Name: ____ NetID: __________________

I wish you all good skill! Read these instructions FIRST!

Please put your name and NetID on this page and your name on the rest of the pages. I unstaple these to feed them into the scanner and I have (at least once!) dropped the stack of exams and had to put them back together…

Please print your name neatly on this page so the gradescope scanner can understand it!!!

Please be smart in your time management. This is an assessment.. I want to understand your level of understanding. Don't get stuck on a question. Do the questions you are most sure about first.

Be concise, but be clear and complete. If you make assumptions, write them out.

Code quality rules still apply (except for destructors and the rule of three). So your code must be reasonably performant (e.g. O(1) where it should be O(1)), not overly complex, use good names, etc…

Show your work, it helps me give you partial credit even if you get lost. I really hate taking off all the points and writing "No attempt made"

You will have until the posted end time to complete the exam.

Desks must be clear. No talking. No notes or electronic devices will be allowed other than a calculator (you shouldn't need one). Don't take pictures of the exam.

If you need to use the restroom, just go – no need to ask. We're adults and we should operate from a level of trust.

For all code, you may assume that we are `using namespace std;` and that we've done

- `#include <iostream>`
- `#include <string>`
- `#include <vector>`
- `#include <stdexcept>`

If the exam is not on the front table in the box when I call time, then you will receive a zero. Please understand that I truly mean this – I will not tolerate anyone trying to extend the exam. It is not fair to those students who finish the exam on time.

Please initial here to indicate that you understand all this and that you WILL put your name on every page [1 point for complying]: __________

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1a) Let's write a good C++ function <u>header</u> that will pass muster for a code quality review. The function will take a configuration string that describes what values I want to select and a vector of integers from which I will select my matches. I want it to fill in another vector with any matching values it finds in the input and return the number of matches it found.

1b) Show me five methods related to file input that I can use on a C++ `ifstream` I just opened.

```
int x;
ifstream input("myinfo.txt");

if ( input.                                    ) {
  input >> x;
  cout << input.                                    << endl;

  cout << input.                                    << endl;

  cout << input.                                    << endl;

  cout << input.                                    << endl;

}
```

1c) Write C++ code that will read good values into three integers (x,y,z) from the stream we opened in (1b). I want to be able to detect and print those values (if any) are good.

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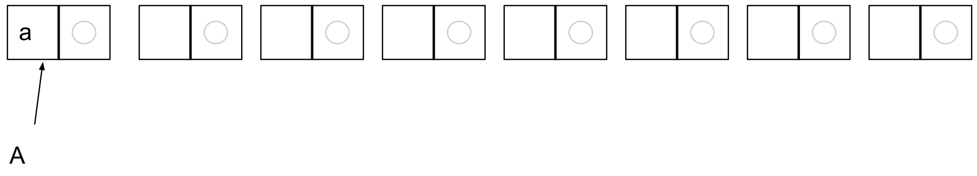
2. Given the definition of `Node` below, draw what the memory looks after running the rest of the code like using the node boxes below. Use an arrow to indicate what variables are pointing to (e.g. if a variable named `head` points to a node, then write the word `head` and add an arrow pointing from the word `head` to the appropriate box). Use a clear and consistent indication for null pointers (leaving it blank is <u>not</u> a clear indication).



```
struct Node {
    Node(char c) : payload(c), next(nullptr) { }
    char payload;
    Node* next;
};

  Node* A = new Node('a'); // I've drawn this already
  Node* B = new Node('b');
  Node* C = new Node('c');
  C->next = C;
  C->next->next = B;
  B->next = A;
  Node* D = new Node('d');
  D->next = A;
  Node* E = new Node('e');
  E->next = new Node('f');
  E->next->next = new Node('g');
  E->next->next->next = new Node('h');
  E->next->next = C;
  E->next->next->next->next = A;
  C->next = E;
  C->next->next->next->payload = 'x';
```

