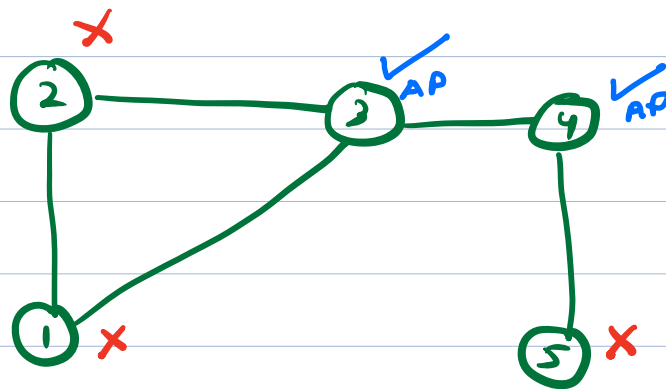


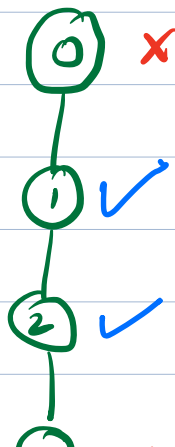
6 oct  
Thursday  
9 PM

## Articulation Points.

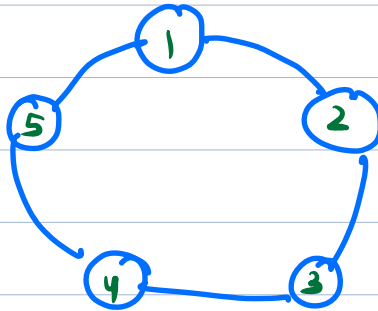
- What is AP
- How to cal APs



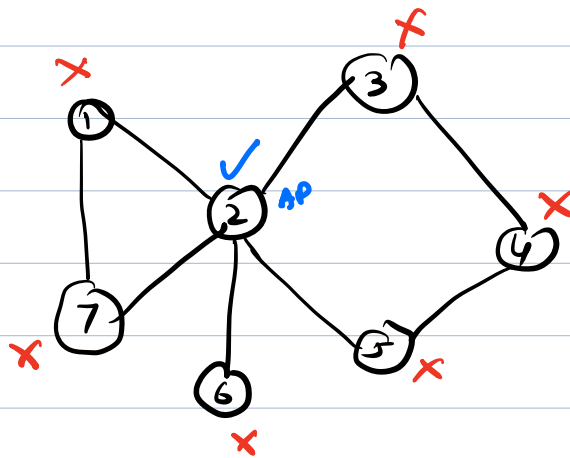
A vertex is an articulation point, if removing that vertex from the graph; will disconnects the graph.



(3) X



No APs



APs: 2

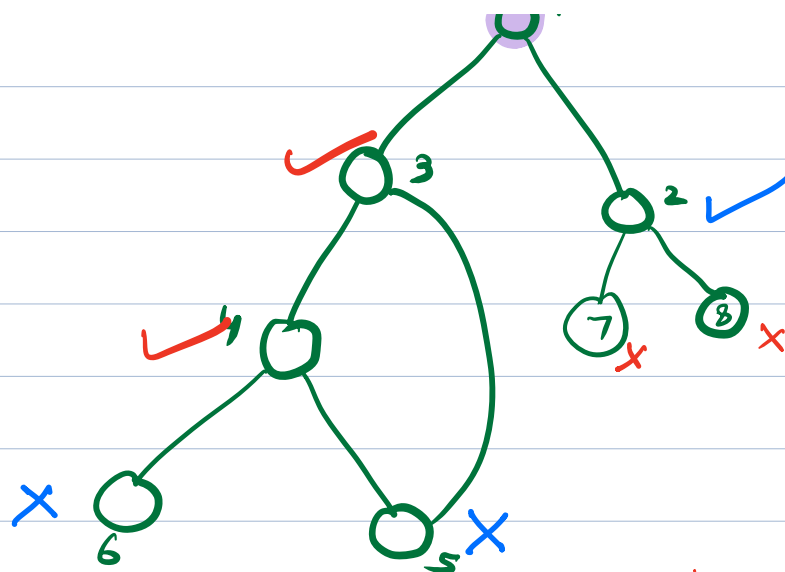
Calculation of APs:

Check every vertex, delete it and see if graph is disconnected.

