

Note: These problems are written by TAs and are not necessarily representative on the final exam. For each bolded topic, we have provided at least 2 problems. For topics that have 2 longer code writing or code tracing problems, you would likely only expect to see one of those on a final. To time this out like a “practice exam,” we’d suggest completing just one problem from each section.

Key: CW = code writing, CT = code tracing, SA = short answer, MC = multiple choice,

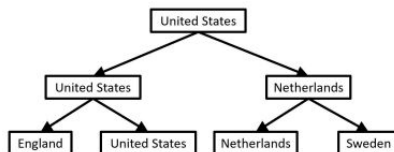
List methods and recursion

1. **CW:** Write the **recursive** method `sumOfPositiveEvens(L)` that takes in a list `L` and returns a sum of all the even and positive integers in the list. For example, `sumOfPositiveEvens([1,2,3,4,5])` should return 6 and `sumOfPositiveEvens([-2,-4,-6,-8])` should return 0.
2. **CW:** Write the destructive function `shuffleQueue(L, n)` that takes in a list of songs represented as strings and an integer `n`, and shuffles the input list `L` **destructively** `n` times by choosing two random songs in the list and switching their locations. If the two songs randomly chosen on a given iteration are the same song, do not count the current iteration in the `n` shuffles.

Trees and recursion

1. **CW:** We are back at it representing a tournament as a binary tree. Recall how the information from last time worked... (“United States” is misspelled “United States” on accident in a few)

For example, the following bracket represents the last two rounds of the Women’s World Cup in 2019.



In our binary tree dictionary format, this would look like:

```

t1 = { "value" : "United States",
      "left" : { "value" : "United States",
                  "left" : { "value" : "England", "left" : None, "right" : None },
                  "right" : { "value" : "United States", "left" : None, "right" : None } },
      "right" : { "value" : "Netherlands",
                  "left" : { "value" : "Netherlands", "left" : None, "right" : None },
                  "right" : { "value" : "Sweden", "left" : None, "right" : None } }
    }
  
```

Write the function `opponentsBeat(tree, team)` which takes a tournament bracket in (as a tree) and a team from that bracket (as a string), then returns a result list of all the opponents that that team beat in the bracket. Note that it should return an empty `[]` if the team beat no one and should be done **recursively**. Observe that since this is a bracket, it means every node that isn’t a leaf must have two children since it takes two teams to play a game.

Hint: Recommended to have 1 base case that checks for a leaf (figure out why that is); observe that if the node is not a leaf, then the children of the node are the team itself and the opponent they beat.

Exs:

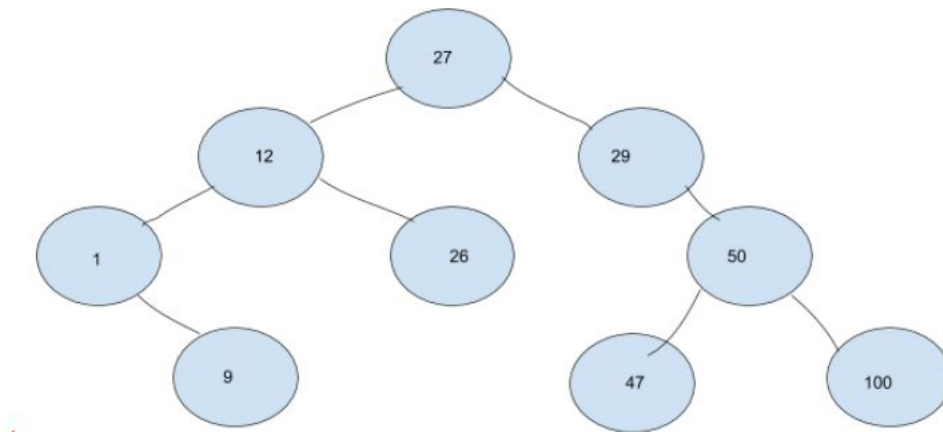
```

opponentsBeat(t1, "United States") → ["Netherlands", "England"]
opponentsBeat(t1, "England") → [ ]
  
```


2. **CT:** Consider the following function:

```
def oddValuesTree(tree):
    if tree == None:
        return []
    else:
        if tree["value"] % 2 == 0:
            return oddValuesTree(tree["left"]) + oddValuesTree(tree["right"])
        else:
            return [tree["value"]] + oddValuesTree(tree["left"]) +
                oddValuesTree(tree["right"])
```

Passed the tree below, what should the return value be?



