack.top());
    myStack.pop();
  }
  return reversedVector;
}
```

(5)

(5, 4)

(5, 4, 3)

USE CASES OF QUEUES IN THE REAL WORLD



(Round Robin Scheduling)

- Is it NOT a linear data structure?
- What operations would you like to see in a Queue ADT?
- How is it different from Stack?

v = Q[0];

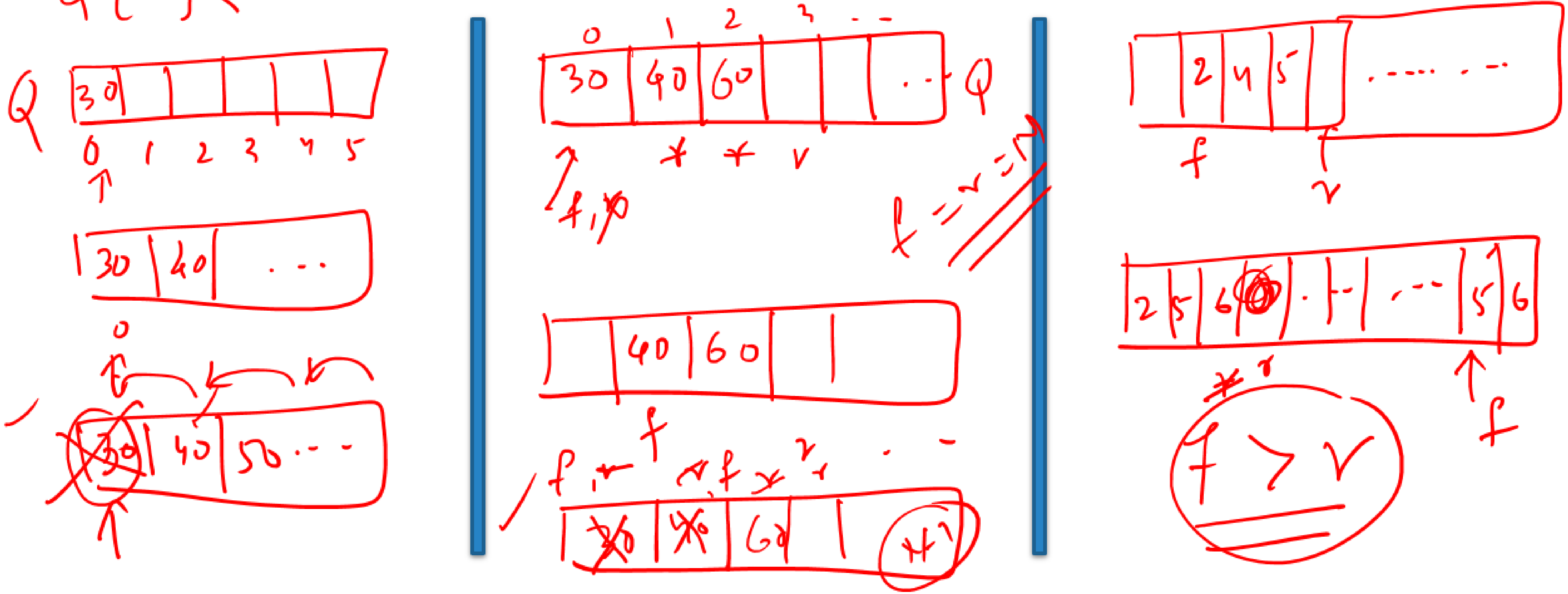
%

QUEUE IMPLEMENTED USING ARRAYS

f ≤ r

- Multiple Approaches: 1. Q[0]:front; 2. f, r, and n; 3. Circular array (with %)

Q[0] ← 30



OPERATIONS USING CIRCULAR ARRAY & INTERFACE

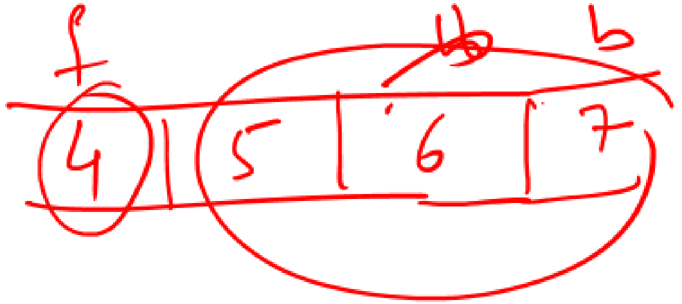
```
Algorithm size()
   return n
Algorithm empty()
   return (n == 0)
```

```
Algorithm dequeue ()
   if empty() then
      throw QueueEmpty
     else
      data = Q[f];
      f ← (f + 1) mod N;
      n = n – 1;
return data;
```

