Programming Abstractions

CS106B

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Today's Topics

Abstract Data Types

- Last time: What is an ADT? And two ADTs: Vector, Grid
- This time: More ADTs!
  - Stack
  - Queue
  - Application of Stack

- Announcements:
  - Sections are starting this afternoon!
    - Check your assigned section or do late registration at **cs198.stanford.edu**
  - Assignment 1 due Friday

Stacks

OUR NEXT ORDERED ADT
IT USES “LIFO” ORDER
(LAST-IN, FIRST-OUT)

New ADT: Stack

```
#include "stack.h"

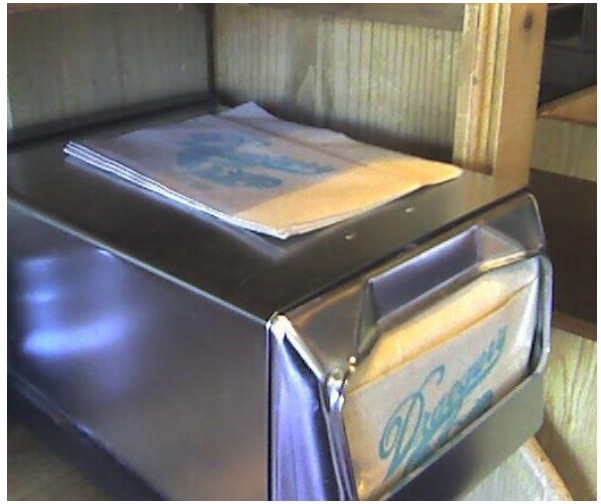
Stack<string> recentCalls;
recentCalls.push("Neel");

recentCalls.push("Julie");

recentCalls.push("Esteban");

recentCalls.push("Minh");

while (!recentCalls.isEmpty()) {
    cout << recentCalls.pop() << " ";
}
```



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New ADT: Stack

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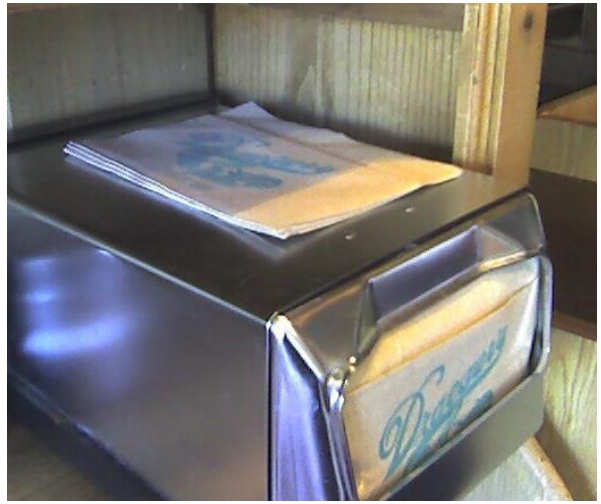

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while (!recentCalls.isEmpty())
    cout << recentCalls.pop() <
}
```

**"Why do I need Stack??
I could have done that with a Vector!"
—ADT skeptic**

Stack and Vector, side-by-side

0	1	2	3
Neel	Julie	Esteban	Minh

```
Stack<string> recentCalls;
recentCalls.push("Neel");
recentCalls.push("Julie");
recentCalls.push("Esteban");
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while (!recentCalls.isEmpty()) {
    cout << recentCalls.pop() << " ";
}
```

```
Vector<string> recentCalls;
recentCalls.add("Neel");
recentCalls.add("Julie");
recentCalls.add("Esteban");
recentCalls.add("Minh");

while (!recentCalls.isEmpty()) {
    string last = recentCalls[recentCalls.size() - 1];
    cout << last << " ";
    recentCalls.remove(recentCalls.size() - 1);
}
```

Stack and Vector, side-by-side

0	1	2	3
Neel	Julie	Esteban	Minh

```
Stack<string> recentCalls;
recentCalls.push("Neel");
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while (!recentCalls.isEmpty()) {
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}
```

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while (!recentCalls.isEmpty()) {
    string last = recentCalls[recentCalls.size() - 1];
    cout << last << " ";
    recentCalls.remove(recentCalls.size() - 1);
```

This Vector code isn't terrible, but it is harder to read quickly, and is probably more error prone.

