PRIORITY QUEUES REVISITED

COMPLEXITY ANALYSIS OF OF GRAPH SEARCH

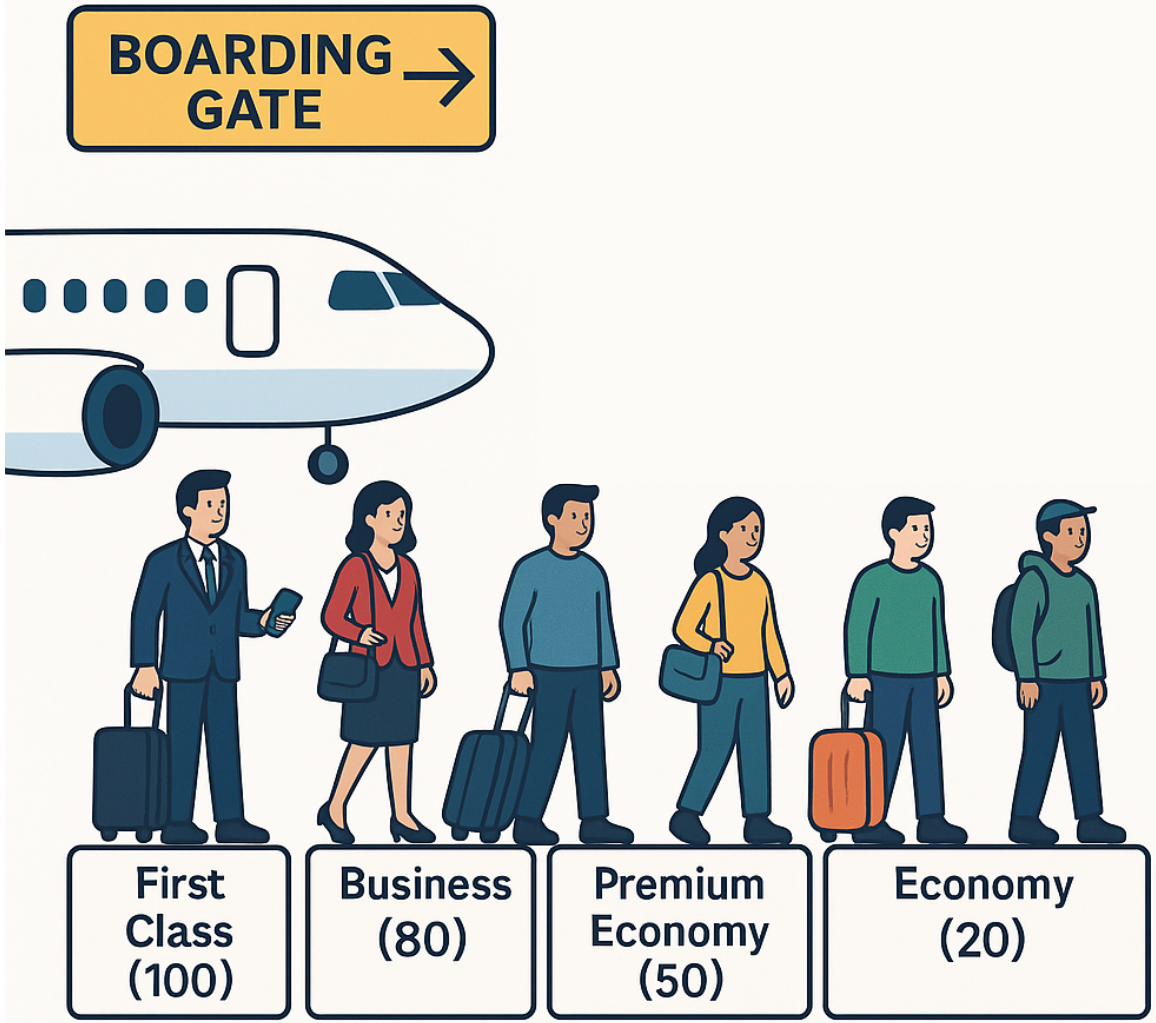
Tips for studying for the final exam

Detailed tips here: https://ucsb-cs24.github.io/s25/lectures/no-lecture-e02/

- **Do Leetcode sets in reverse (lp05 → lp01)**
  Focus on solving efficiently (~20 min/problem), skip & revisit harder ones.
- **Review lecture slides & handouts after practice**
  Resolve class problems yourself, then compare with annotated solutions.
- **Use recorded lectures for deeper understanding**
  Focus on *why* algorithms work, key patterns, and common pitfalls.
- **Revisit labs & projects for real-world context & usage of C++ STL ADTs**
  Recall what you built, which data structures you used, and why.
- **Make a quick-reference sheet + simulate the exam**
  Track key concepts, then do timed practice—explain your thinking out loud.