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3. Some Big O questions. Given the data structures and algorithms we've talked about in class, tell me what their Big O for each of the algorithms and tasks below. Also briefly tell me why you think that is the right value.

a. Search an array for the maximum value

b. Return a pointer to the middle element of a linked list (round down).

c. Find the 3 biggest values in a heap

d. Sort an array of N values with quicksort

e. Sort an array of N values with mergesort

f. BinarySearchTree::remove(key)

g. TwoThreeTree::insert(key)

h. RedBlack::insert(key)

i. HashTable::resize(N)

j. Queue::push(value)

k. Stack::pop(value)

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4. We can implement stacks, queues, and deques using linked lists or with arrays. List some of the tradeoffs for each implementation method (i.e. linked list vs array, not stack vs queue).

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5. Suppose I have a testing routine that will time a couple of functions. It takes a vector of ints and a couple of functions that do some work. It will tell me if the first is faster or the second is faster.

I want to know if MergeSort is faster or if Quicksort is faster so I'm going to call it with a vector A of size N, a function that does MergeSort, and a function that does QuickSort. So it will call MergeSort(A) with a timer, then call QuickSort(A) with a timer and report the fastest one.

What is the Big O cost to run this timer function with these arguments? Why? Will this timer function accurately tell me which is the faster algorithm? Why or why not?

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Blank page for scratch work or problem overflow

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6. Write high quality code for a normal queue of integers (pick an appropriate, Big O correct, and non-overly complicated implementation). You do **not** need to write the destructor, nor the normal rule of 3 methods, but I otherwise want it to be complete [memory safe, support const values, good names, etc…]. I want the queue to support `push(), pop(), first(), and is_empty()`. The `first()` method should return a reference to the value at the front of the queue [this is normally called front(), but I didn't want everyone to have a front member AND a front method which would be an error!]

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7. I’ve got a class that implements a 2-3 tree. I want to add a bool “contains” method. Please write this method as an inline member function of this class. Do **not** use a helper function.

```
class TwoThree {
  struct Node {
    string A,B;
    int cnt;  // Keycount. This is bad name but saves you writing time
    Node *left, *middle, *right;
    Node():cnt(0),left(nullptr),middle(nullptr),right(nullptr) {}
  };
  Node* root = nullptr;
public:
  TwoThree();
  TwoThree(const TwoThree&) = delete;
  TwoThree& operator=(const TwoThree&) = delete;
  ~TwoThree();
  void insert(const string& key);
  void remove(const string& key);
```

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8. Please draw the BST that results for each question…
   a. INSERT 65, 47, 57, 63, 32, 75, 44, 30, 80, 76
   b. INSERT 46, 42, 50, 39, 40, 44, 43, 45, 30
   c. INSERT 98, 32, 49, 1, 25, 22, 33, 19, 20
   d. For the tree you drew for part (b), please draw what the tree looks like after removing 42

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9, The following questions are about heaps

a. Tell me what a heap is

b. Why is the Big O for heapsort O(n log n)?

c. Why are heaps normally represented with arrays instead of nodes and pointers?

d. I have an array representing a heap. I have a value at index 100. Tell me the position of its

