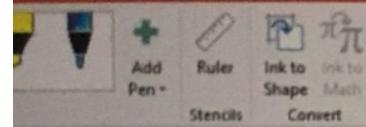


5. Draw the binary tree representation of the following arithmetic expression:

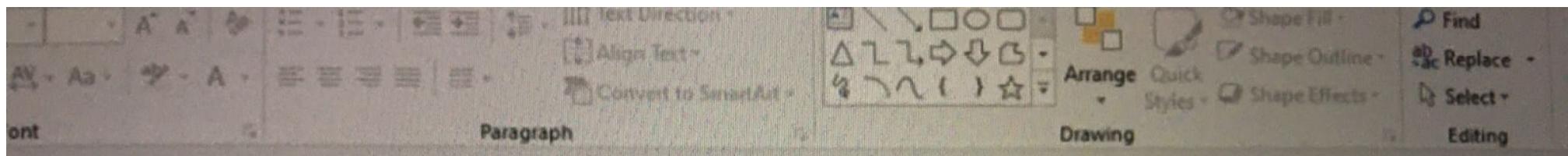
$$(((5+2) * (2-1)) / ((2+9)+(7-2)-1)) * 8$$



12. Draw the BST that results when you insert the keys E A S Y Q U E S T I O N, in that order (associating the value i with the ith key, as per the convention in the text) into an initially empty tree. How many compares are needed to build the tree?

E



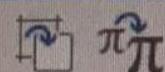


1. Draw a binary tree T that simultaneously satisfies the following:
  - Each internal node of T stores a single character.
  - A preorder traversal of T yields EXAMFUN.
  - An inorder traversal of T yields MAFXUEN.



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## COMPUTER ENGINEERING DATA STRUCTURES MIDTERM

Name/Surname: \_\_\_\_\_

Student Number: \_\_\_\_\_

**Problem 7 (15 points)** Suppose that the Java library java.util.LinkedList is implemented using a doubly-linked list, maintaining a reference to the first and last node in the list, along with its size.

```
public class LinkedList {
    private Node first;
    // the first node in the linked list
    private Node last;
    // the last node in the linked list
    private int N;
    // number of items in the linked list
    private class Node {
        private Item item;
        // the item
        private Node next, prev;
        // the next and previous nodes
    }
}
```

Using the 64-bit memory cost model (int and pointers use 64 bit memory space), how much memory (in bytes) does a Node object use and how much does a LinkedList object use to store  $N$  items? Do not include the memory for the items themselves but do include the memory for the references to them.

- Memory of a Node:

- Memory of a LinkedList with  $N$  items:

- (a) What is the order of growth of the worst-case running time of each of operation below? Write down the best answer in the space provided, using one of the following possibilities.

1       $\log N$        $\sqrt{N}$       N       $N \log N$        $N^2$

<u>addFirst(item)</u>	prepend the item to the beginning of the list	
<u>get(i)</u>	return the item at position $i$ in the list	
<u>set(i, item)</u>	replace position $i$ in the list with the item	

2) Given a H-Heap storing  $15[1 \dots 15]$   
array-based representation of complete binary tree

- a) Find preorder traversal of H
- b) Find inorder traversal of H
- c) Find postorder traversal of H

10. We can define a binary tree representation  $T'$  for an ordered general tree  $T$  as follows (see Figure 8.21):

- For each position  $p$  of  $T$ , there is an associated position  $p'$  of  $T'$ .
- If  $p$  is a leaf of  $T$ , then  $p'$  in  $T'$  does not have a left child; otherwise the left child of  $p'$  is  $q'$ , where  $q$  is the first child of  $p$  in  $T$ .
- If  $p$  has a sibling  $q$  ordered immediately after it in  $T$ , then  $q'$  is the right child of  $p'$  in  $T'$ ; otherwise  $p'$  does not have a right child.

Given such a representation  $T'$  of a general ordered tree  $T$ , answer each of the following questions:

- Is a preorder traversal of  $T'$  equivalent to a preorder traversal of  $T$ ?
- Is a postorder traversal of  $T'$  equivalent to a postorder traversal of  $T$ ?
- Is an inorder traversal of  $T'$  equivalent to one of the standard traversals of  $T$ ? If so, which one?

