UNIVERSITY OF TORONTO
Faculty of Arts and Science

Midterm 1 Solutions CSC148H1F

Duration: 50 min. Instructors: Diane Horton, David Liu. **Examination Aids**: Provided aid sheet

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Name:

Student Number:

Please read the following guidelines carefully.

- Please print your name and student number on the front of the exam.
- This examination has **4** questions. There are a total of **15 pages, DOUBLE-SIDED**.
- The last page is an aid sheet that may be detached.
- You may always write helper functions/methods unless explicitly asked not to.
- Docstrings are *not* required unless explicitly asked for.

Take a deep breath.

This is your chance to show us

How much you've learned.

We **WANT** to give you the credit

That you've earned.

A number does not define you.

Question	Grade	Out of
Q1		9
Q2		4
Q3		9
Q4		7
Total		29

1. **[9 marks]** The following questions test your understanding of the terminology and concepts from the course. For the short-answer questions, you may answer in either point form or full sentences; **you do not need to write much to get full marks**!

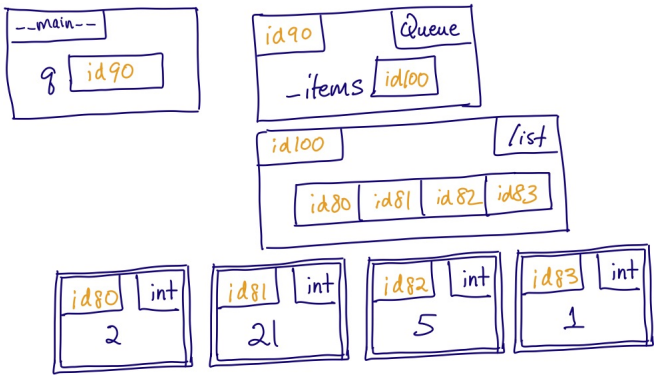
   (a) **[4 marks]** The following function attempts to filter a queue. It runs without crashing, but it doesn't pass its doctests.

```
def filter_queue(q: Queue[int], minimum: int) -> None:
    """Remove all items from <q> that are less than <minimum>.

    >>> q = Queue()
    >>> q.enqueue(2)
    >>> q.enqueue(21)
    >>> q.enqueue(5)
    >>> q.enqueue(1)
    >>> filter_queue(q, 10)
    >>> q.dequeue()
    21
    >>> q.is_empty()
    True
    """
    temp_queue = Queue()

    while not q.is_empty():

        value = q.dequeue()

        if value >= minimum:

            temp_queue.enqueue(value)

    q = temp_queue
```

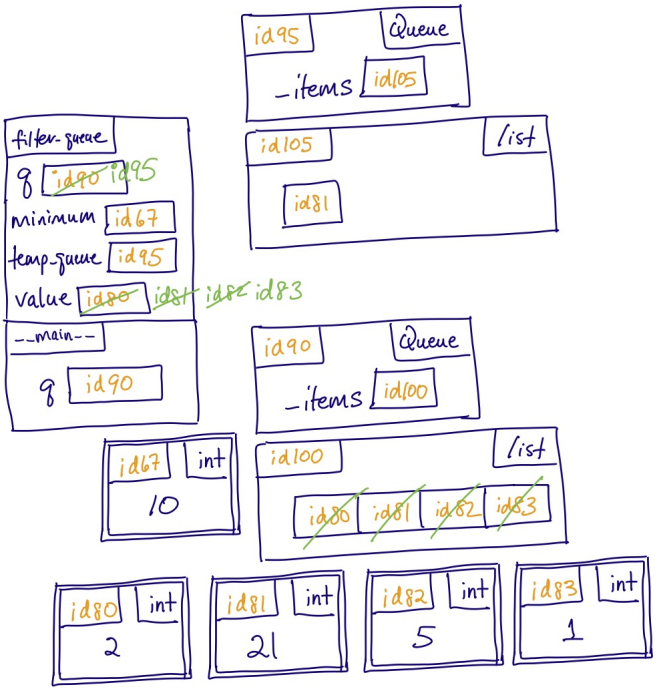
   On the next page, we have drawn the state of memory after a `Queue` has been constructed and given contents as in the doctest:

```
>>> q = Queue()
>>> q.enqueue(2)
>>> q.enqueue(21)
>>> q.enqueue(5)
>>> q.enqueue(1)
```

