Question 1. [5 marks]

Consider the following code:

```
class BagOfStuff:
    def __init__(self, stuff: List[str]) -> None:
        self.stuff = stuff

if __name__ == '__main__':
    some_stuff = ['wallet', 'phone', 'keys']
    my_stuff = BagOfStuff(some_stuff)
    some_stuff.append('snacks')
    your_stuff = BagOfStuff(some_stuff)
    assert len(my_stuff.stuff) == 3 and len(your_stuff.stuff) == 4
```

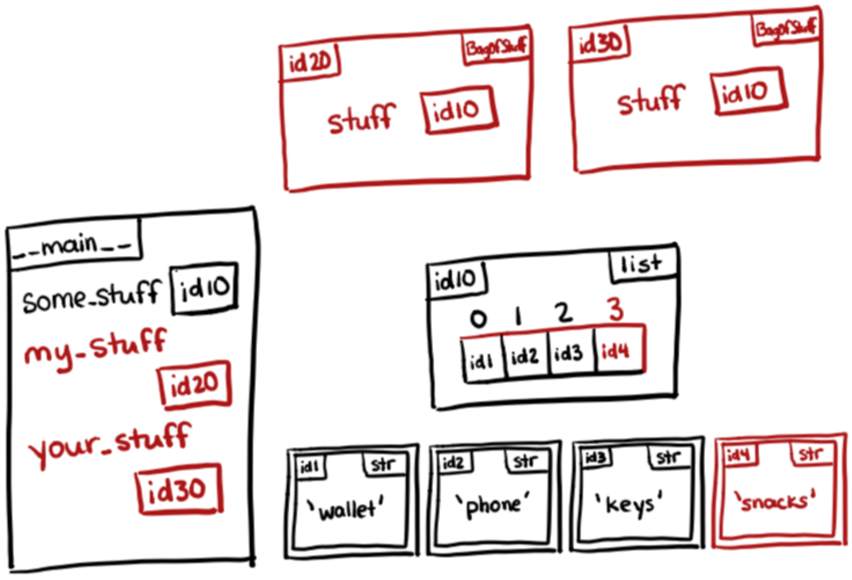
When we run this code, the assertion fails!

Part (a) [3 marks]

To debug the code, we have begun to trace the code in the `__main__` block. The memory model diagram shows the state of memory right after the line `some_stuff = ['wallet', 'phone', 'keys']` has been executed. Complete the diagram to show the state of memory immediately before the `assert` line runs.

You can trace through the calls on the call stack if it helps you, but you do not have to include them in your final diagram. You don't have to include anything from the `assert` line in your diagram.

Solution:



Part (b) [2 marks]

What causes the assertion to fail, and what needs to be changed inside the class `BagOfStuff` to fix this issue? Be specific and use correct terminology.

Solution:

The assertion fails because both lists have len == 4. To fix it, the init method needs to copy the list. For example, using [:] We accepted any fix to init. We did not accept changes to __main__ because that would not fix the bug.

Question 2. [6 MARKS]

Part (a) [3 MARKS] For each pair of classes from Assignment 0 or Assignment 1, check the box to indicate whether they have a Composition relationship, an Inheritance relationship, or neither.

Class 1	Class 2	Composition?	Inheritance?	Neither?
`Chirper`	`Cheep`	X		
`Customer`	`Item`	X		
`ExpressLine`	`Customer`	X		
`ExpressLine`	`SelfServeLine`			X
`PriorityQueue`	`Container`		X	
`GroceryStore`	`GroceryStoreSimulation`	X		

Part (b) [1 MARK] Give an example from Assignment 1 of where you used polymorphism. You can write an example line of code, with the types indicated, or describe in words.

`Calling the do method on events in the simulator, or calling the checkoutline methods in GrocerySt`

Part (c) [1 MARK] One of the subclasses of `CheckoutLine` was `RegularLine`, which represented a line with no special features. Why did we have to create this subclass, rather than just creating an instance of `CheckoutLine`?

`CheckoutLine is an abstract class and so cannot be instantiated`

Part (d) [1 MARK] Assume the code below has been run.

For Part b, we accepted answers that said something about calling or using a method without knowing type. We did not accept answers that talked about different ways of inheriting methods.