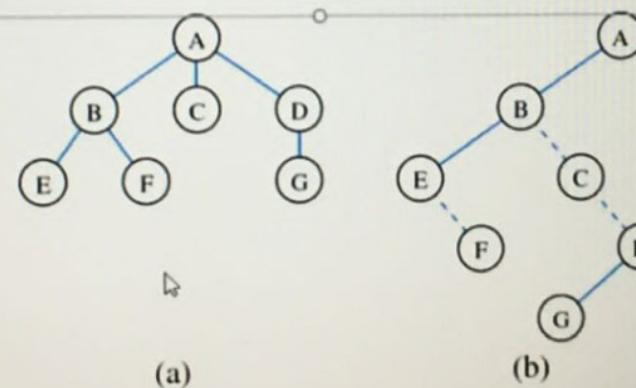
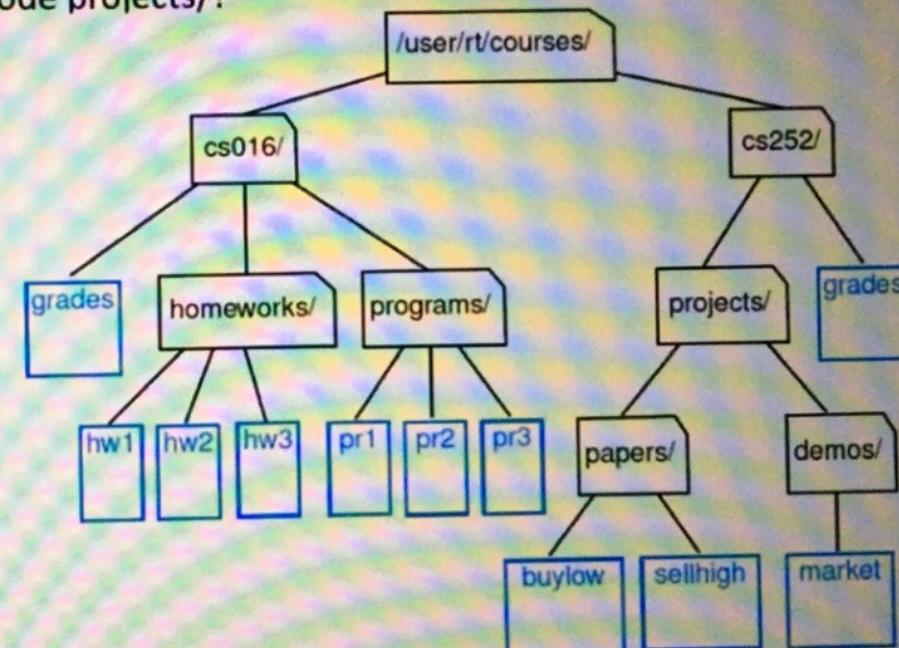


Figure 8.21: Representation of a tree with a binary tree: (a) tree  $T$ ; (b) binary tree  $T'$  for  $T$ . The dashed edges connect nodes of  $T'$  that are siblings in  $T$ .

2. The following questions refer to the tree of Figure 8.3.

- a. Which node is the root?
- b. What are the internal nodes?
- c. How many descendants does node cs016/ have?
- d. How many ancestors does node cs016/ have?
- e. What are the siblings of node homeworks/?
- f. Which nodes are in the subtree rooted at node projects/?
- g. What is the depth of node papers/?
- h. What is the height of the tree?





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## COMPUTER ENGINEERING DATA STRUCTURES MIDTERM

Name/Surname: \_\_\_\_\_

Student Number: \_\_\_\_\_

**Problem 4 (15 points)** For the expression  $1 - 6 * 2 + 7 = (12 - (4 * 3)) + 8$  trace the following algorithm and show the content of stacks after any push and pop operation. Keep in mind operator  $\leq$  has lower precedence than  $+/-$  and  $*$  has precedence over  $+/-$ .