```
Algorithm enqueue (P)
{
   if size() == N then
      throw QueueFull

   else {

      Q[r] ← P;
      r ← (r+1) mod N;
      n = n + 1;
 }
}
```

```
template <typename E>

class Queue {
public:
   int size() const;
   bool empty() const;
   const E& front() const
      throw(QueueEmpty);
   void enqueue (const E& e);
   void dequeue()
      throw(QueueEmpty);
};
```

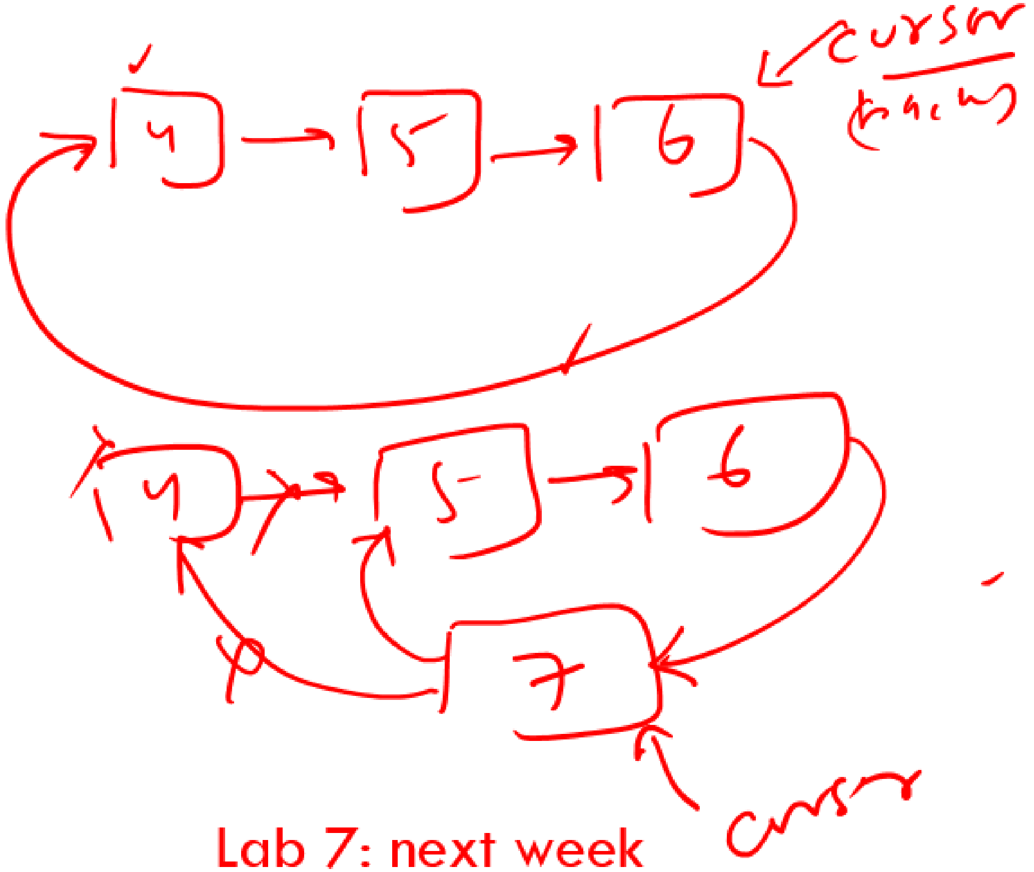
USING CIRCULAR LINKED LIST



```
typedef string Elem;
class LinkedQueue {

public:
    LinkedQueue();
    int size() const;
    bool empty() const;
    const Elem& front() const throw(QueueEmpty);

    void enqueue(const Elem& e);

    void dequeue() throw(QueueEmpty);
private:

CircleList C;

int n;