C++ Priority Queue ≡ Airport Priority Boarding

True/False: PQ can only store data for an ordering is defined.




```
priority_queue<int> pq;
// New passengers arrivals
pq.push(20);
pq.push(20);
pq.push(80);
pq.push(50);
pq.push(100);

// Whose boarding next?
cout << pq.top();

// Next passenger to board
pq.pop();
```

Leetcode practice (LP04)

LP04 (PQ + Hashtables): https://ucsb-cs24.github.io/s25/lp/lp04/

Priority Queues must know problems:

1. Kth Largest Element in an Array (medium): https://leetcode.com/problems/kth-largest-element-in-an-array/description/

2. Top K Frequent Elements (medium): https://leetcode.com/problems/top-k-frequent-elements/description/

* Practice configuring a PQ in different ways using a comparison class

Configuring std::priority_queue

```
template <
      class T,
      class Container= vector<T>,
      class Compare = less <T>
      > class priority_queue;
```

The template for priority_queue takes 3 arguments:

1. Type elements contained in the queue.
2. Container class used as the internal store for the priority_queue, the default is **vector<T>**
3. Class that provides priority comparisons, the default is **less**

Configuring std::priority_queue

```
//Template parameters for a max-heap
priority_queue<int, vector<int>, std::less<int>> pq;

//Template parameters for a min-heap
priority_queue<int, vector<int>, std::greater<int>> pq;
```

Trace the output of this code

```
int arr[]={10, 2, 80};
priority_queue<int*> pq;
for(int i=0; i < 3; i++)
     pq.push(arr+i);

while(!pq.empty()){
     cout<<*pq.top()<<endl;
    pq.pop();
}
```

How can we change the way pq prioritizes pointers?

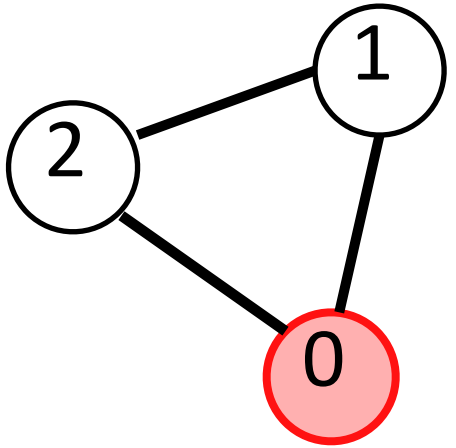
Write a comparison class to get the desired output

```
class cmpPtr{
      bool operator()(int* a, int* b) const {
            return ____________________;
       }
};
int arr[]={10, 2, 80};
priority_queue<int*, vector<int*>, cmpPtr> > pq;
for(int i=0; i < 3; i++)
     pq.push(arr+i);

while(!pq.empty()){
     cout<<*pq.top()<<endl;
    pq.pop();
}
```

```
Output: 80
        10
         2
```

BFS: Running Time Complexity



Algo exploreBFS (Graph G, vertex s):

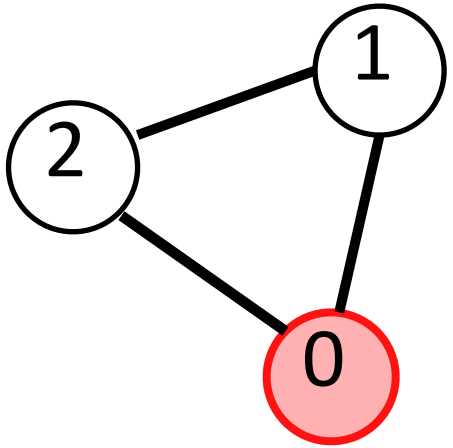
- Mark all the vertices as “not visited”
- Mark ***s*** as visited
- push ***s*** into a queue
- while the queue is not empty:
  - pop the vertex ***u*** from the front of the queue
  - for each of ***u***’s neighbor (***v***)
    - If ***v*** has not yet been visited:
      - Mark ***v*** as visited
      - Push ***v*** in the queue

n: number of vertices
m: number of edges

How many times does the while loop run?