Two stacks:

- opStk holds operators
- valStk holds values
- Use \$ as special "end of input" token with lowest precedence

Algorithm doOp():

```
x ← valStk.pop();
y ← valStk.pop();
op ← opStk.pop();
valStk.push( y op x )
```

Algorithm repeatOps( refOp ):

```
while ( valStk.size() > 1 ∧
       prec(refOp) ≤
       prec(opStk.top()))
doOp()
```

Algorithm EvalExp()

Input: a stream of tokens representing an arithmetic expression (with numbers)  
 Output: the value of the expression

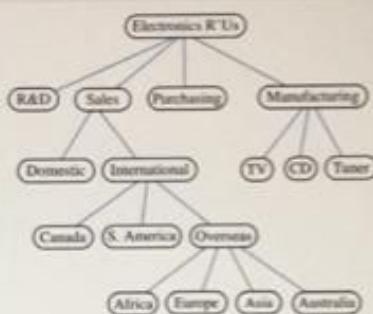
while there's another token z

```
if isNumber(z) then
    valStk.push(z)
else
    repeatOps(z);
    opStk.push(z)
repeatOps(S);
return valStk.top()
```

7

The figure shows the Electronics R'Us Tree.

What is the depth of the tree?  
(7 Points)



4

8

Draw a binary tree T that simultaneously satisfies the following:

- Each internal node of T stores a single character.
- A preorder traversal of T yields QWRFMFUN.
- An inorder traversal of T yields MRFWUQN.

Write your answer to a paper and send a picture of it as a jpeg file. (Non-anonymous question)

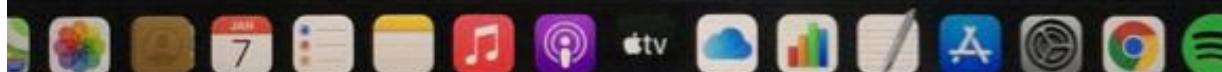
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(30 Points)

8.JPG

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\$ % ^ & \* ( ) -  
4 5 6 7 8 9 0

search

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1

Using the Electronics R'Us tree answer the question: How many ancestors does node Australia have? \*

(7 Points)

4

2

Using the Electronics R'Us tree answer the question: Which nodes are in the subtree rooted at node S. America? \*

(7 Points)

None of them, S. America does not have any children

3

Draw the binary tree representation of the following arithmetic expression:

$((5+2) \cdot (2-1))/((2+9) + ((7-2)-1)) \cdot 8$

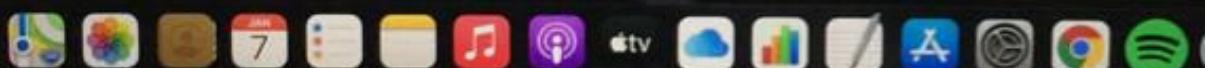
Write your answer to a paper and send a picture of it as a jpeg file. (Non-anonymous question)

\*

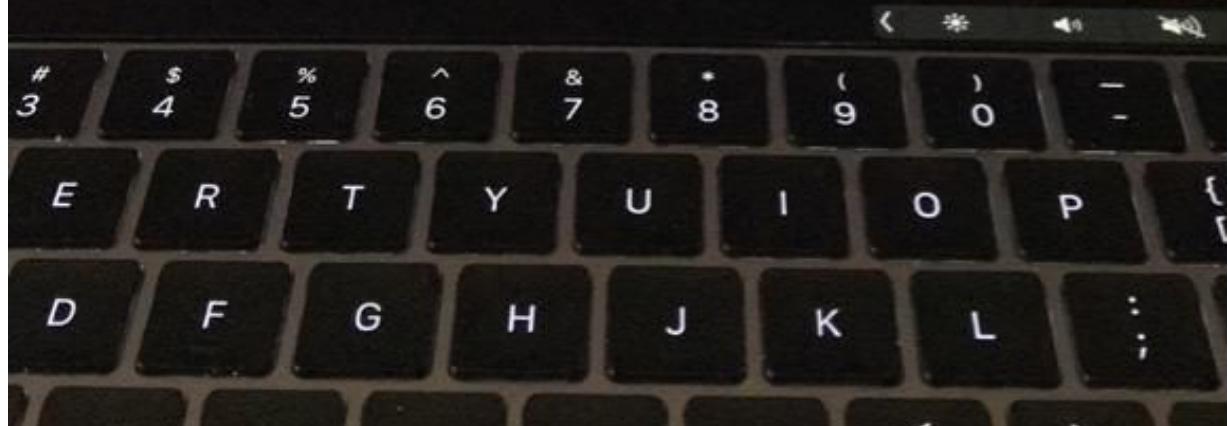
(30 Points)

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## COMPUTER ENGINEERING DATA STRUCTURES MIDTERM

Name/Surname: \_\_\_\_\_

Student Number: \_\_\_\_\_

**Problem 4 (15 points)** For the expression  $1 - 6 * 2 + 7 = (12 - (4 * 3)) + 8$  trace the following algorithm and show the content of stacks after any push and pop operation. Keep in mind operator  $\leq$  has lower precedence than  $+/-$  and  $*$  has precedence over  $+/-$ .