}
```

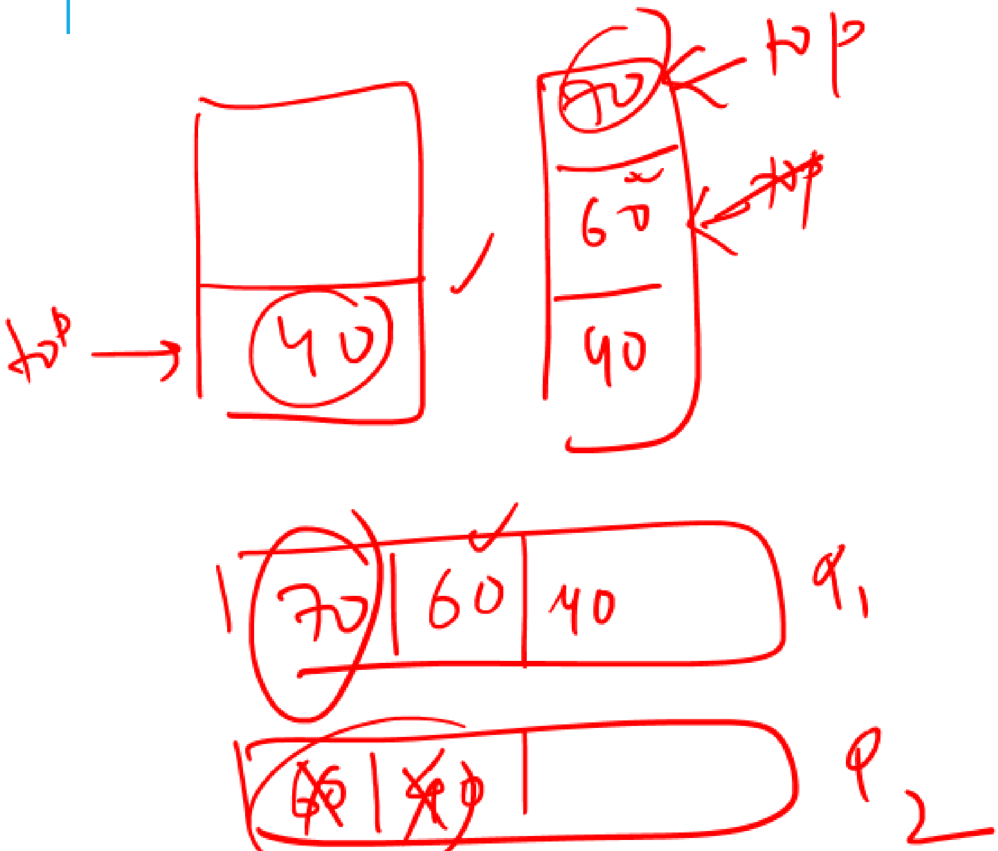
(class structure for Linked queue)

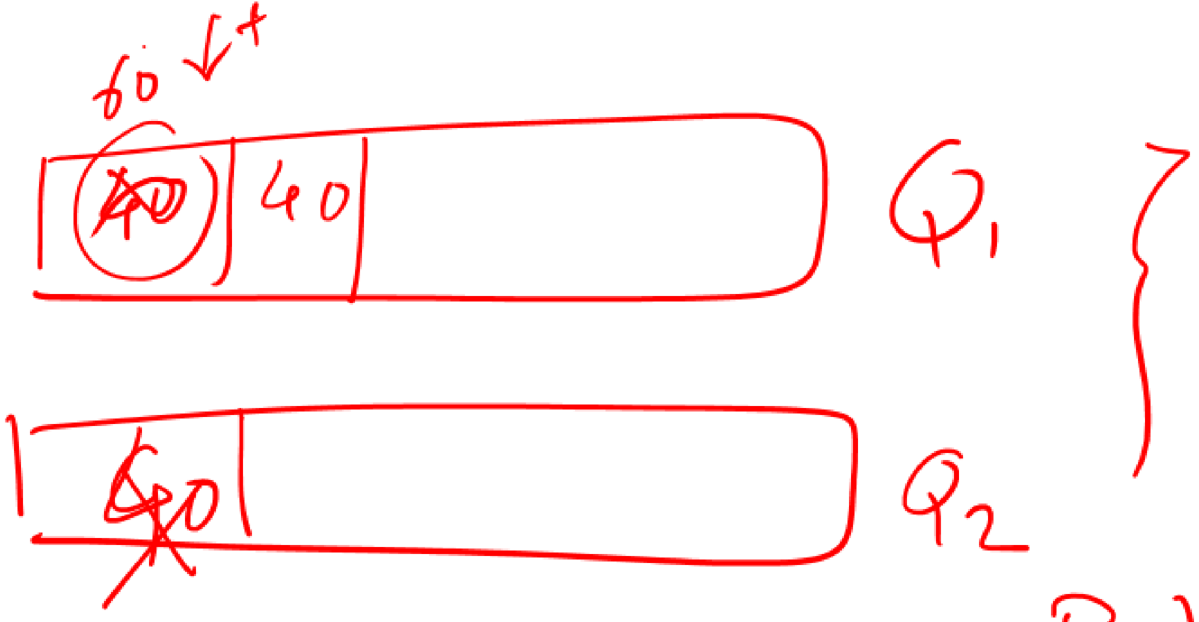
How will you do enqueue and dequeue?



Lab 7: next week

IMPLEMENTING STACK USING QUEUES





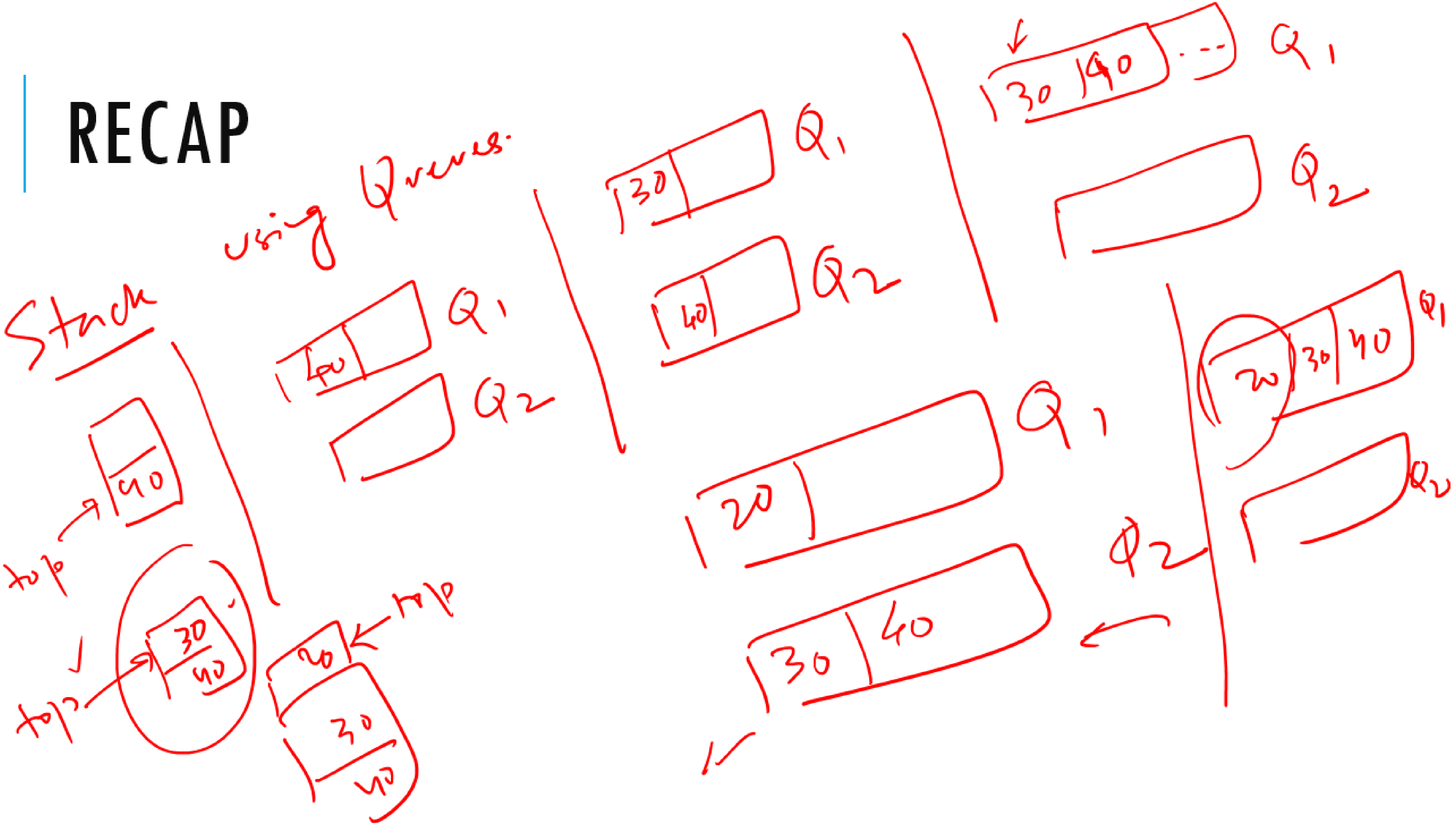
Lab 7: next week

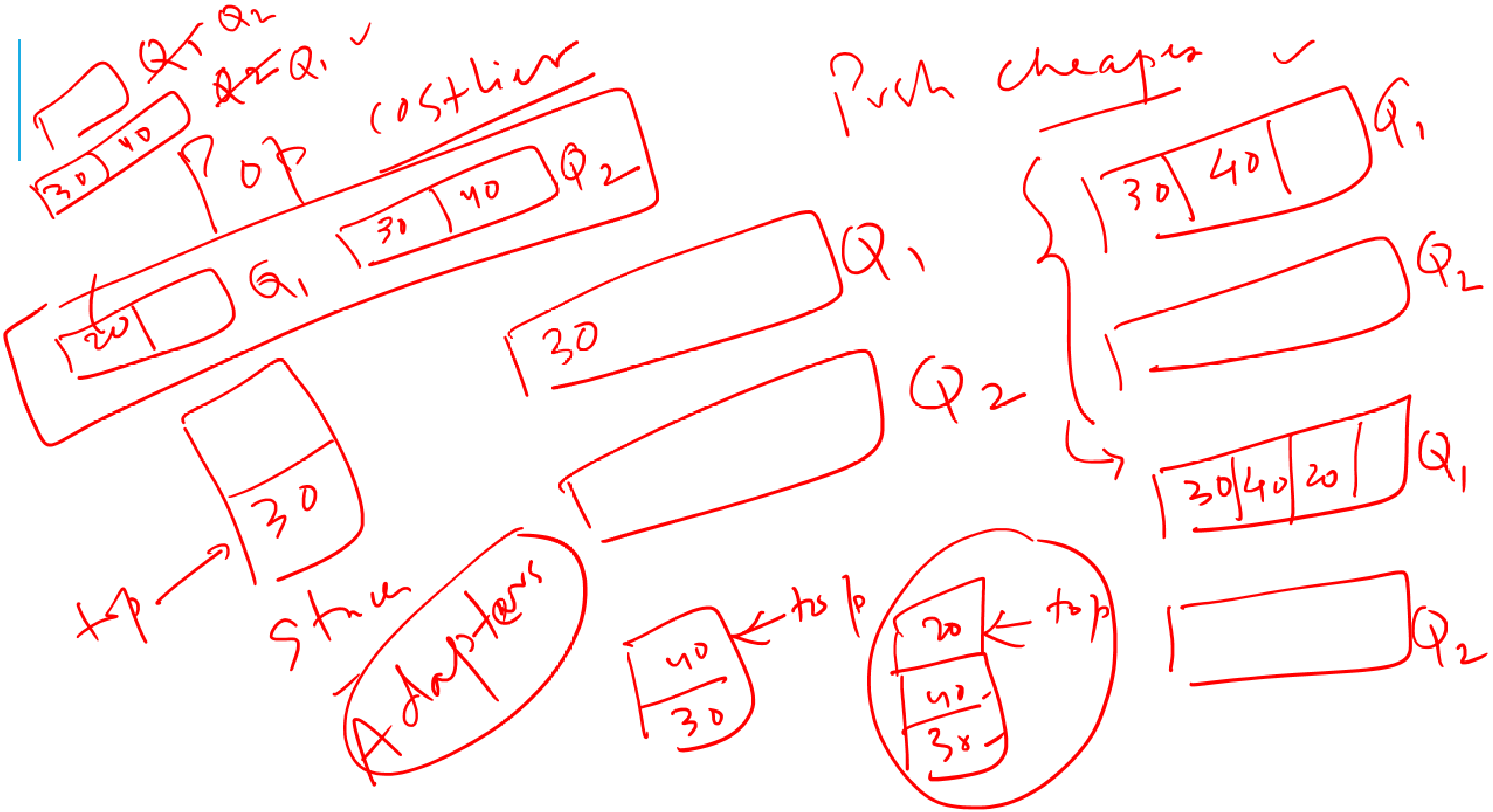
Push
O(n)

Costly.

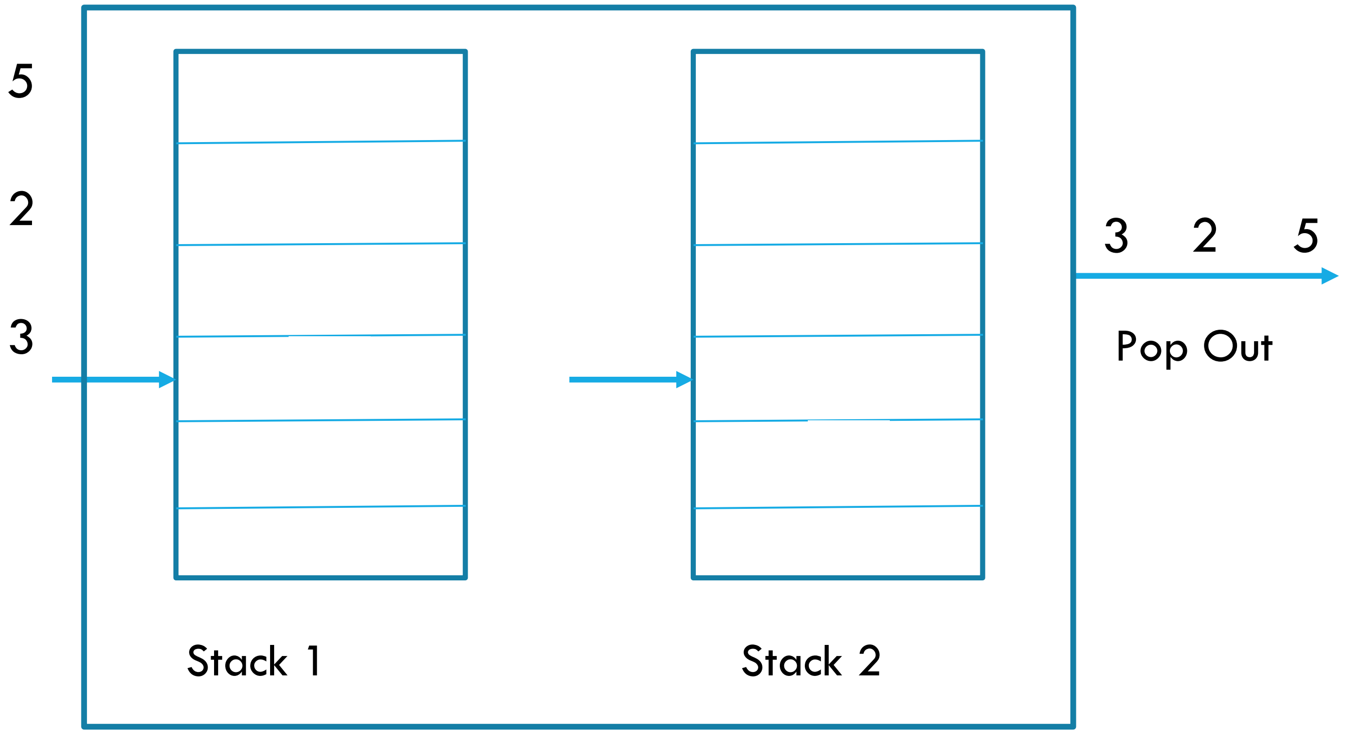
Pop
O(1)

RECAP


Stack
using Queues:
top
40
top
30
40
top
20
30
40
Q1
Q2
40
Q1
30
Q2
