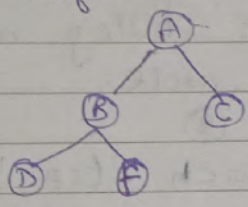
5 = Trees

* A tree is a non-linear D.S that organizes data in a hierarchical str & this is a recursive def.
* It is a set of 1 / more nodes, with 1 node identified as the tree's root and all remaining nodes partitionable into non-empty sets, each of which is a subtree of the root.



(A) → root node.

→ Tree d.s.

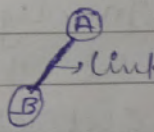
(B) (D) (E) → left subtree

(C) → right subtree.

→ Tree Terminologies =

* Node = It is a unit of data that contains a key / value as well as pointers to its child nodes.

* Edge = connecting link b/w 2 nodes. is → a link.



* Root = Topmost node in a tree. This is where the tree is originated frm.
  eg → (A)
* parent node / ancestor = It is a node that has a branch frm it to another node.
  eg → (B)

* Child node / descendant / successor =
It is a node that is a descendant of another node.
eg → (B) & (C) child node of (A) ...

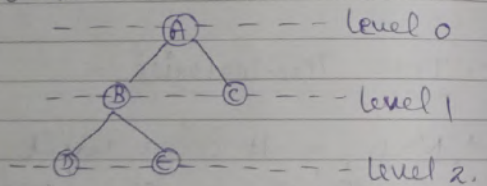
* Sibling nodes = Nodes that have the same parent
eg → (D) & (E).

* Leaf node = node which does not have any child , eg → (D) (E) (C)
(terminal node)

* Internal node = nodes having at least a child node.
eg → (A) (B)

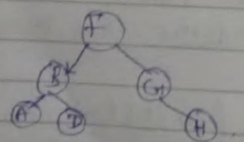
* Level of a tree = Each step from top to bottom in a tree

eg →



* path = a sequence of consecutive edges.
* Branch = a path ending in a leaf node

* In-degree of a node = no. of edges arriving at that node (entering)
* Out degree of a node = no. of children it has

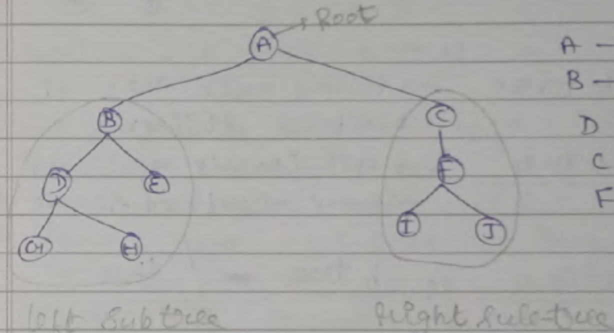


* R. node = F
* leaf node = A, D, H
* Branch. node = B, G
* B is parent of child node A & D.
* A & D → siblings

Indegree → 1 [F → B]
Outdegree → 2. [A & D].

∴ Total degree = 3

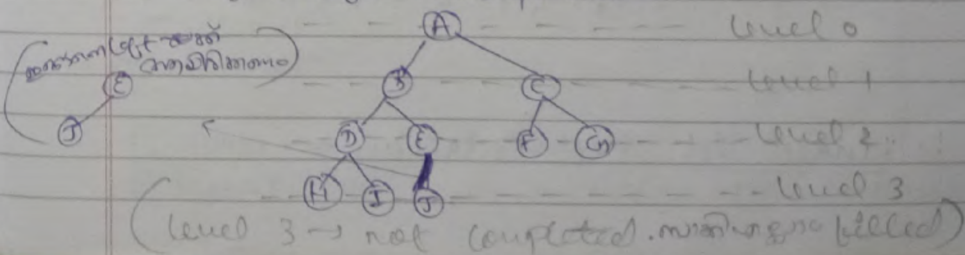
⇒ Binary tree =
* It is a spl tree where each node can have no more than 2 children. (max 2 node)
* A non-empty b.tree consist of —
a) A node → root node
b) A left sub-tree
c) A right sub-tree.