A. n
B. m
C. n + m
D. nm
E. None of the above

BFS: Running Time Complexity



Algo exploreBFS (Graph G, vertex s):

For each iteration of the while loop, the for loop runs a variable number of times. How should we proceed to analyze the Big-O running time?

- while the queue is not empty:
  - pop the vertex ***u*** from the front of the queue
  - for each of ***u***'s neighbor (***v***):
    - If ***v*** has not yet been visited:
      - Mark ***v*** as visited
      - Push ***v*** in the queue

A. Bound the maximum number of times the for loop runs **per iteration** of the while loop

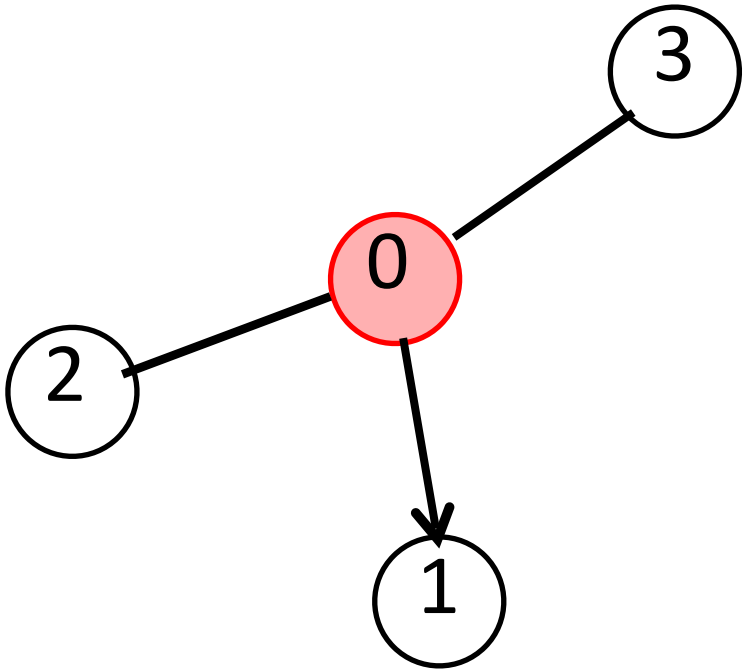
B. Compute the total number of times the for loop runs over **the entire run of exploreBFS**

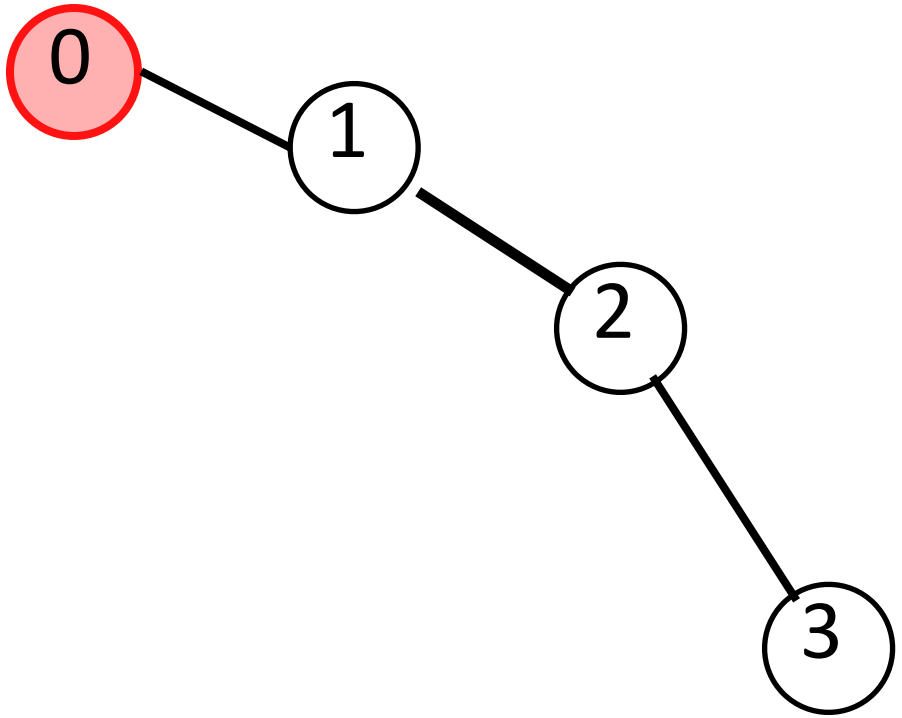
C. Cannot compute Big-O because running time depends on two parameters (n, m)