For Part c, you needed to say something about why you shouldn't create a CheckoutLine object

```
class A:
    def hey(self) -> None:
        print("I'm an A")

class B(A):
    def hey(self) -> None:
        print("I'm a B")

class C(A):
    def some_method(self) -> None:
        print('C is for Cat')

def type_checker(things: List[A]) -> None:
    for thing in things:
        thing.hey()
```

What happens when the following calls are executed? Either give the output if the call runs without error, or explain why an error occurs.

(i) `type_checker([A(), B()])`

```
I'm an A
I'm a B
```

(ii) `type_checker([C()])`

```
I'm an A
```

Question 3. [8 marks]

You are responsible for creating a class to represent a playlist containing songs. Each song in the list has a title, an artist, and a duration. None of those three attributes are unique, but each artist has at most one song with a particular title. That is, there are no (title, artist) duplicate pairs.

Here is sample usage of the Playlist class.

```
>>> pl = Playlist()
>>> pl.play_next() # nothing happens
>>> pl.add_song('Free Falling', 'Tom Petty', 4.5)
>>> pl.add_song('Zombie Zoo', 'Tom Petty', 3.5)
>>> pl.add_song('Hello', 'Lionel Richie', 4.0)
>>> pl.add_song('Hello', 'Adele', 5.0)
>>> pl.add_song('Hello', 'Adele', 5.0) # not added again
>>> pl.get_total_duration()
17.0
>>> pl.play_next()
'Free Falling by Tom Petty'
>>> pl.play_next()
'Zombie Zoo by Tom Petty'
>>> pl.reset()
>>> pl.play_next()
'Free Falling by Tom Petty'
>>> pl.get_songs_by('Tom Petty')
['Free Falling', 'Zombie Zoo']
```

Below and on the next pages complete the implementation of this class so that the example code above will run as shown. You may choose any reasonable way to store the necessary data.

Do not add anything to the public interface for this class beyond what is demonstrated in the example code. You can add private attributes and private helper methods.

We have imported the types we think you will need from typing, however you can assume any others you need for your type contracts are also available, and you do not need to use all the imported ones.

You do not need to do any additional handling of errors or behaviours beyond what is demonstrated in the sample usage.

The TAs used some abbreviations for common deductions:

H → issue with a method header

II → inconsistent with initializer

PA → public attribute that should be private
ie. a change to the public interface

T → TypeError.

Solution:

```
class Playlist:
    """A class to represent a book of songs.

    === Attributes ===
    _songs: A list of songs in the order they were added. Each song is a tuple (title, artist, duration)
    _position: The position to play next in the _songs list.
    """
    _songs: List[Tuple]
    _position: int

    def __init__(self) -> None:
        self._songs = []
        self._position = 0

    def play_next(self) -> Optional[str]:
        if self._position < len(self._songs):
            song = self._songs[self._position]
            self._position += 1
            return '{0} by {1}'.format(song[0], song[1])

    def add_song(self, title: str, artist: str, duration: float) -> None:
        is_new = True
        for song in self._songs:
            if song[0] == title and song[1] == artist:
                is_new = False
        if is_new:
            self._songs.append((title, artist, duration))


    def get_total_duration(self) -> float:
        total = 0.0
        for song in self._songs:
            total += song[2]
        return total

    def reset(self) -> None:
        self._position = 0

    def get_songs_by(self, artist: str) -> List[str]:
        result = []
        for song in self._songs:
            if song[1] == artist:
                result.append(song[0])
        return result
```

Question 4. [6 marks]

Recall the Stack class that we have used in the course. You can find an implementation of `Stack` on the provided aid sheet, and you can assume everything from the aid sheet has been imported for you to use.

Suppose we want to define a new kind of Stack called a MegaStack. A MegaStack has the same public interface as a Stack, plus two more operations, implemented as public methods.

- The method `mega_push` takes a Queue object and pushes everything from the Queue onto the MegaStack in the order it is removed from the Queue. When the method returns, the Queue will be empty, and all of its contents will now be on the MegaStack. `mega_push` returns nothing.
- The method `mega_pop` takes an integer value, and pops up to that many items from the MegaStack and returns them in a Queue object. If there are less than the given number of items in the MegaStack, the MegaStack is empty and all its items are returned in the Queue. The items are added in the Queue in the same order they are popped from the MegaStack.

Write this new class. Part of the marks will be for good design. In particular, avoid repeated code. Your solution should not contain even a single line that has been previously written.

You must write complete type contracts, but you do not need docstrings (but you can if it helps you!)