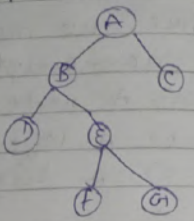
1/2 children
A → B & C
B → D & E
D → G & H
C → F
F → I & J.

→ Types of b.tree =

a) complete b.tree =
* A tree T is said to be complete if all its levels, except possibly the last, must be completely filled & all the leaf nodes must appear as far left as possible.



b) **full b.tree** = It is a sple type of tree in which the leaf nodes will hve 0 children & other non-leaf nodes will hve exactly 2 children.



leaf node → D, F, G, C → 0 children

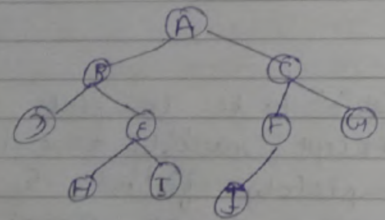
(full nodes) non-leaf node → A → B & C
B → D & E
E → F & G

c) **Rooted b.tree.** → Every node has at most 2 children.

d) **perfect b.tree** → all leaves are at same depth. / same level

→ **Representation of b.tree / tree** =

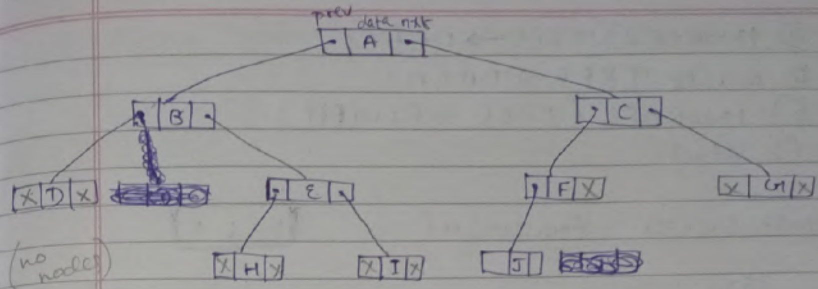
a) **Array representation** =



A → B C
B → D E
C → F G
D → no nodes so 2 blanks — —
E → H I
F → J —
G → — —

(root) A	B	C	D	E	F	G	–	–	H	I	J	–	–	–
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

b) **Linked list representation** =



X → no nodes / childrens

→ **Applications of b.tree** =

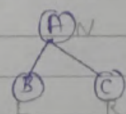
* for rapid & easy access to data.
* Routing algorithms.
* To implement heap d/s.
* Syntx tree, b. search tree, hash trees —

→ **Binary tree traversal** = (using recursion)

can be traversed in 3 different ways :—

1) **In-order traversal** = **LNR**

* Traverse left subtree of R
* process the root R
* Traverse right subtree of R.



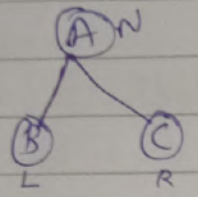
inorder → LNR ⇒ BAC

* (A1) INORDER.

1) start.
2) Repeat steps 2 to 4 while TREE != NULL

3) INORDER (TREE → LEFT). (L)
4) write TREE → DATA. (N)
5) INORDER (TREE → RIGHT) (R)
6) Stop.

② pre-order traversal = N L R

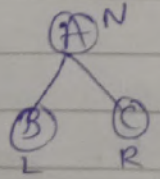


N L R
→ ~~N L R~~ ⇒ A B C

* (A1) PREORDER.

1) Start.
2) Repeat stps 2 to 4 while TREE != NULL
3) write TREE → DATA. (N)
4) PREORDER (TREE → LEFT) (L)
5) PREORDER (TREE → RIGHT) (R)
6) Stop.

③ post-order traversal = L R N



→ L R N ⇒ B C A

* (A1) POSTORDER.

1) Start.
2) Repeat stps ....
3) POSTORDER (TREE → LEFT) (L)
4) POSTORDER (TREE → RIGHT) (R)
5) write TREE → DATA. (N)
6) Stop.