40
Q1
30
40
Q2
Q1
20
Q2
30
40
Q1
20
30
40
Q2


~~Q1~~ Q2
~~Q2~~ Q1
Pop costlier
30 | 40
Q2
30 | 40
Q1
20
30
Q1
Q2
30
top
Stack
Adapters
40
30
top
20
40
30
top
Push cheaper
30 | 40
Q1
Q2
30 | 40 | 20
Q1
Q2

A QUEUE USING TWO STACKS



Enqueue: push the elements into the Stack 1.

Dequeue: push all the elements from Stack 1 into Stack 2, and then pop from Stack 2.

Which operation is costly here?

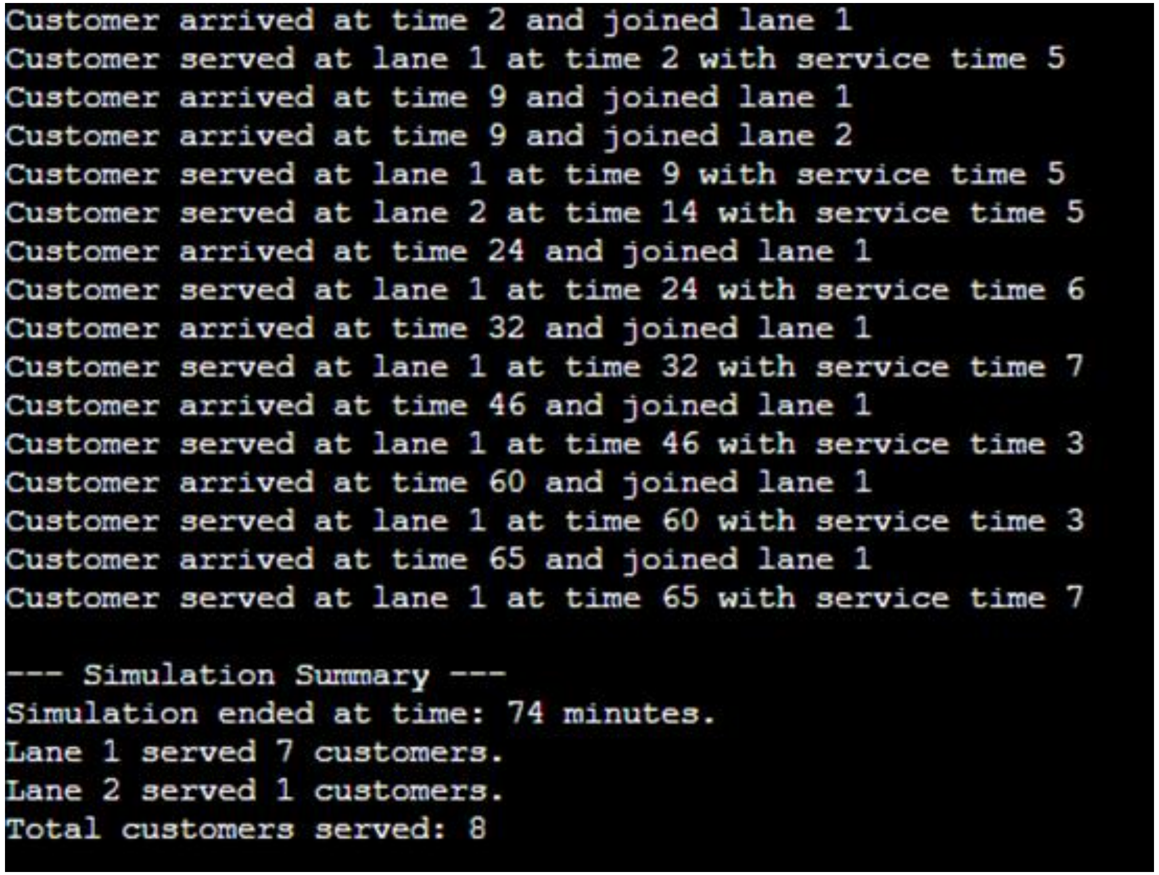
```
#include <queue>   using std::queue;  queue<int>myQueue; push(e); pop(); front(); back(); size(); empty;
```

C++ STL QUEUE (SUPERMARKET CHECKOUT)

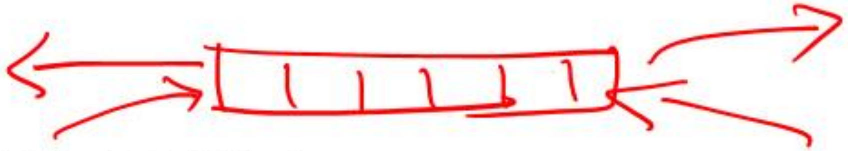
```
while (current_time < simulation_time) {
    //Check for new customer arrival
    if (random() < arrival_rate)
        new_customer = {arrival_time: current_time, service_time: random(1, 5)};
        shortest_lane = lane with the shortest queue;
        lanes[shortest_lane].enqueue(new_customer);