Solution:

```
class MegaStack(Stack):

    def mega_push(self, to_push: Queue) -> None:
        while not to_push.is_empty():
            self.push(to_push.dequeue())

    def mega_pop(self, num: int) -> Queue:
        result = Queue()
        for _ in range(num):
            if self.is_empty():
                return result
            result.enqueue(self.pop())
        return result
```

Here we were looking for:
1) using Stacks + Queues
2) designing with inheritance

Question 5. [4 marks]

Consider the following code:

```
def search_queue(q: Queue, item: Any) -> bool:
    """Return True iff item is contained in q.

    >>> queue = Queue()
    >>> queue.enqueue(1)
    >>> queue.enqueue(2)
    >>> search_queue(queue, 2)
    True
    >>> search_queue(queue, 3)
    False
    """
    found = False
    temp_q = Queue()
    while not q.is_empty():
        cur = q.dequeue()
        if cur == item:
            found = True
        temp_q.enqueue(cur)
    q = temp_q
    return found
```

Part (a) [1 mark]

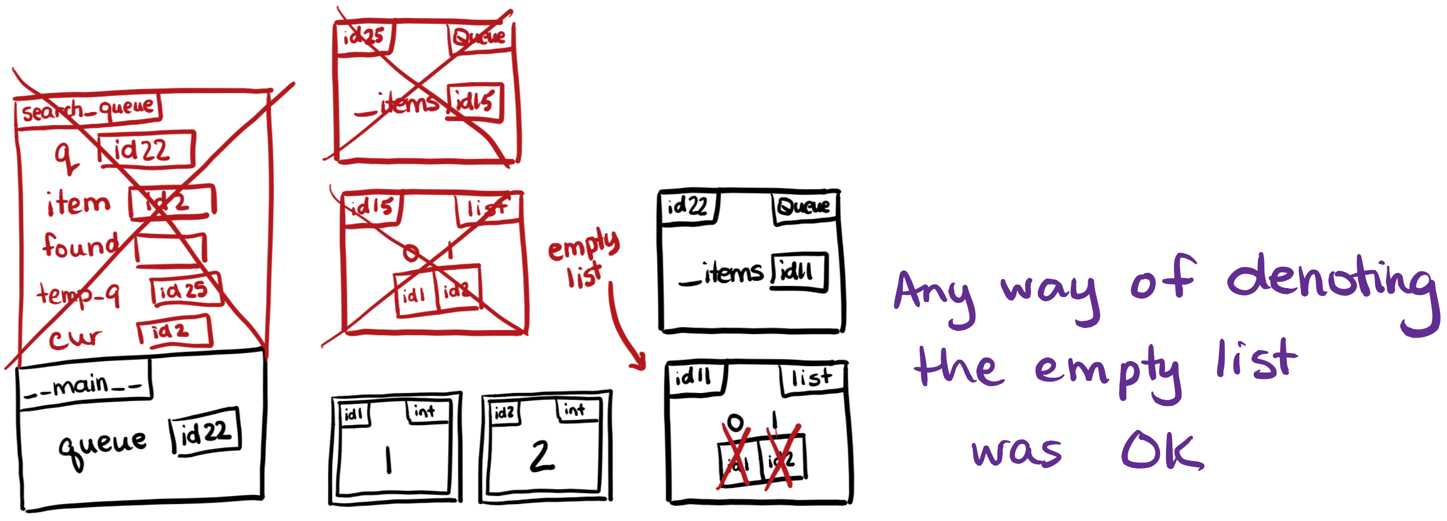
Does this function pass its doctest? Circle one: Yes No **Solution:** Yes

Part (b) [3 marks]

We have begun to trace the code in the docstring in the code block above. The memory model diagram shows the state of memory right *before* `search_queue(queue, 2)` is executed. Complete the diagram to show the state of memory immediately *after* `search_queue(queue, 2)` returns.

You may find it helpful to draw out all stack frame and any objects that are created during the function call, however you do not need to include them in your final diagram. You can assume in the diagram that Python uses the shortcut that allows it to create aliases to the same immutable object.

Solution:



Question 6. [8 MARKS]

Answer the questions below about LinkedLists. You can assume these are part of the `LinkedList` implementation on the aid sheet. Note the preconditions – you do not need to worry about an index out of range for this question. **You will likely find it very helpful to draw yourself some pictures.**

Part (a) [4 MARKS]

The following implementation of `LinkedList.insert` does not work correctly, although it is pretty close. In fact, there are only two lines in the entire method that need to be fixed.