(i) Modify the diagram to show the state of memory if we have called `filter_queue(q, 10)` and have paused right before the function returns (immediately after executing the line `q = temp_queue`).
Note: this implementation of `Queue` uses the *front* of the `_items` list as the front of the queue.



Solution



(ii) The first doctest expects:

```
>>> q.dequeue()
21
```

What would actually be returned/happen?

Solution

The queue is now empty, so when we call dequeue it returns None. (The aid sheet says that this is its behaviour on an empty queue.)

(iii) The second doctest expects:

```
>>> q.is_empty()
True
```

What would actually be returned/happen?

Solution

Returns True.

(iv) Finally, *fix the code* by making changes directly on the given code on the previous page. Clearly cross out any parts you want to remove, write any new code that should be added, and clearly indicate where the new code should go.

Solution

We have to mutate the original queue object by putting the items from the temporary queue into it.

Remove the line `q = temp_queue`, and replace it with:

```
while not temp_queue.is_empty():
    q.enqueue(temp_queue.dequeue())
```

Note that the filtering work could have been done in this loop instead of while creating the temporary queue. That approach wastes space, because it saves things in the temporary queue that do not have to be saved.

Marking scheme

- **2 marks** for correctly showing the memory model diagram changes.
  - **1 mark** for showing the aliasing of `q` and `temp_queue`.
  - **1 mark** for showing that the original queue is no empty, and unchanged.
  - Deduct at most **0.5 marks** for small errors.
- **1 mark** for (ii) and (iii) (0.5 marks each).
  - For (ii) you can give the mark if students say that an error is raised.
- **1 mark** for correct change. No partial credit here.

(b) **[2 marks]** State *two* differences between *methods* and *top-level functions*. The differences can be design-related or technical (code-related).

Solution

Possible answers include:

- A method is defined within a class (indented within the `class A` block), while a function is defined outside a class.
- A method is logically some behaviour/computation that is associated with instances of a class, while a function's purpose can be more general.
- A method can access private attributes/methods inside a class, while top-level functions should only make use of the public interface of a class.
- A method is normally called using dot notation, while a function is not.
- The first parameter of a method should always be called `self`, referring to the instance of the class; a function has no such restriction on the order or names of its parameters.

Marking scheme **1 mark** for each of *two* different reasons. Note that the reasons really do need to be distinct, not just rewordings of each other.

(c) **[3 marks]** Suppose we have an abstract class defined as follows:

```
class MyAbstractClass:
    def __init__(self, x, y):
        # Body omitted, but there is an implementation here.

    def method1(self):
        raise NotImplementedError

    def method2(self):
        # Body omitted, but there is an implementation here.
```

Now suppose we want to write a subclass of `MyAbstractClass` called `MySubclass` that is *not* abstract.

(i) What method(s) *must* be implemented by `MySubclass`? Only write the method name(s).

Solution

`method1`

(ii) What might go wrong if we do not implement this/these method(s)?

Solution

If we create an instance of `MySubclass` and call `method1` on the instance, we'll get an error (`NotImplementedError`).

(iii) What method(s) can we choose to override in `MySubclass`? Only write the method name(s).

Solution

`__init__` and `method2`

(iv) What is one reason we might not want to override this/these method(s)?

Solution

We want to use the default behaviour already implemented in `MyAbstractClass`.