    //Process each checkout lane
    for each (lane ∈  lanes)
      if (lane is NOT empty && cashier_available[lane] <= current_time)
          customer = lane.dequeue();
          cashier_available[lane] = current_time + customer.service_time;
          waiting_time = current_time - customer.arrival_time;
          total_customers_served += 1;
          total_waiting_time += waiting_time;

    // Increment time
    current_time += 1;
}
```

Lab 7: next week

Output:

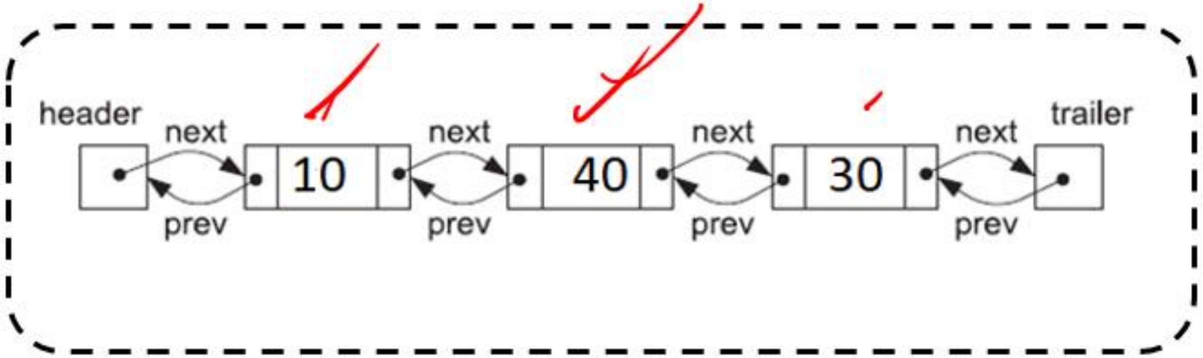