The function has now changed to this...

```
def oddValuesTree(tree):
    if tree == None: #base case
        return []
    else: #recursive case
        if tree["value"] % 2 == 0:
            return oddValuesTree(tree["right"]) + oddValuesTree(tree["left"])
        else:
            return oddValuesTree(tree["right"]) + oddValuesTree(tree["left"]) +
                [tree["value"]]
```

Passed the same tree, what is the return value now?

Simulation - Randomness & Monte Carlo**1. CW:**

Write a simulation function `runTrial()` that takes in 0 parameters and simulates rolling an eight-sided die 3 times. The function should return `True` if the first dice roll is EVEN, the second roll is ODD, and that the third roll is LESS THAN 5. Otherwise, it should return `False`.

Ex: if Die 1 rolls a 4, Die 2 rolls a 7, and Die 3 rolls a 3 → returns `True`

Ex2: If Die 1 rolls 2, Die 2 rolls 5, and Die 3 rolls a 8 → returns `False`

Make sure to import the necessary modules!

2. MC:

Which of these statements is/are false (can be more than one)?

- A. Computers can produce truly random numbers using functions from the random module
- B. Law of large numbers says that if the number of trials is around 100,000, the exact expected value will be reached.
- C. Testing a simulation with 10 runs of it will give a bad estimate of the expected value
- D. Monte Carlo methods are used to repeat simulations over and over again

Simulation - model/view/controller

1. **CW:** For this problem, you have two different circles, the entries in `makeModel` marked with a 1 correspond to the first circle and the entries marked with a 2 correspond to the second. Implement this MVC program by modifying `makeModel` and filling in `keyPressed` and `mousePressed`, assuming you have a 400x400 board:

If the left half of the board is clicked, then only circle 1 is allowed to move

If the right half is clicked, then only circle 2 is allowed to move

If a half is clicked and it is the half of the circle currently allowed to move, then neither circle is allowed to move

If the right or left arrow is pressed, then the circle that's currently allowed to move will move, if neither is allowed, then neither will move

```
def makeModel(data):
    data["cx1"] = 100
    data["cy1"] = 100
    data["cx2"] = 300
    data["cy2"] = 300
    data["size"] = 50
    data["color1"] = "cyan"
    data["color2"] = "pink"
```


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```
def makeView(data, canvas):
    canvas.create_oval(data["cx1"] - data["size"], data["cy1"] -
data["size"], data["cx1"] + data["size"], data["cy1"] + data["size"],
fill=data["color1"])
    canvas.create_oval(data["cx2"] - data["size"], data["cy2"] -
data["size"], data["cx2"] + data["size"], data["cy2"] + data["size"],
fill=data["color2"])
```

2. **CW:** Given the setup below, write a function such that when you click on a random spot on the screen, a circle of size 50 is added to the board. Assume the board is 400x400
The circle is added at the spot clicked and needs to have a randomly selected color(you need at least two colors on the board). (update mouseClicked)
The circle will then start to float until it hits the top of the board(no specific bound, just be close to the top). (update runRules for this)
We will use a dictionary implementation for the circles with relevant entries being displayed in makeview. These circles should be stored in a list in data.