(v) Suppose we choose *not* to override the initializer of `MyAbstractClass`, and then run the following code:

```
>>> obj = MySubclass(10, 20)
>>> print(obj.x + obj.y)
```

What is the result of executing this code? If there is output, explain. If there is an error, explain. If it is impossible to tell from the information given, explain.

Solution

Impossible to tell from the information given! Because we haven't provided the documentation for `MyAbstractClass`, or the implementation of its initializer, we don't know whether `x` and `y` are instance attributes of the class, and even if they are, what their types are.

Marking scheme **0.5 marks** for each of (i) to (iv). **1 mark** for (v) that includes both the correct result *and* explanation.
No partial credit for any part. In (v), students do *not* get any credit if they only write "impossible to tell" with no justification.

2. **[4 marks]** Here is a function that operates on a stack. Complete its docstring by adding three elements:

   (a) An English description of what the function does.

   (b) A doctest example that makes use of a stack of size at least 3.

   (c) Any preconditions necessary to ensure the function will not raise an error.

```
def mystery(s: Stack) -> None:
    """
```

Solution

```
    Swap the top and bottom element of the given stack.

    Precondition: the input stack contains at least two elements.

    >>> s = Stack()
    >>> s.push(1)
    >>> s.push(2)
    >>> s.push(3)
    >>> s.push(4)
    >>> mystery1(s)
    >>> s.pop()
    1
    >>> s.pop()
    3
    >>> s.pop()
    2
    >>> s.pop()
    4
    >>> s.is_empty()
    True
```

Marking scheme

- **1 mark** for a reasonable English description.
  - Note that students don't need to explicitly state that all other Stack elements remain unchanged.
- **1 mark** for a correct precondition.
  - A precondition that only says "non-empty" (i.e., size ≥ 1) does not get this mark.
  - "Size ≥ 3" (off-by-one) is okay.
- **2 marks** for a good doctest.
  - For full marks, students must show in the doctest that the very bottom of the stack has changed.
  - Students *don't* need to do a call to `is_empty` at the very end.
  - Give **at most 1 mark** here if students access a private attribute like `_items`.

```
    """
    one = s.pop()
    temp = Stack()
    while not s.is_empty():
        temp.push(s.pop())
```

```
two = temp.pop()
s.push(one)
while not temp.is_empty():
    s.push(temp.pop())
s.push(two)
```

3. **[9 marks]** You are responsible for designing a class to keep track of a simple guessing game in which people enter guesses for the number of jellybeans in a jar. The winner of the game is the one whose guess is closest to the actual number of jellybeans.

   Here is an example of how we want to use it:

```
>>> g = JellyBeanCompetition(1000)     # There are 1000 jellybeans in the jar.
>>> g.record_guess('homer', 'doh@gmail.com', 20)
>>> g.record_guess('marge', 'blue@gmail.com', 800)
>>> g.record_guess('lisa', 'sax@gmail.com', 1002)
>>> g.record_guess('bart', 'cow@gmail.com', 1500)
>>> g.winner()
sax@gmail.com
```

   Below and on the next page, we have a very incomplete class design for this class. You have tasks marked 'TODO' in the code:

   - Document all the **attributes** of the `JellyBeanCompetition` class. You may choose any reasonable way to store the necessary data. Make all attributes private.
   - Implement the class initializer so that it is compatible with the example code above.
   - Complete the docstring for `winner`, and implement the method. It's up to you to decide what happens when there are multiple guesses that are the closest to the correct number of jellybeans.

   Note: you do *not* need to write any documentation or code for `record_guess`; assume this has been implemented properly to be consistent with the above code and the attributes you've chosen.