```
Customer arrived at time 2 and joined lane 1
Customer served at lane 1 at time 2 with service time 5
Customer arrived at time 9 and joined lane 1
Customer arrived at time 9 and joined lane 2
Customer served at lane 1 at time 9 with service time 5
Customer served at lane 2 at time 14 with service time 5
Customer arrived at time 24 and joined lane 1
Customer served at lane 1 at time 24 with service time 6
Customer arrived at time 32 and joined lane 1
Customer served at lane 1 at time 32 with service time 7
Customer arrived at time 46 and joined lane 1
Customer served at lane 1 at time 46 with service time 3
Customer arrived at time 60 and joined lane 1
Customer served at lane 1 at time 60 with service time 3
Customer arrived at time 65 and joined lane 1
Customer served at lane 1 at time 65 with service time 7

--- Simulation Summary ---
Simulation ended at time: 74 minutes.
Lane 1 served 7 customers.
Lane 2 served 1 customers.
Total customers served: 8
```

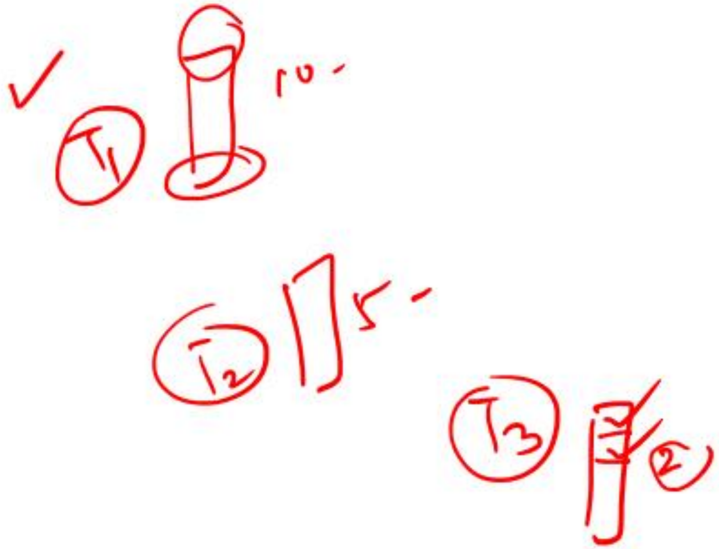


DOUBLE-ENDED QUEUE ADT: DEQUE

list



```
#include <deque>

deque<int>myDeque;

myDeque.push_front(10);

myDeque.push_back(40);

myDeque.push_back(30);

myDeque.pop_front();
```



"aba" ✓ a, b, a

C++ STL DEQUE

b, a

a

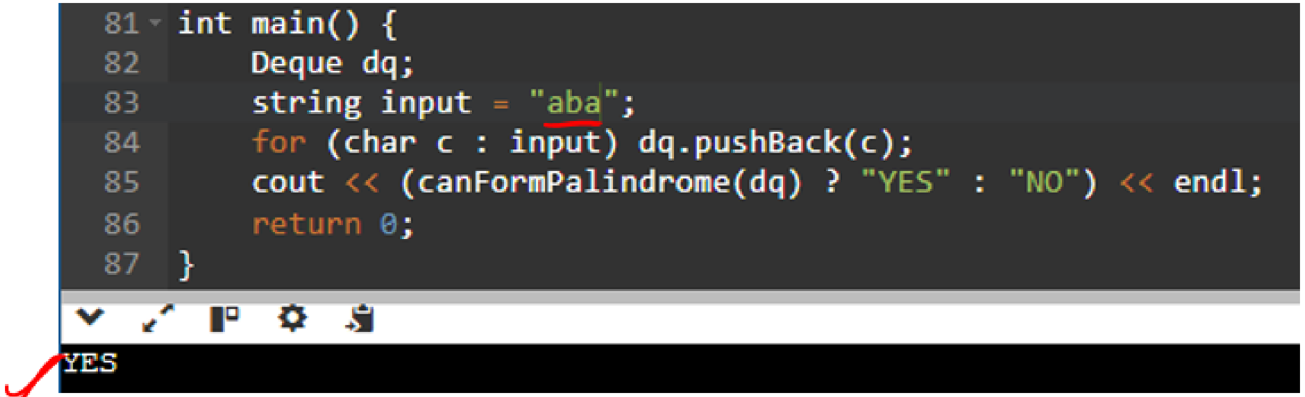
"a"

"ab"

madam c ✓

a a c d m m

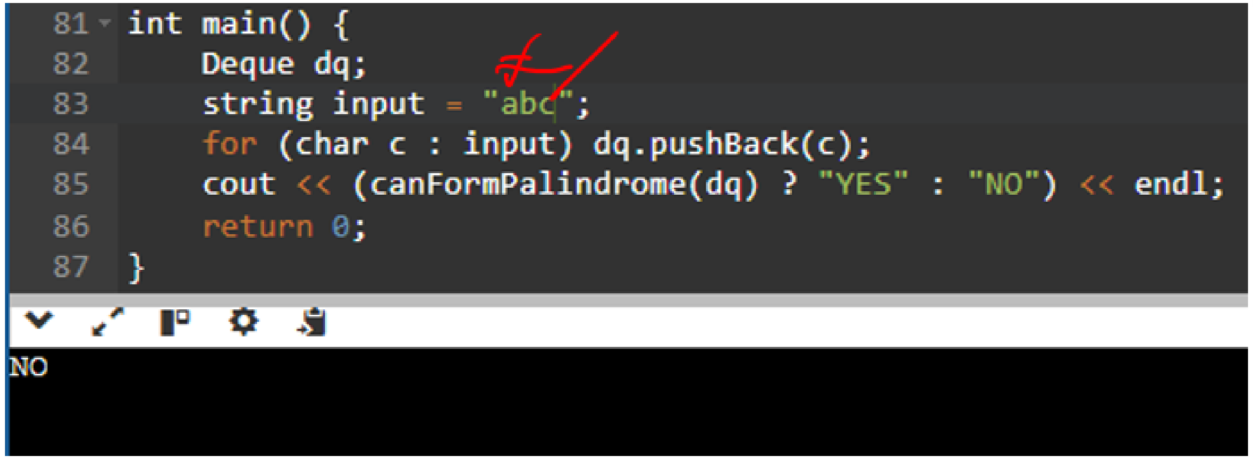
bool canFormPalindrome(Deque& dq, string s="")