→ Binary tree traversal = (without recursion)

a) pre-order (t) =

1) start with root node & push onto stack
2) Repeat while stack is not empty -
   - pop the top element (PTR) from stack. & process the node.
   - PUSH right child of PTR onto a stack.
   - PUSH left child of PTR onto a stack.

b) In-order (t) =

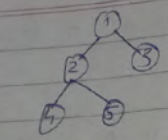
1) start from root, call it PTR.
2) PUSH PTR onto stack if PTR is not null
3) move to left of PTR & repeat stp 2.
4) if PTR is null & stack is not empty then pop element from stack & set as PTR.
5) process PTR & move to right of PTR, go to stp 2.

c) post-order (t) =

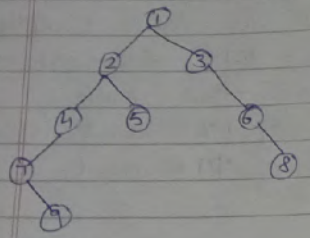
1) push root node to stack one
2) repeat stps while 1st stack is not empty.
   a) pop a node from 1st stack & push it to and stack.
   b) push left & right children of popped node to 1st stack.
3) print contents of 2nd stack.

* inorder =

(LNR)

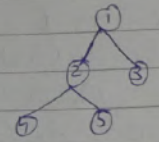


→ 4 → 2 → 5 → 1 → 3



→ 7 → 9 → 4 → 2 → 5 → 1 → 3 → 6 → 8.

* preorder =

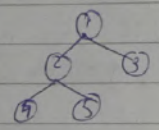


→ 1 → 2 → 4 → 5 → 3

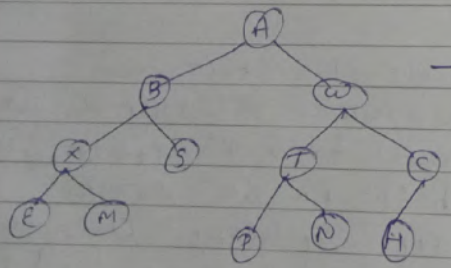
(NLR)

* postorder =

(LRN)



→ 4 → 5 → 2 → 3 → 1.

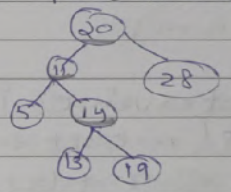


→ E M X S B P N T H C W A.

⇒ Binary Search tree (BST) =

* It is a spl b.tree used for efficient storage of data.
* The nodes in BST are arranged inorder.
* It allows for the simpleing of all of items.
* It is a b.tree where each node can have a max of 2 children.
* It has follow (pro) →
  a) All the elements in left subtree is less than the root node.
  b) All the elements in right subtree is > than root node.

eg →



→ BST

→ operations =

(1) search =

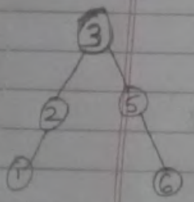
1) if root = NULL
   return null.
2) else
   if root → data = x
   return root.
3) else
   if x < root → DATA.
   return search (ROOT → LEFT, x)
   else.
   return search (ROOT → RIGHT, x)

① insertion =

1) if TREE = NULL
2) Allocate memory for TREE.
3) Set TREE → DATA = VAL
4) Set TREE → LEFT = TREE → RIGHT = NULL
5) else
   if VAL < TREE → DATA.
   insert (TREE LEFT, VAL)
   else
   insert (TREE RIGHT, VAL)

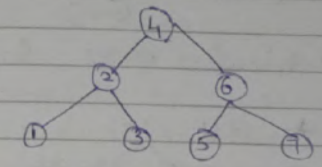
(P.gm)

```
insert(value, root) {
    if (root == NULL) {
        root = new node(value);    3
        return;
    }
    if (root.data > value) {
        if (root.left == NULL) {
            root.left = newnode (value);
            return;
        }
        insert(value, root.left);
    }
    if (root.data < value) {
        if (root.right == NULL) {
            root.right = newnode(value)
            return;
        }
        insert (value, root.right);
    }.
```