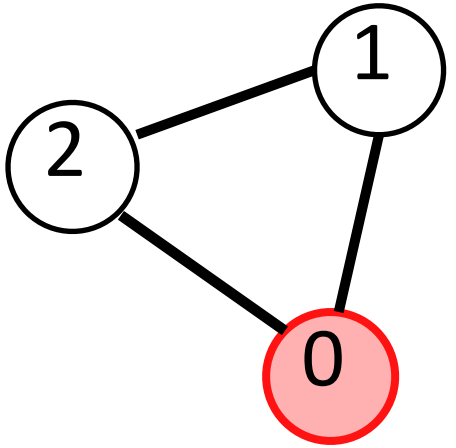
BFS: Running Time Complexity

Total number of times the for loop runs over **the entire run of exploreBFS**

Total number of times each neighbor (u) is checked over **the entire run of exploreBFS**







BFS: Time Complexity

n: number of vertices
m: number of edges

What is the time complexity of exploreBFS?

A. O(n)
B. O(m)
C. O(n + m)
D. O(nm)
E. None of the above

BFS Traverse: Space Complexity

n: number of vertices
m: number of edges

What is the Big -O auxiliary space complexity of exploreBFS?
A. O(n)
B. O(m)
C. O(n + m)
D. O(n^2)
E. None of the above

- Auxiliary Space complexity: Additional space usage (not including input and output)

exploreDFS: Time Complexity

```
exploreDFS(v, visited)
  visited[v] = true
  For each edge (v,w):
    If not w.visited
      exploreDFS(w)
```

n: number of vertices
m: number of edges

What is the time complexity of exploreDFS?
A. O(n)
B. O(m)
C. O(n + m)
D. O(n^2)
E. None of the above

exploreDFS: Space Complexity

```
exploreDFS(v, visited)
  visited[v] = true
  For each edge (v,w):
    If not w.visited
      exploreDFS(w)
```

n: number of vertices
m: number of edges

What is the worst-case space complexity of exploreDFS?

A. O(n)
B. O(m)
C. O(n + m)
D. O(n^2+ n.m)
E. None of the above

Leetcode practice (LP05)

Max number of fish (medium)
https://leetcode.com/problems/maximum-number-of-fish-in-a-grid/description/

0	2	1	0
4	0	0	3
1	0	0	4
0	3	2	0

```
grid =
[[0,2,1,0],[4,0,0,3],[1,0,0,4],[0,3,2,0]]

Output: 7

Explanation: The fisher can start at cell
(1,3) and collect 3 fish, then move to
cell (2,3) and collect 4 fish.
```

Return *the **maximum** number of fish the fisher can catch if he chooses his starting cell optimally, or* 0 if no water cell exists.

Discuss how you would approach this problem?

Leetcode practice (LP05)

LP05 (BFS/DFS/Divide& Conquer): https://ucsb-cs24.github.io/s25/lp/lp05/

Must know: 1 - 5

1. Find if path exists (easy) https://leetcode.com/problems/find-if-path-exists-in-graph/description/

2. Keys and Rooms (medium) https://leetcode.com/problems/keys-and-rooms/description/

3. Rotting Oranges (medium) https://leetcode.com/problems/rotting-oranges/description/

4. Max number of fish (medium)
https://leetcode.com/problems/maximum-number-of-fish-in-a-grid/description/

5. LCA in a binary tree (medium)
https://leetcode.com/problems/lowest-common-ancestor-of-a-binary-tree/

Extra challenge, can skip or leave for later
6. Minimum Operations to convert number (medium)
https://leetcode.com/problems/minimum-operations-to-convert-number/description/