```
def makeModel(data):
    # Set up your simulation components here
    data['circleDicts'] = [ ]

def makeView(data, canvas):
    # The simulation view is written here, using the Tkinter canvas
    for circle in data['circleDicts']:
        cx = circle['cx']
        cy = circle['cy']
        size = circle['size']
        color = circle['color']
        canvas.create_oval(cx-size, cy-size, cx+size, cy+size,
fill=color)

def runRules(data, call):
    pass

def mousePressed(data, event):
    pass
```

Runtime/Big O

1. **SA** Determining tractability
 - a. Consider a problem called 3COL: Given an undirected graph, can we color the vertices with 3 colors so that no two adjacent vertices share the same colors?
 - i. Imagine we have an algorithm that solves the 3COL problem by trying all the possible combinations of colors for all the vertices. Is this algorithm tractable or intractable?
 - ii. Now we have an algorithm such that we go over each edge of the graph and check if both vertices connected by the edge have the same colors, if so we return False, else return True. Is this verifying process tractable or not?
 - iii. Based on your answers to parts i and ii, what complexity class is the 3COL problem in?

- b. Label the following Big-O complexities as either tractable or intractable
- $O((5^n)\log(n))$
 - $O(n^{247})$
 - $O(n!)$

2. **SA:** What's the big O of the following function?

```
def mystery(n):
    result = 0
    start = 1
    while start <= n:
        result += start
        start *= 2
    for i in range(result * n):
        print("Hello")
```

- What is the Big-O complexity of this function if we only count the **bolded multiplication step**?
- What is the Big-O complexity of this function if we only count the **bolded print statements**?

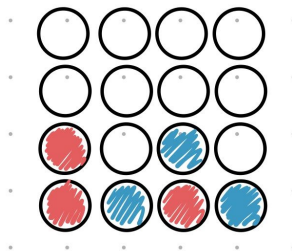
ML and AI

- MC:** Categorize each of the following as either a classification, regression, or clustering problem:
 - Based on a set of symptoms, determine what illness a patient has.
 - Group a set of pictures into three groups, with similar pictures being in the same group
 - Using the number of people who show up to a movie premiere to predict how much money the movie will make

- SA:** From this connect-four board, draw the next level of the game tree for the red player.

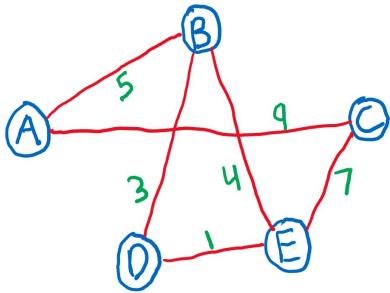
(If you aren't familiar with connect-four, you can read about it here!

<http://www.ludoteka.com/connect-4.html#:~:text=The%20aim%20for%20both%20players,be%20vertical%2C%20horizontal%20or%20diagonal.&text=Before%20starting%2C%20players%20decide%20randomly,made%20alternatively%2C%20one%20by%20turn>)



Graphs and Search

1. **CW:** Write a function `maxEdgeWeight` that takes in a graph `g` and returns a list of the maximum weight edge, represented as a 2 element list of the nodes the edge is connected to, connected to each node in the graph. If there are no edges connected to a given node, don't add anything to the result list for this node.

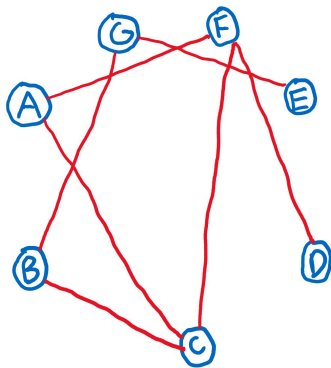


For ex., the output for the above graph would be `[["A", "C"], ["B", "A"], ["C", "A"], ["D", "B"], ["E", "C"]]`
 Remember that the above graph would be represented as follows:

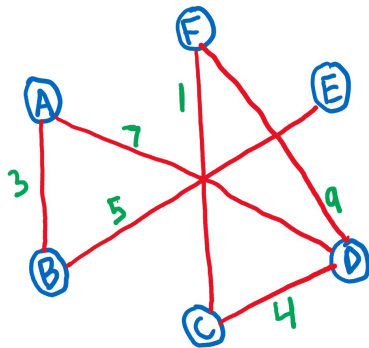
```

g = {
    "A" : [ ["B", 5], ["C", 9] ],
    "B" : [ ["A", 5], ["D", 3], ["E", 4] ],
    "C" : [ ["A", 9], ["E", 7] ],
    "D" : [ ["B", 3], ["E", 1] ],
    "E" : [ ["B", 4], ["C", 7], ["D", 1] ]
}
  
```

2. **SA:**
 - a. Perform a BFS and DFS starting at node B for the graph shown below:



- b. Now perform a **weighted** BFS and DFS on the graph below starting from node B, where instead of visiting neighbors in lexicographic order, you visit neighbors based on their connecting edge weight, from greatest to least.



Search/Sort, Hashing

1. **CT:** Given the following function, trace the