5 cases

② Create BST with 4, 2, 3, 6, 5, 7, 1

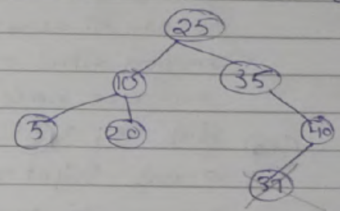


③ Deletion =

3 cases

case1 → dlt leaf node

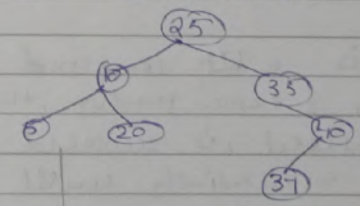
It is the simplest case, here, replace the leaf node with NULL & simple free the allocated space



If we want to dlt 37, jst dlt it.

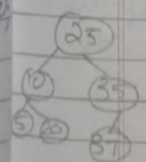
case 2 → dlt a node with 1 child.

* go to parent node of targeted node.
* replace the targeted with node with its child node.

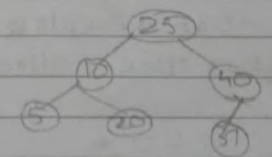


If we want to dlt 35
① parent node of 35 → 25
then dlt 35
② So 25 links to 40.

dlt 40 →



eg - ②

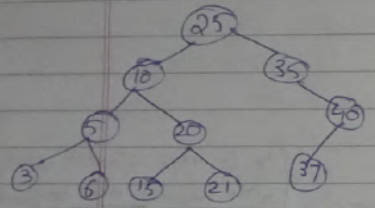


eg - ①

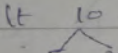
In this case ② replace the node with its child node, which now contains the value which is to be deleted, simply replace it with the NULL & free allocated space.

case 3 = delt a node with 2 child.

2 ways { a) find min in right (or) b) find max in left.



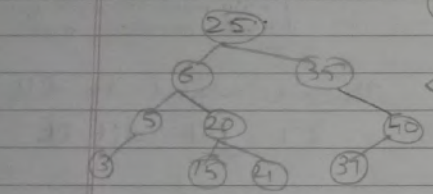
* delt 10.



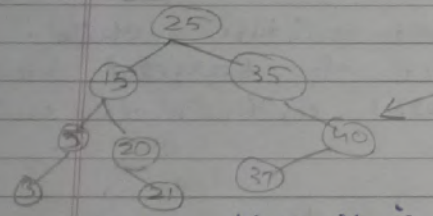
after delting 10, we can set it in 2 ways-

(a) ① 10-ന്റെ left-ലെ nodes ൽ ഏറ്റവും വലുത്, അതിന്റെ താഴെ max value ൽ root node ആക്കുക. (i.e) 5, 3, 6 → root node.

② 10-ന്റെ right-ലെ nodes ൽ ഏറ്റവും ചെറിയ min value-ൽ root node ആക്കാം.



(b)



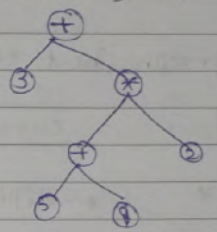
Here, it is a bit complexed case compare to other 2 cases. However, the node which is to be delted, is replaced with its inorders successor recursively until the node value is placed on the leaf of the tree. After that, replace the node with NULL & free the allocated space.

⇒ Application of BST =

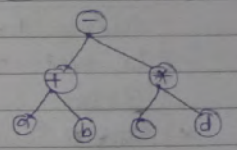
1) Implement various searching algorithms.
2) For dynamic sorting.

⇒ Expression tree =

* It is a spl type of b-tree that is used to store algebraic exp.
* In an exp tree, each internal node corresponds to operator & each leaf node corresponds to the operand.
* ~~A node that holds a non is a leaf node~~
* eg → ① 3 + (5+9) * 2)



② x = (a+b) - (c*d)




```
void insert (int)
struct node {
    int data;
    struct node *left;
    struct node *right;
};
struct node *root;
```