   i. Parent =

   ii. Left child =

   iii. Right child =

   iv. Grandparent =

   v. Root =

e. Draw the heap tree represented by

   98, 73, 97, 69, 71, 70, 61, 30, 39, 36, 17, 19, 21, 6, 24, 2

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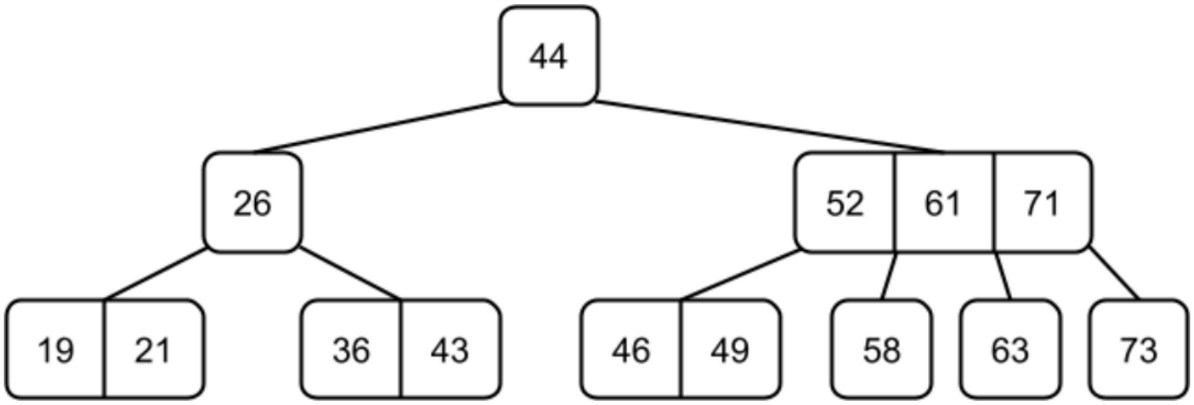
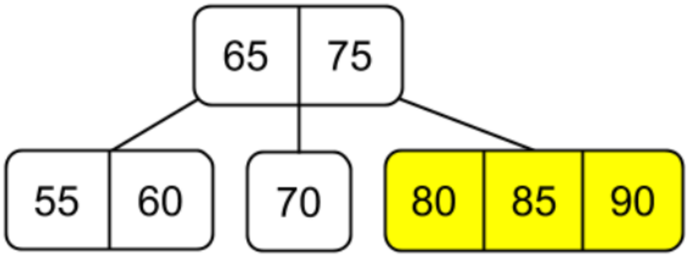
10. 2-3-4 Tree

a. Draw the tree after a left rotation at [52,72,61]



B. Please insert the key 100 and draw the resulting 2-3-4 tree



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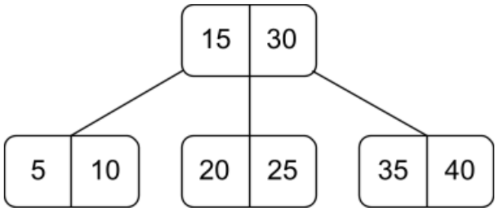
11. 2-3 trees

a. Insert the values [8, 15, 11, 10, 16, 12] into a 2-3 tree and draw that tree below

b. Delete the values 5 and 10 from the tree drawn below and draw the resulting tree. What operation did you perform as part of the removal to get that tree?



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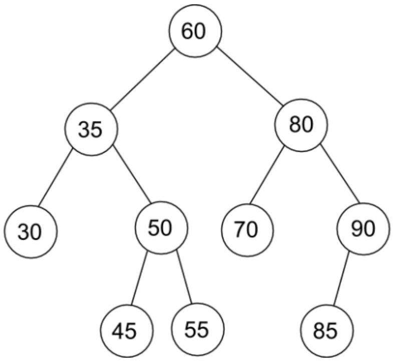
12. AVL and Red-Black
    a. AVL trees are BST with the balance factor property. Tell me what that property is and why it is important

    b. What are the rules for red-black trees?

    c. Insert 48 into the AVL tree below and draw to the right



    d. Show me the series of red-black trees you get by inserting
        i. [20]
        ii. [20,30]
        iii. [20,30,40]

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13. Hash warm-up
    a. What are the required and desired attributes of a hash function

    b. The Linux password system never stores your password as clear text; how does it work?

    c. I have a hash function that only returns even numbers. How would that affect your insertion into a hash table?

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14. My hash function is int H(int x) { return x % 10; } My collision strategy is to apply quadratic probing with c1 = 1 and c2 = 1.

a. Please insert the keys [85, 95, 56, 105, 66, 116] into this table of size 10.

0	
1	
2	
3	
4	
5	
6	
7	
8	
9	

b. Suppose I remove the key 95. Tell me what I need to do for the removal and how I would subsequently find the 105 key.