T.C:  $O(V(V+E))$



1 2 3 4 5 6 7



APs: 1, 3, 7, 2

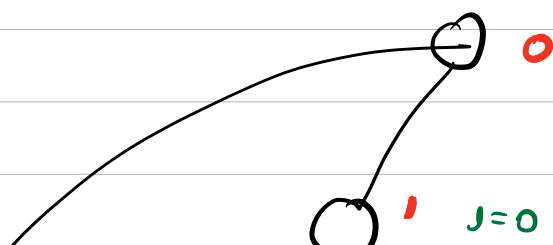
While doing DFS

1.  $u$  is root, it has atleast 2 child

It is AP.

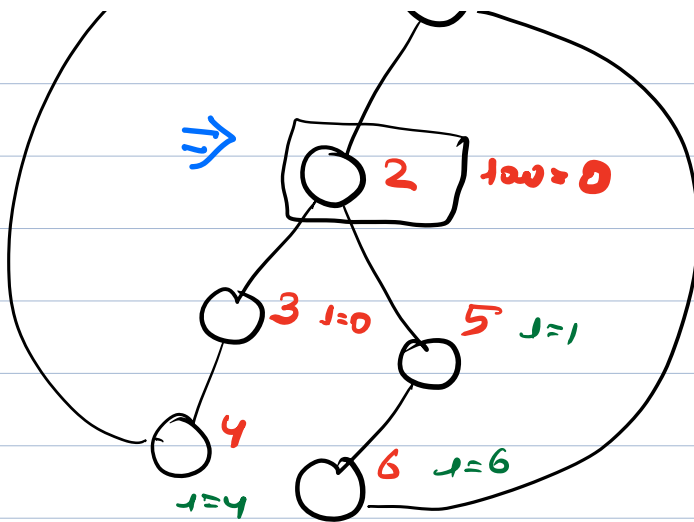
2.  $u$  is not a root, If it has atleast one child such that no vertex in the subtree of that child, have a back edge to one of the ancestor of  $u$

Then  $u$  is a AP.



$t=0$

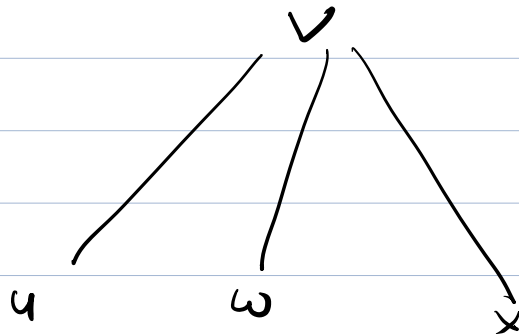
discovery



lowest

0  
1

lowest of a particular vertex



if any of  $u, w, x$

low of  $[u/w/x] \geq \text{disc}[v]$

$v$  is node, for any child  $u$

if  $\text{low}[u] \geq \text{disc}[v]$

Then  $v$  is AP.

$\text{isAP}[n] = \{ \text{true} \}$

Disc ✓  
low ✓

isAP ✓

```
void dfs ( curr, par, time, low[], disc[], vis[] )
```

```
    disc[curr] = low[curr] = time
```

```
    time++
```

```
    vis[curr] = True
```

```
    children = 0
```

```
    for ( auto j : adj[curr] )
```

```
        if ( j != par )
```

```
            if ( vis[j] == False )
```

```
                children++
```

```
                dfs ( j, curr, ... )
```

```
                low[curr] = min ( low[curr], low[j] )
```

```
                if ( parent != -1 &&
```

```
                    low[j] >= disc[curr] )
```

```
                    isAP[curr] = True
```

```
            else
```