- You need to think carefully about which end of the Vector to use as the top of the stack (0th or `size()-1`th), and performance impacts
- It would be easy to forget the "`-1`" when you print/remove `size()-1`th

Queues

FIFO – FIRST IN, FIRST OUT
(OR "FIRST COME, FIRST SERVE")

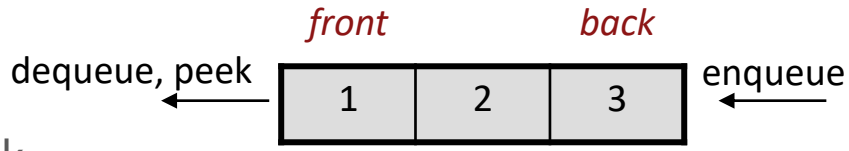
Queues

queue: First-In, First-Out ("FIFO")

- Elements stored in order they were added
- Can add only to the back,
  can only examine/remove frontmost element

queue operations

- enqueue: Add an element to the back
- dequeue: Remove the front element
- peek: Examine the front element



The Queue class

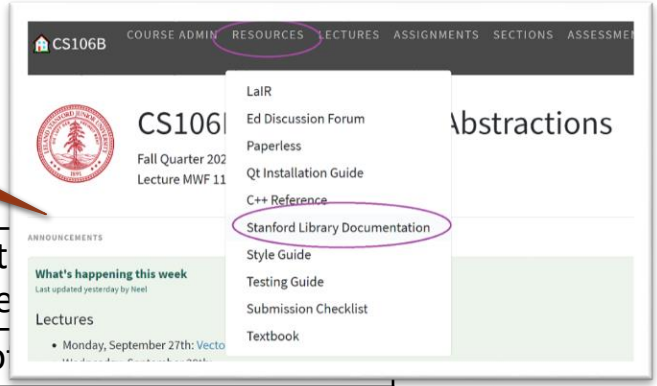
```
#include "queue.h"
```

q.**dequeue**()	removes **front** value and returns it; throws an error if queue is empty
q.**enqueue**(*value*)	places given value at **back** of queue
q.**isEmpty**()	returns `true` if queue has no elements
q.**peek**()	returns **front** value without removing; throws an error if queue is empty
q.**size**()	returns number of elements in queue

```
Queue<int> q;                    // {}   front -> back
q.enqueue(42);                   // {42}
q.enqueue(-3);                   // {42, -3}
q.enqueue(17);                   // {42, -3, 17}
cout << q.dequeue() << endl;     // 42   (q is {-3, 17})
cout << q.peek() << endl;        // -3   (q is {-3, 17})
cout << q.dequeue() << endl;     // -3   (q is {17})
```

The Queue class

As usual, for more information check course website!