```
int main() {
    Deque dq;
    string input = "aba";
    for (char c : input) dq.pushBack(c);
    cout << (canFormPalindrome(dq) ? "YES" : "NO") << endl;
    return 0;
}
```

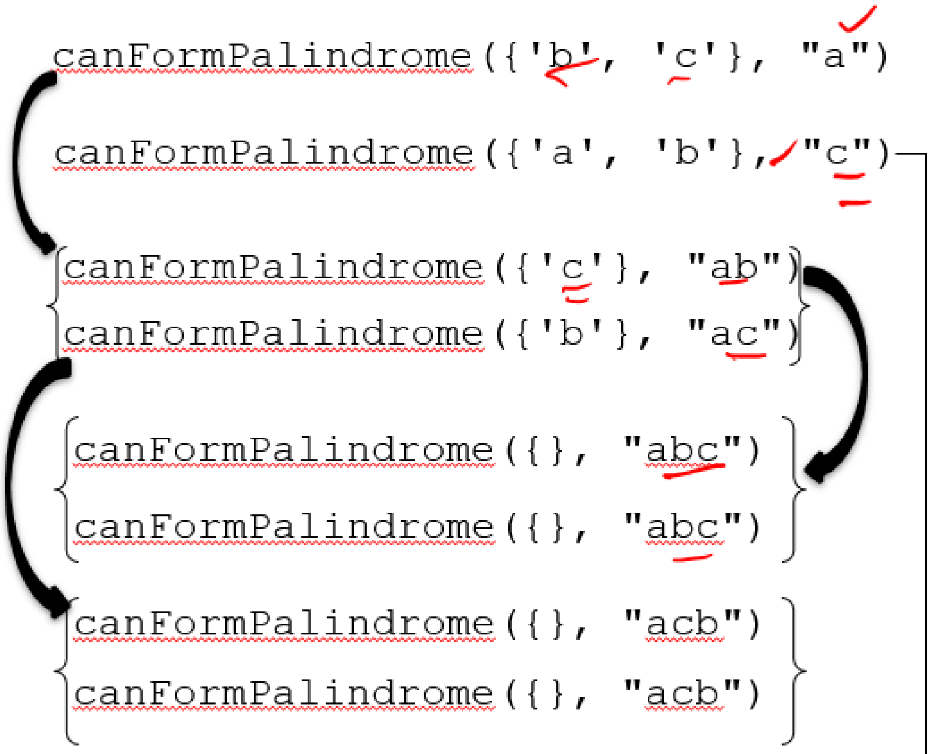
```
YES
```

✓



```
int main() {
    Deque dq;
    string input = "abc";
    for (char c : input) dq.pushBack(c);
    cout << (canFormPalindrome(dq) ? "YES" : "NO") << endl;
    return 0;
}
```

```
NO
```



```
canFormPalindrome({'b', 'c'}, "a")

canFormPalindrome({'a', 'b'}, "c")

canFormPalindrome({'c'}, "ab")
canFormPalindrome({'b'}, "ac")

canFormPalindrome({}, "abc")
canFormPalindrome({}, "abc")

canFormPalindrome({}, "acb")
canFormPalindrome({}, "acb")
```

As all paths fail, backtrack to Step 1 and try the second option: ‘c’ first.

…

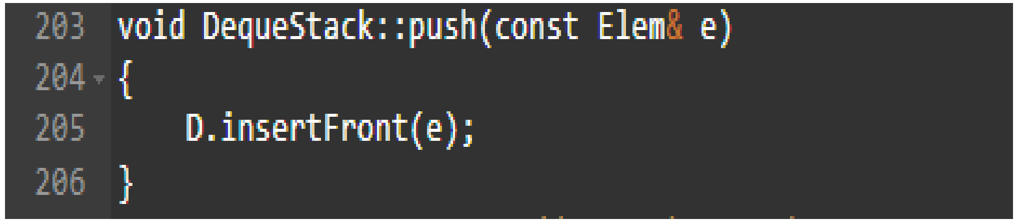
Lab 7: next week

ADAPTER DESIGN PATTERN

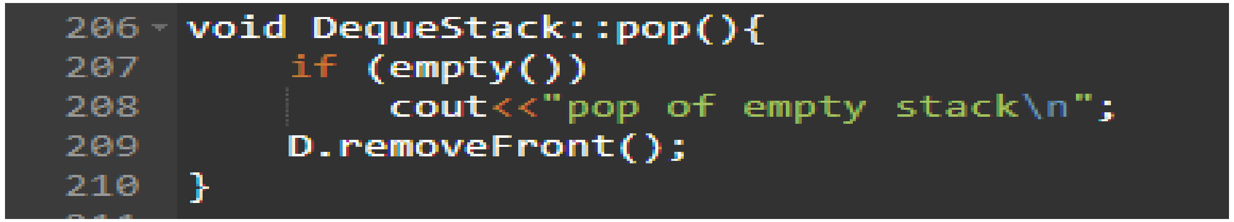
Deque	Stack	Queue
insertFront()	-	-
insertBack()	Push()	Enqueue()
removeFront()	-	Dequeue()
removeBack()	Pop()	-
Size()	Size()	Size()
Empty()	Empty()	Empty()

```
typedef string Elem;
DequeStack {// stack as deq
  public:
       DequeStack();
       int size() const;
       bool empty() const;
       const Elem& top();
       void push(const Elem& e);
       void pop();
  private:
       LinkedDeque D;
};
```

```
// A queue using a deque:
template<typename E>
void Queue<E>::enqueue(E elem)
{
    dq.insertBack(elem);
}
template<typename E>
void Queue<E>::dequeue() {
  if(dq.empty())
     throw “Queue Underflows!”;
  dq.removeFront();
}
```



```
void DequeStack::push(const Elem& e)
{
    D.insertFront(e);
}
```



```
void DequeStack::pop(){
    if (empty())
        cout<<"pop of empty stack\n";
    D.removeFront();
}
```

THANK YOU!

Next Class: Vectors, Amortization, and Iterators …