Two stacks:

- opStk holds operators
- valStk holds values
- Use \$ as special "end of input" token with lowest precedence

Algorithm doOp():

```
x ← valStk.pop();
y ← valStk.pop();
op ← opStk.pop();
valStk.push(y op x);
```

Algorithm repeatOps( refOp ):

```
while ( valStk.size() > 1 ∧
        prec(refOp) ≤
        prec(opStk.top()))
    doOp()
```

Algorithm EvalExp()

Input: a stream of tokens representing an arithmetic expression (with numbers)  
Output: the value of the expression

while there's another token z

```
if isNumber(z) then
    valStk.push(z)
else
    repeatOps(z);
    opStk.push(z)
repeatOps($);
return valStk.top()
```

words



English (United States)

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HW4...



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BURAK ERÇIKTI

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Request control



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**Problem 3** (15 points) Implement a program that takes a sequence of words and checks if there are any two of the same words come next to each other and then eliminates them. The program continues to check and eliminate remaining sequences until there is no double left. At the end of the program it should print the number of remaining words.

**Hint:** The program is easier to be implemented using stacks

**Note:** You are allowed to use "java.util.Stack", or any other data structure you find suitable.

Array will not be easy as your length stays constant.

**Example 1:**

**Input:** data structure structure

data hw lab

**Output:** 2

Step 1: data structure structure

data hw lab

Step 2: data-data hw lab

2

**Example 2:**

**Input:** stack queue queue stack

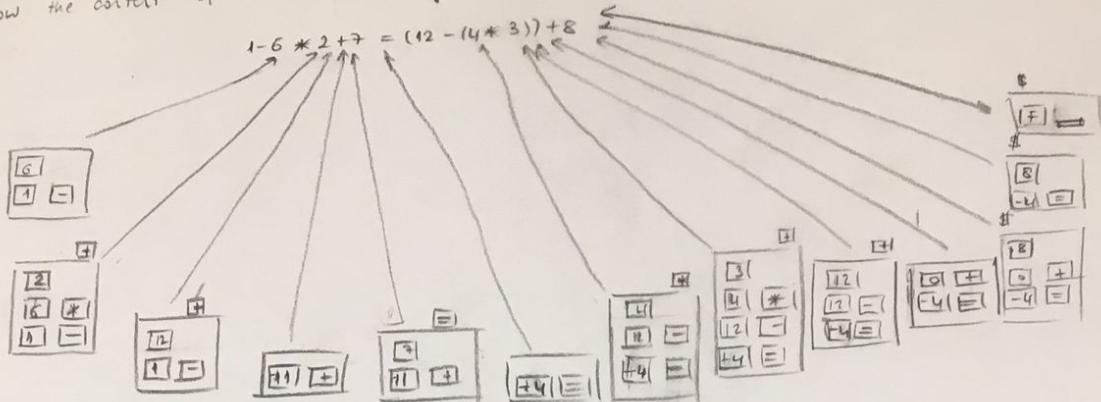
**Output:** 0

Step 1: stack queue queue stack

Step 2: stack stack

0

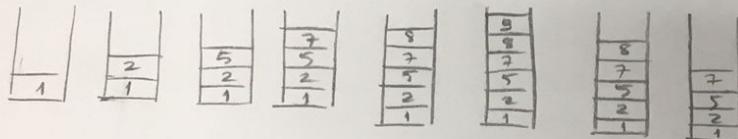
Problem 4 For the expression  $i-6 * 2 + 7 = (12 - (4 * 3)) + 8$  trace the following algorithm and show the content of stacks after any push and pop operation.