```
def someSort(lst):
    for i in range(len(lst)):
        min_index = i
        for j in range(i, len(lst)):
            if lst[j] < lst[i]:
                min_index = j
        # this function destructively swaps the values at the two
        # indices if they are different indices
        swap(i, min_index)
```

```
traceList = [2, 8, 5, 3, 1]
someSort(traceList)
```

i	list
0 start (value of lst at the start of the loop iteration)	[2, 8, 5, 3, 1]
0 end (value of lst at the end of the loop iteration)	[1, 8, 5, 3, 2]
1 start	
1 end	
2 start	
2 end	
3 start	
3 end	
4 start	
4 end	

2. **MC/SA**

What is the runtime of mergesort and why?

You are given the following hash function which takes in a string `elem`

```
def hash(elem):
    lowercase = elem.lower()
    first = ord(lowercase[0])
    return first - ord("a")
```

```
lst = ["hello", "bazooka", "Christmas", "Santa", "present"]
```

If we hash the elements in the list above using our hash function, and place them in a hash table of length 5 as shown below, what will be the final state of the hash table? Hash the items in the list from left to right and order them as such in the table below. As an example, "apple" would be hashed to index 0 of the table, as the hash function would return 0.

Index 0	Index 1	Index 2	Index 3	Index 4

Authentication & Encryption

1. **SA:** What are the two types of authentication and briefly describe how they work. Give an example of both types.
2. **CW:** You and your friend want to send each other secret encrypted messages that only you two can encrypt and decrypt. Write an encryption and decryption function, `encryptMessage(key, message)` and `decryptMessage(key, message)`, which are both given some key, a list of letters where the letter at the *i*th index corresponds to the *i*th+1 letter of the alphabet (i.e. index 0 of key is the letter corresponding to "a", the first letter of the alphabet), and a string message. When encrypting, the letter in the message will determine the index in the key, and the new letter will be letter to the left of the index in the key (if the letter in the message is "a", then the encrypted letter will be the letter corresponding to the index of "z", the last index of the key). Decryption will occur in the opposite way. This way, even if someone were to find the key, they will not be able to decrypt the message immediately.

You may assume that the messages and keys will all be lowercase letters and that the length of key will always be 26. Leave spaces and punctuations unchanged. An example is shown below:

```
key = ["b", "z", "k", "m", "f", "l", "i", "a", "x", "u", "w", "e", "q",
      "h", "j", "o", "p", "n", "c", "v", "t", "g", "s", "d", "r", "y"]
encryptMessage(key, "hello world") = "imwwh ghpwk"
decryptMessage(key, "lhhkbdm") = "goodbye"
```

Hint: For encryption, you may find the string function `.islower()`, which returns whether the string it is called on is all lowercase, useful. For decryption, you may find the list function `.index(elem)`, which returns the first index `elem` appears in the list it is called on, useful!

Parallelism, Pipelining, MapReduce

1. **CW:** The university wants to count the number of full time students for the semester using each student's course information. To be considered full-time, a student must have taken at least 36 units and received a final grade of at least 60 in every class they take. To parallelize this process, the university wants to use MapReduce.

Course Information is represented as a dictionary with the key being the course name and the value being a two element list, where the first element is the number of units for the course and the second is the student's grade in that course.

Ex:

```
courseDict = {"Principles of Computing": [10, 90], "Calculus 1": [10, 92],
              "Principles of Microeconomics": [9, 83], "Experimental
              Chemistry": [6, 77], "Global Business": [9, 96]}
```

- a. Write the map function that takes a student's course information for the semester and maps it to a boolean value representing the student's full-time status.
 - b. Write the reduce function that takes the results from the map function and outputs the number of full time students
2. **MC/SA**
Select which of the following are True:
 - a) Deadlocks can be resolved by programs locking important resources that other programs need
 - b) Pipelining is useful in scenarios where every sub-task is dependant on the previous sub-task and the task is performed only once
 - c) The length of time of a pipelined process depends on the length of the longest task
 - d) The mapper passes on its output directly to the reducer which then combines the output

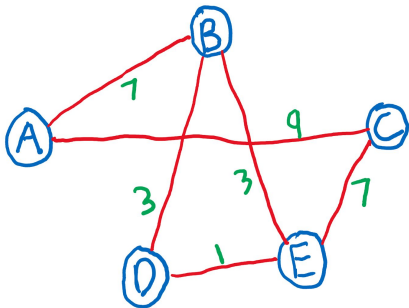
Data Analysis/Visualization

1. **CW:** Write a function that randomly samples 100 choices from a list that contains 4 flavors of ice cream (Vanilla, Chocolate, Mint, and Caramel), and then creates a bar chart of the number of times each flavor was sampled. For example, if each flavor is sampled 25 times, then the corresponding bar chart should have 4 bars (1 for each flavor) each with height 25. Use the `random.choice()` function from the `random` library, and use the `plt.bar()` function from the `matplotlib` library. The `plt.bar()` function takes two parameters: the first is a list of labels for the bars on the x-axis, and the second is the list of heights corresponding to each bar.
2. **SA:** Given the following types of data, name the best visualization method to display that data:
 - A. Numerical × Ordinal
 - B. Numerical
 - C. Ordinal × Ordinal
 - D. Categorical
 - E. Numerical × Numerical × Numerical

Dicts and Trees/Graphs

- CW:** Write a function `combineCovidDicts` that takes in two dictionaries, `dict1` and `dict2`, each of which contains keys that represent cities (strings) with the corresponding value being the percentage of individuals in that city with Covid (float). This function should output a result dictionary which combines the two inputs as specified below:
 - If a city is key both `dict1` and `dict2`, set that city as a key in your result dictionary with a value equal to the percentage for that city in `dict2` - the percentage for that city in `dict1`
 - If a city is only in `dict2`, then just set that city as a key in your result dictionary with a value equal to the percentage for that city in `dict2`
 - If a city is only in `dict1`, then just set that city as a key in your result dictionary with a value equal to the percentage for that city in `dict1`
- CT:** Given the following mystery function, what would it return when given the graph below as input?

```
def f(g):
    result = {}
    for node in g:
        for neighbor in g[node]:
            if neighbor[1] not in result:
                result[neighbor[1]] = []
            result[neighbor[1]].append([node, neighbor[0]])
    return result
```



Remember that the above graph would be represented as follows:

```
g = {
    "A" : [["B", 7], ["C", 9]],
    "B" : [["A", 7], ["D", 3], ["E", 3]],
    "C" : [["A", 9], ["E", 7]],
    "D" : [["B", 3], ["E", 1]],
    "E" : [["B", 3], ["C", 7], ["D", 1]]
}
```


Concurrency, Internet

1. SA:

You find that when you download a movie from movielovers.com, it takes much more time than other websites to download the document due to an extremely slow internet speed. The internet company claims that it happens because the movielovers.com did not pay them for the excessive internet access due to the huge number of movies downloaded. What term describes the company's behavior and what principle has the company violated?

2. MC: Match the following internet terms with their corresponding definitions:

Terms:	Definitions:
Packet	A computer that stores URL's and their associated IP addresses
DNS Server	A type of system that has failsafes and backups in place for when things go wrong
IP Address	Type of organization that connects a user's computer to the internet
Fault Tolerant	Information sent to an IP address
ISP	The set of numbers that uniquely identifies a computer hosting a website

3. SA

Draw out the concurrency tree for the following expression: $(((a+b)**c)*(d-2*e))/f$

How many levels are there?

What's the number of steps?

What's the number of time steps in the concurrency tree (time steps = non-leaf levels)?