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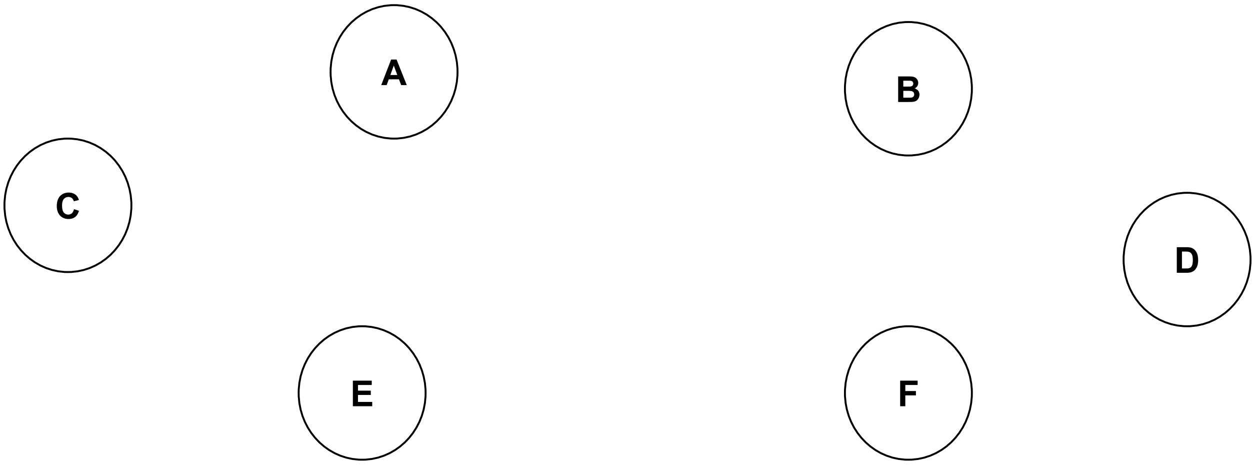
15. Adjacency Matrix
In the adjacency matrix below; 0 (blank) means no connection and a positive integer represents a weight. Row A:Column C means an edge from A to C. I've drawn just the nodes below. Please fill in the edges

	A	B	C	D	E	F
A	2	4	3			3
B				5		
C	6					7
D			1			9
E		8	7			
F					5	



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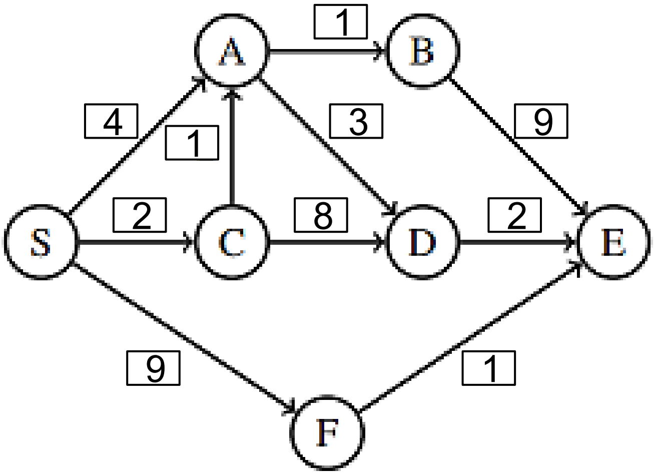
16. Djikstra’s Method

a. Please list the steps required to perform Djikstra’s method on a graph

b. For the directed graph I’ve given below, please fill in the table using Djikstra’s method to find all the shortest paths from start symbol S. I want to see the history of your choices, so DO NOT ERASE PRIOR ENTRIES (e.g. please enter the first value, cross it out before entering the second, etc…)

Label	V	Shortest path found so far	Previous node in backward path
S			
A			
B			
C			
D			
E			
F			



1
A
B
4
1
3
9
2
8
2
S
C
D
E
9
1
F