Circle the two lines that need to be corrected, and rewrite the corrected lines next to them. Do not rewrite the other lines.

```
def insert(self, index: int, item: Any) -> None:
    """Insert the given item at the given index in this list.

    Precondition: 0 <= index <= len(self)
    Note that adding to the end of the list is okay.
    """
    new_node = _Node(item)
    if index == 0:
        new_node.next = self._first.next
        self._first = new_node
    else:
        cur = self._first
        i = 0
        while cur is not None and i < index - 1:
            cur = cur.next
            i += 1
        new_node.next = cur.next
        cur = new_node
```

Solution:

```
Bug #1: new_node.next = self._first.next SHOULD BE new_node.next = self._first
Bug #2: cur = new_node SHOULD BE cur.next = new_node
```

Question 6. (continued)

Part (b) [4 marks]

Complete the implementation of `LinkedList.pop` below. Your solution must follow the structure outlined in the starter code.

```
def pop(self, index: int) -> Any:
    """Remove and return the item at position <index>.

    Precondition: 0 <= index < len(self)

    >>> lst = LinkedList([1, 2, 10, 200])
    >>> lst.pop(1)
    2
    >>> lst.pop(2)
    200
    >>> lst.pop(0)
    1
    """
    # pop the first node
    if index == 0:
        removed = self._first
        self._first = self._first.next
        return removed.item
    # pop another node
    else:
        cur = self._first
        i = 0
        # complete the while loop condition and body to find the node to modify
```

Solution:

```
        # complete the while loop condition and body to find the node to modify
        while cur is not None and i < index - 1:
            cur = cur.next
            i += 1
        # remove the node at index from the list and return its item
        removed = cur.next
        cur.next = cur.next.next
        return removed.item
```

Question 7. [7 MARKS]

In Assignment 1, you implemented your `PriorityQueue` using an underlying Python list, as in the code below. For this question, you can assume all items have unique priority – there are no duplicate priorities.

```
class PriorityQueue:
    def __init__(self) -> None:
        """Initialize an empty PriorityQueue"""
        self._items = []

    def remove(self) -> Any:
        """Remove and return the highest priority item from this PriorityQueue"""
        return self._items.pop(0)

    def add(self, item: Any) -> None:
        """Insert <item> into this PriorityQueue"""
        i = 0
        while i < len(self._items) and self._items[i] < item:
            i += 1
        self._items.insert(i, item)
```

Part (a) [1 MARK] Write down the Big-Oh expression for the running time in terms of n for **removing** one item from a `PriorityQueue` with n items using the implementation above.

Part (b) [1 MARK] Write down the Big-Oh expression for the running time in terms of n for **adding** one item from a `PriorityQueue` with n items using the implementation above.

Now, assume you change the `PriorityQueue` class above to be implemented with an underlying `LinkedList`, as defined on the aid sheet. Assume the `insert` and `pop` methods are the ones from Question 6, and that they are implemented correctly.

Review the implementation and answer the questions on the following page.

Question 7. (continued)

```
class PriorityQueue:
    def __init__(self) -> None:
        """Initialize an empty PriorityQueue"""
        self._items = LinkedList([])

    def remove(self) -> Any:
        """Remove and return the highest priority item from this PriorityQueue"""
        return self._items.pop(0)

    def add(self, item: Any) -> None:
        """Insert <item> into this PriorityQueue"""
        i = 0
        cur = self._items._first
        while cur is not None and cur.item < item:
            cur = cur.next
            i += 1
        self._items.insert(i, item)
```

Part (c) [1 mark] Write down the Big-Oh expression for the running time in terms of n for removing one item from a `PriorityQueue` with n items using the `LinkedList` implementation.

Part (d) [2 marks] Describe the situation where adding one item to a `PriorityQueue` with n items using the `LinkedList` implementation would take the ***fewest*** steps. Then, give the Big-Oh expression for the running time in terms of n.

Part (e) [2 marks] Describe the situation where adding one item to a `PriorityQueue` with n items using the `LinkedList` implementation would take the ***most*** steps. Then, give the Big-Oh expression for the running time in terms of n.

Solution:

same regardless of where it is added

```
a) O(n)
b)  O(n)
c) O(1)
d) The item being added has higher priority than everything else in the PQ. O(1)
e) The item being added has lower priority than everything else in the PQ. O(n)
```