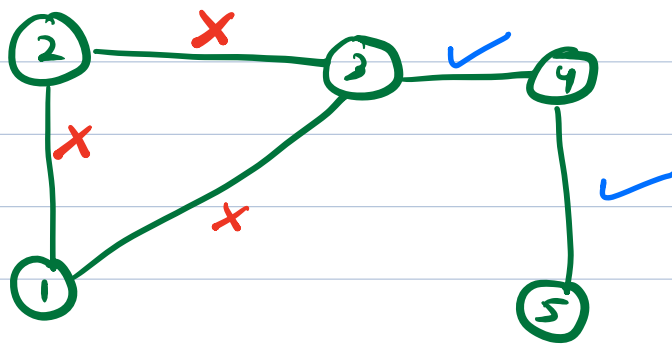
```
                low[curr] = min ( low[curr], low[j] )
```

```
    if ( parent == -1 && children > 1 )
```

is AP[curr] = True.

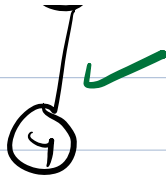
TC:  $O(V + E)$

Bridges.



A edge is an Bridge, if removing that edge from the graph; will disconnects the graph.



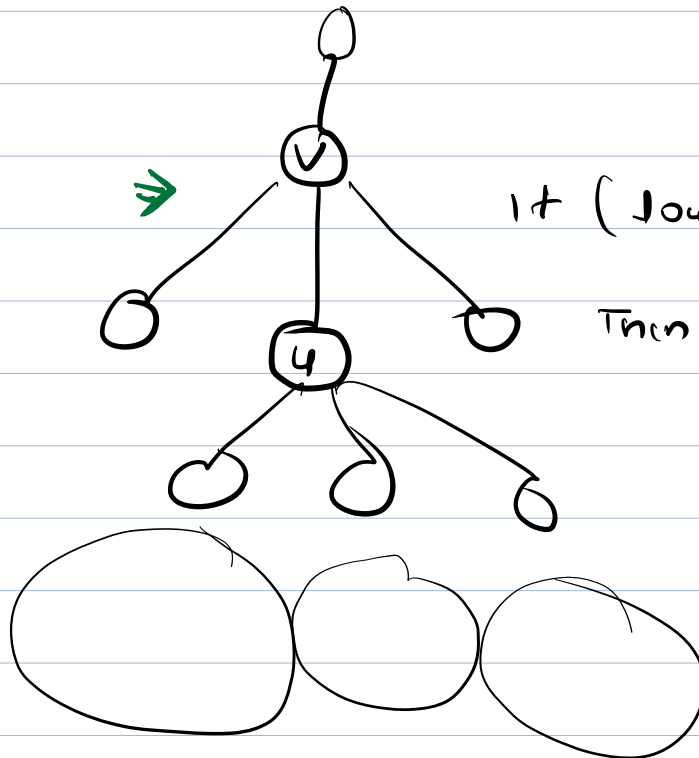


Brute Force :

Consider any edge

- Remove the edge
- check graph is disconnected
- Add the edge.

TC:  $O(E(V+E))$



if  $(low[u] > disc[v])$

Then  $v-u$  is  
bridge.

Disc ✓  
low ✓

Edge ✓

```
void dfs ( curr, par, time, low[], disc[], vis[] )
```

```
    disc[curr] = low[curr] = time
```

```
    time++
```

```
    vis[curr] = True
```

```
    children = 0
```

```
    for ( auto j : adj[curr] )
```

```
        if ( j != par )
```

```
            if ( vis[j] == False )
```

```
                children++
```

```
                dfs ( j, curr, ... )
```

```
                low[curr] = min ( low[curr], low[j] )
```

```
                if ( low[j] > disc[curr] )
```

```
                    print ( curr + ' ' + j )
```

```
            else
```

```
                low[curr] = min ( low[curr], low[j] )
```



$$TC: O(V+E)$$



AP

How cal  $(V+E)$

Bands

How to cal  $(V+E)$

6<sup>th</sup> Oct  
Thursday  
9pm

AVL / Red Black Trees