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cout << q.peek() << endl;        // -3    (q is {-3, 17})
cout << q.dequeue() << endl;     // -3    (q is {17})
```

Application of Stacks

WE'VE SEEN ONE (BUFFERING INPUT NAMES AND GIVING THEM BACK IN REVERSE). WHAT ELSE ARE STACKS GOOD FOR?

Operator Precedence and Syntax Trees

Go to pollev.com/cs106b to respond!

Ignoring operator precedence rules, what are all the distinct results for the following arithmetic expression?

- 3 * 3 + 3 * 3

Reverse Polish Notation

Ambiguities don't exist in RPN

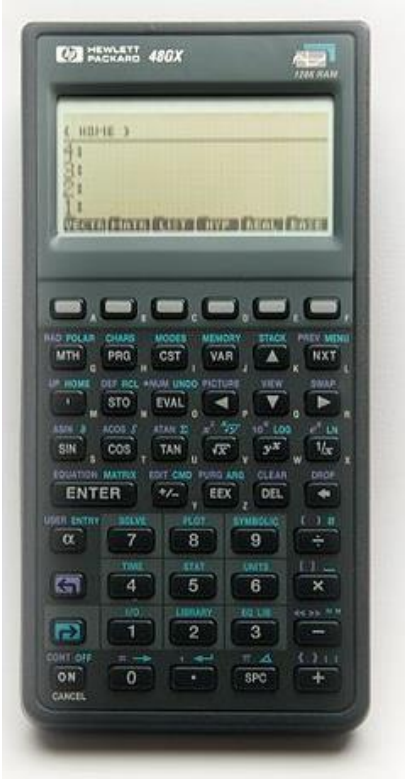
Also called "postfix" because the operator goes after the operands

Postfix (RPN):

- 4 3 * 4 3 * +

Equivalent Infix:

- (4*3) + (4*3)



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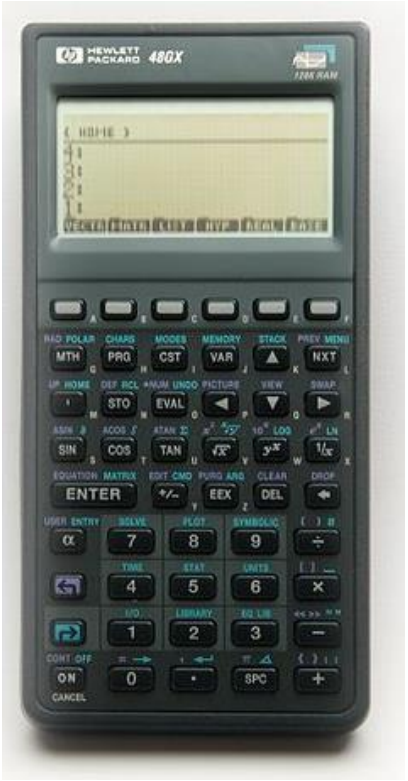
Reverse Polish Notation

#TBT: Me in 1991, I was 12 years old



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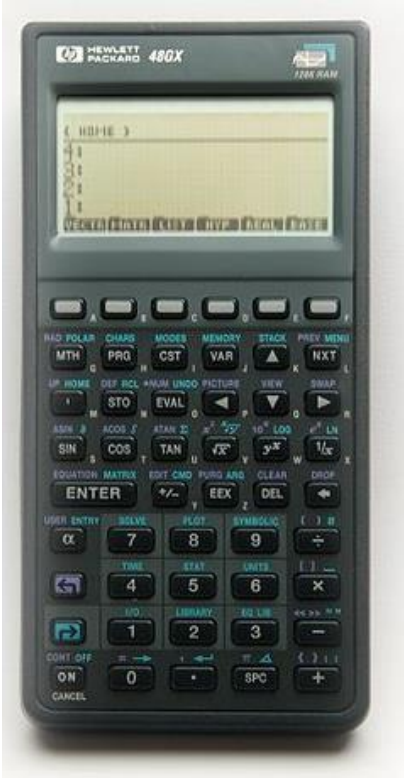
Reverse Polish Notation

This postfix expression:

- 4 3 * 7 2 5 * + +

Is equivalent to this infix expression:

A. ((4*3) + (7*2)) + 5
B. (4*3) + ((7+2) + 5)
C. (4*3) + (7 + (2*5))
D. Other/none/more than one



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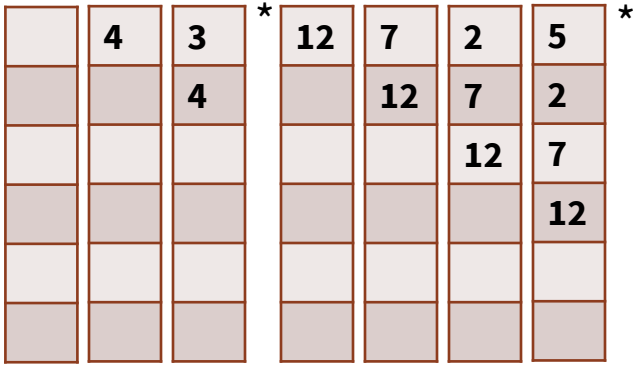
Stacks and RPN

- Evaluate this expression with the help of a stack
  - Encounter a **number**? **PUSH** it
  - Encounter an **operator**? **POP** two numbers and **PUSH** result