Problem 1 Show the results of the following sequence of events, by drawing state of the data structure: add(1), add(2), add(5), add(7), add(8), add(9), remove(), remove()

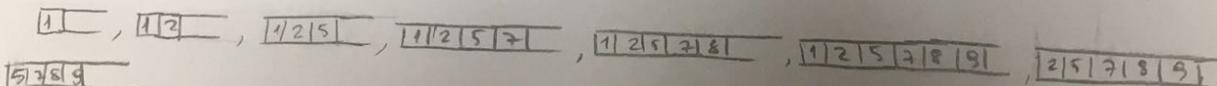
a) Stack

$\{1, \{1, 2\}, \{1, 2, 5\}, \{1, 2, 5, 7\}, \{1, 2, 5, 7, 8\}, \{1, 2, 5, 7, 8, 9\}, \{1, 2, 5, 7, 8\}, \{1, 2, 5, 7\}$



b) Queue

$\{1, 3, \{1, 2\}, \{1, 2, 5\}, \{1, 2, 5, 7\}, \{1, 2, 5, 7, 8\}, \{1, 2, 5, 7, 8, 9\}, \{2, 5, 7, 8, 9\}, \{5, 7, 8, 9\}$



Problem 8 Write a function, shuffle(A), that rearranges the elements of array A randomly.

```
public void shuffle(int[] A) {
    Random rand = new Random();
    for (int i = A.length(); i > 0; i--) {
        int r = rand.nextInt(i+1);
        int temp = A[i];
        A[i] = A[r];
        A[r] = temp;
    }
}
```

# Algorithm for Evaluating Expressions

Two stacks:

- opStk holds operators
- valStk holds values
- Use \$ as special “end of input” token with lowest precedence

Algorithm doOp()

```
x ← valStk.pop();
y ← valStk.pop();
op ← opStk.pop();
valStk.push( y op x )
```

Algorithm repeatOps( refOp ):

```
while ( valStk.size() > 1 ∧
        prec(refOp) ≤
        prec(opStk.top()))
    doOp()
```

Algorithm EvalExp()

Input: a stream of tokens representing an arithmetic expression (with numbers)

Output: the value of the expression

while there's another token z

```
if isNumber(z) then
    valStk.push(z)
else
    repeatOps(z);
    opStk.push(z)
repeatOps($);
return valStk.top()
```

## COMPUTER ENGINEERING DATA STRUCTURES MIDTERM

Name/Surname: \_\_\_\_\_

Student Number: \_\_\_\_\_

**Problem 4** (15 points) For the expression  $1 - 6 * 2 + 7 = (12 - (4 * 3)) + 8$  trace the following algorithm and show the content of stacks after any push and pop operation. Keep in mind operator  $\leq$  has lower precedence than  $+/-$  and  $*$  has precedence over  $+/-$ .

Two stacks:

- opStk holds operators
  - valStk holds values
  - Use \$ as special "end of Input" token with lowest precedence
- Algorithm doOp()
- ```
x <- valStk.pop();
y <- valStk.pop();
op <- opStk.pop();
valStk.push(y op x)
```
- Algorithm repeatOp[ refOp ]:
- ```
while ( valStk.size() ) > 1 &
      prec[refOp] <
      prec[opStk.top()]
doOp()
```

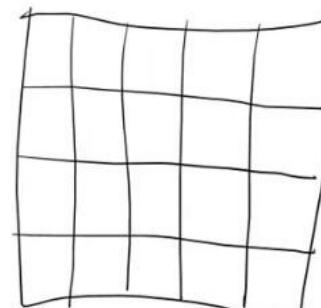
Algorithm EvalExp()

```
Input: a stream of tokens representing an arithmetic expression (with numbers)
Output: the value of the expression
```

while there's another token z

```
if IsNumber(z) then
    valStk.push(z)
else
    repeatOp(z);
    opStk.push(z)
```

**Problem 5** (15 points) Write a recursive algorithm to compute the sum of all elements in an  $n \times n$  (two-dimensional) array of integers. What is your running time and space usage?



fnd LA

**Problem 6** (15 points) Draw a binary tree T that simultaneously satisfies the following:

- Each internal node of T stores a single character.
- An preorder traversal of T yields EXAMFUN.
- An inorder traversal of T yields MAFXUEN.

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## COMPUTER ENGINEERING DATA STRUCTURES MIDTERM

Name/Surname: \_\_\_\_\_

Student Number: \_\_\_\_\_

**Problem 1** (10 points) Show the results of the following sequence of events, by drawing the state of the data structure: add(1) add(2) add(5) add(7) add(8), add(9), remove(), remove(). Where add and remove are the operations that correspond to the basic operations in a:

- a) Stack
- b) Queue

**Problem 2** (15 points) for the input values inserted in the following order 35 33 42 10 14 19 27 44 26 31 construct a heap.