- 4 3 * 7 2 5 * + +



Stacks and RPN

- Evaluate this expression with the help of a stack
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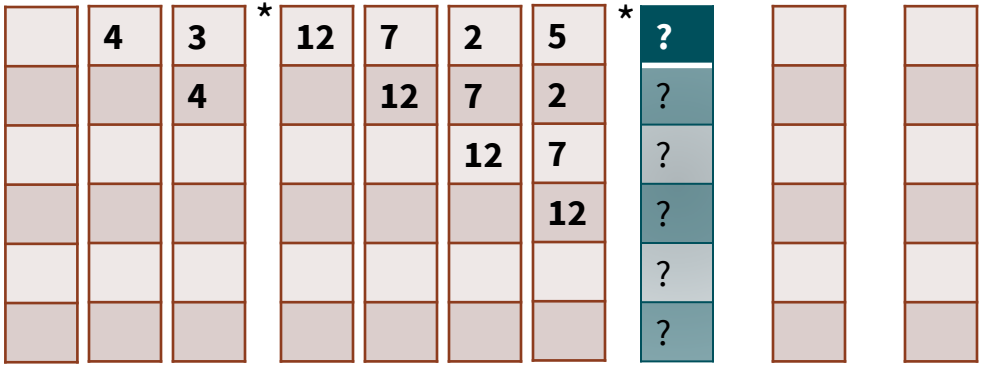


Contents of the stack, reading from top down:

(A) 7, 12

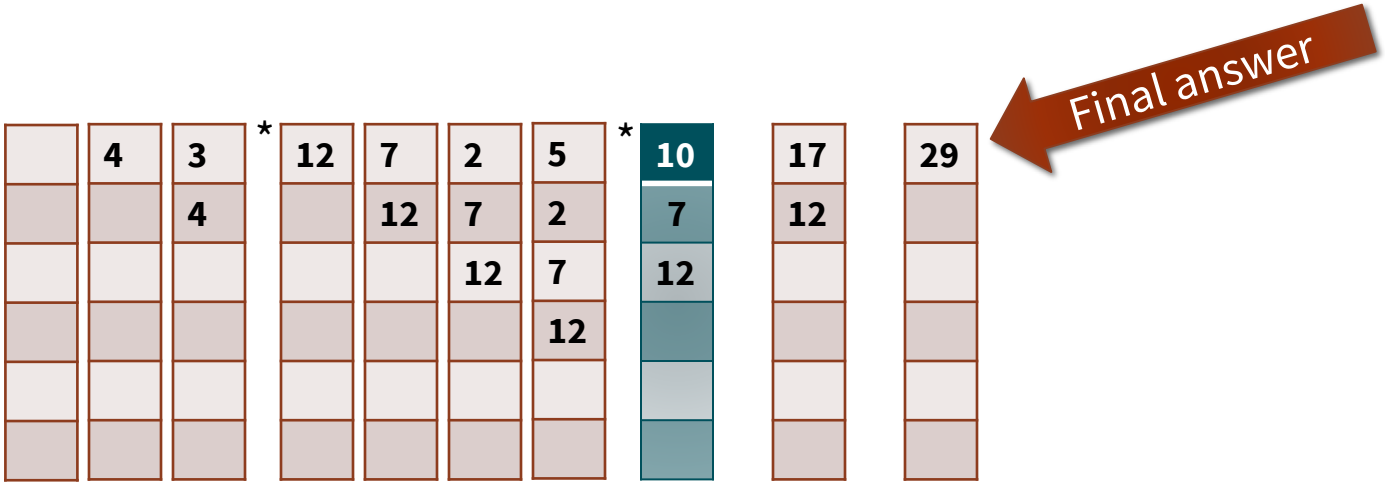
(B) 10, 7, 12

(C) 10, 5, 2, 7, 12

(D) Other

Stacks and RPN

- Evaluate this expression with the help of a stack
  - Encounter a **number**? **PUSH** it
  - Encounter an **operator**? **POP** two numbers and **PUSH** result
- 4 3 * 7 2 5 * + +



- **Question:** what are some signs that an expression is badly formatted?

Final code of parser

```
bool calculate(string expression, int& result)
{
    Stack<int> memory;
    // Examine each character of input, left to right
    for (char c : expression) {
        // if digit, store it
        if (isdigit(c)) {
            int value = charToInteger(c);
            memory.push(value);
        // if operator, perform operation
        } else if (isSupportedOperator(c) && memory.size() >= 2) {
            int rhs = memory.pop();
            int lhs = memory.pop();
            memory.push(applyOperator(lhs, c, rhs));
        // otherwise parse error
        } else {
            return false;
        }
    }
    // should be single number in memory, that's our answer
    if (memory.size() != 1) {
        return false;
    }
    result = memory.pop();

    return true;
}
```