**Problem 3** (15 points) Implement a program that takes a sequence of words and checks if there are any two of the same words come next to each other and then eliminates them. The program continues to check and eliminate remaining sequences until there is no double left. At the end of the program it should print the number of remaining words.

**Hint:** The program is easier to be implemented using stacks

Note: You are allowed to use "[java.util.Stack](#)", or any other data structure you find suitable. Array will not be easy as your length stays constant.

**Example 1:**  
**Input:** data structure structure  
data hw lab  
**Output:** 2  
**Step 1:** data structure structure  
data hw lab  
**Step 2:** data-data hw lab  
2

**Example 2:**  
**Input:** stack queue queue stack  
**Output:** 0  
**Step 1:** stack queue-queue-stack  
**Step 2:** stack-stack  
0

Page 1 of 6 607 words English (United States)

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**Problem 5 (15 points)** Write a recursive algorithm to compute the sum of all elements in an  $n \times n$  (two-dimensional) array of integers. What is your running time and space usage?

**Problem 6 (15 points)** Draw a binary tree T that simultaneously satisfies the following:

- Each internal node of T stores a single character.
- A preorder traversal of T yields EXAMFUN.
- An inorder traversal of T yields MAFXUEN.

4

Using the Electronics R'Us tree answer the question: How many descendants does node Sales have? \*

(7 Points)

9

5

Using the Electronics R'Us tree answer the question: What are the siblings of node Domestic? \*

(5 Points)

International

6

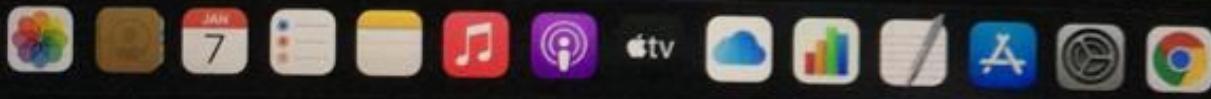
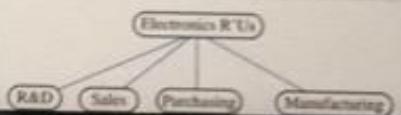
Using the Electronics R'Us tree answer the question: What are the internal nodes for the subtree rooted at node Sales? \*

(7 Points)

International, Overseas

7

The figure shows the Electronics R'Us Tree.



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- 1)
1. Draw the 11-entry hash table that results from using the hash function,  $h(i) = (3i + 5) \bmod 10$ , to hash the keys 12, 44, 83, 88, 23, 14, 1, 39, 20, 16, and 5, assuming collisions are handled by linear probing. (Non-anonymous question①)  
(30 Points)

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2. If we insert the entries (4, A), (10, B), (7, C), (5, D), and (12, E), in this order, into an initially empty binary search tree, what will it look like? (Non-anonymous question①)  
(15 Points)

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3. Consider the sequence of keys (5,16,22,45,2,40,18,30,3,12,1). Draw the result of inserting entries with these keys (in the given order) into an initially empty (2,4) tree.  
(Non-anonymous question①)  
(25 Points)

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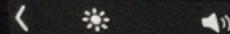
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4. Consider the sequence of keys (5,16,22,45,2,40,18,30,3,12,1). Draw the result of inserting entries with these keys (in the given order) into an initially empty red-black tree.  
(Non-anonymous question①)  
(30 Points)

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## COMPUTER ENGINEERING DATA STRUCTURES MIDTERM

Name/Surname: \_\_\_\_\_

Student Number: \_\_\_\_\_

**Problem 1** (10 points) Show the results of the following sequence of events, by drawing the state of the data structure: **add(1) add(2) add(5) add(7) add(8), add(9), remove(), remove()**  
Where add and remove are the operations that correspond to the basic operations in a:

- a) Stack
- b) Queue

**Problem 2** (15 points) for the input values inserted in the following order 35 33 42 10 14 19 27 44 26 31 construct a heap.

7 words English (United States)

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MS İLYAS ZAFER BARIŞ MURAT EŞ BURAK ERÇIKTI RECEP

c) Find patterns

- 4) Draw a representation of an initial empty list after performing the following sequence of operations  
add(0, 4), add(0, 3), add(0, 2), add(2, 1), add(1, 5), add(1, 6)  
add(3, 7), add(0, 8)

- 7) Starting with an empty 2-4 tree insert back of the given letters, into the tree in the order given, show your work and clearly indicate the final value of the 2-4 tree after all insertions.

6, 12, 1, 13, 5, 19, 8, 18, 15, 20, 9, 14, 7

6. In what order are positions visited during a preorder traversal of the tree of Figure 8.6?

7. In what order are positions visited during a postorder traversal of the tree of Figure 8.6?

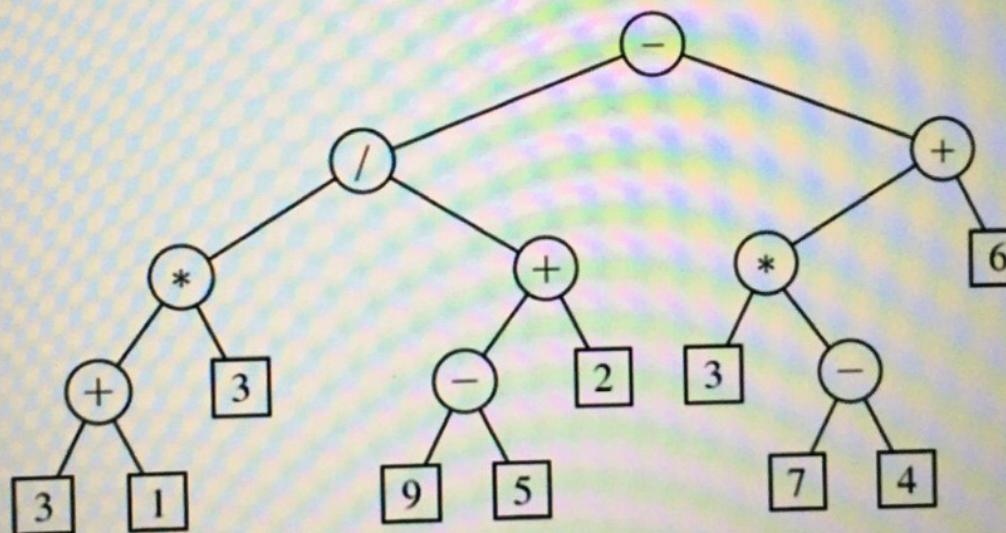


Figure 8.6: A binary tree representing an arithmetic expression. This tree represents the expression  $(((3+1)*3)/((9-5)+2)) - ((3*(7-4))+6)$ . The value associated with the internal node labeled “/” is 2.

1) (20 p) Using the given sequence of inputs build an AVL tree, then remove the nodes in the given order from the tree.

Input Sequence: 23, 64, 28, 12, 89, 15, 3, 98, 74, 82, 56, 17, 42, 36, 48, 24, 25, 51

Nodes to remove: 17, 89, 42, 56, 64

a) Show the tree after all the inputs are inserted.

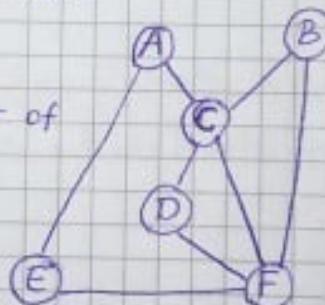
b) Show the tree after all the nodes are removed.

3) (20 p) Write a recursive algorithm that will check if an array A of integers contains an integer  $A[i]$  that is the multiplication of two integers that appear earlier in A, that is, such that  $A[i] = A[j] * A[k]$

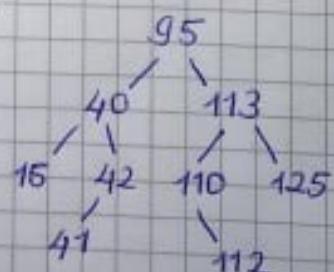
for  $j, k < i$  ?

5) a) (10 p) Show the adjacency matrix representation for the graph.

b) (5 p) What would be the number of zeros in the adjacency matrix of the given graph.



6) (15 p) Given the following Binary Search Tree, show its value after deleting 95.



**Problem 8 - BONUS (15 points)** Write a function, shuffle(A), that rearranges the elements of array A randomly. You may rely on the `nextInt(n)` method of the `java.util.Random` class, which returns a random number between 0 and n-1 inclusive.

```
shuffle(int[] A) {  
    for(int i = 0; i < A.length;i++)  
    {  
        int r = Random.nextInt(A.length);  
        int temp = A[i];  
        A[i] = A[r];  
        A[r] = temp;  
    }  
}
```