Solution

```
class JellyBeanCompetition:
    """A competition for guessing the number of jelly beans in a jar.

    === Attributes ===
    _correct_count
      The actual number of jelly beans in the jar.
    _guesses
      The guesses that have been made.  Each guess
      is represented by a tuple consisting of the
      guesser's name, email address, and their guess.
      The guesses are in order according to when they
      were recorded, with the most recent guess last.
    """
    _correct_count: int
    _guesses: List[Tuple[str, str, int]]
```

Solution

```
def __init__(self, count: int) -> None:
    self._guesses = []
    self._correct_count = count

def winner(self) -> None:
    """Print the email address of the winner of this jellybean competition.
    The winner is the person whose guess is closest to the actual number of jellybeans.

    Precondition: there is at least one guess in the competition.

    **If there is more than one winner, only print out the email address of the
    one who made the guess earliest.**
    """
    # Assumes there is at least one guess.
    best_i_so_far = 0
    best_diff_so_far = abs(self._correct_count - self._guesses[0][2])
    for i in range(len(self._guesses)):
        next_diff = abs(self._correct_count - self._guesses[i][2])
        if next_diff < best_diff_so_far:
            best_diff_so_far = next_diff
            best_i_so_far = i
    print(self._guesses[best_i_so_far][1])
```

Marking scheme

Note that there are many possible ways to keep track of this data, including keeping parallel lists/dictionaries of guess values and emails. We've only provided one possible solution.

- **3 marks** good choice and documentation of attributes.
  - Give **1 mark** for tracking the correct number of jellybeans, **2 marks** for tracking guesses.
  - Generally deduct **1 mark** if the attribute descriptions are unclear. Deduct **2 marks** if there are no descriptions at all, but you can guess what the students mean with the attribute names. Otherwise deduct all 3 marks.
  - Don't penalize students if they do not keep track of names of the people making the guesses.
- **1 mark** for correct type annotations for the attributes.
- **2 marks** for correct implementation of the initializer.
  - No type contract is necessary.
  - Give **at most 1 mark** if there are documented attributes that are not initialized, or attributes that are initialized but not documented.
  - Give **at most 1 mark** if the signature does not match the sample usage.
    However, students may use optional arguments (we haven't covered this in lecture, but it's okay).
- **2 marks** for an implementation of `winner` that correctly prints the right email address when there's only one winner.
  - Remember that students may assume there's at least one guess.
  - Give **at most 1 out of 2** if students initialize a "closest guess" variable that is a large constant, e.g. 10000.
  - This implementation *must* be consistent with their choice of attributes. If it isn't (or if their attributes are incomplete), they'll generally get **0 marks** for this part.
  - Students *may* use the built-in `min` function here, but it's tricky to do so, so don't be afraid to give **at most 1 out of 2** for incorrect uses.
  - Note that the winner's *email address* (not name) should be *printed* (not returned). If students make either error, give **at most 1 out of 2**.
- **1 mark** for describing a reasonable choice for handling ties, and a consistent implementation.
  - Alternatives to the sample solution: break ties based on the person's *name*; print all winner emails.
  - Students *may* be vague here and say something like "one winner is (arbitrarily) chosen to have their email printed." This is the easiest choice.
  - If students want to print all winner emails, they'll likely use a list to keep track of all "best so far" emails.
  - Give **0.5 marks** if the implementation is not consistent with the description. Give **0 marks** here if no description is given.
- Alternate strategy: rather than keep track of all guesses, just keep track of the best guess(es) so far. This puts the interesting code in `record_guess` and so makes the problem easier, but you can still give full marks.
- If students use another class, they *must* document the attributes of that class as well. Otherwise students generally get **1 out 3** for "attribute descriptions" above.
- Sample alternate implementation of `winner`:

```
best_guess = min(self._guesses, key=lamabda g: abs(self._correct_count - g[2]))
print(best_guess[1])
```

4. [**7 marks**] Implement the following function according to its docstring.

   For this question, you should refer to the documentation of the `LinkedList` class found on the aid sheet. You may use all attributes (public and private) of the `LinkedList` and `_Node` classes, and you may use their initializers. You may not use any other linked list methods.

```
def swap(lst: LinkedList, i: int, j: int) -> None:
    """Swap the values stored at indexes <i> and <j> in the given linked list.

    Precondition: i and j are >= 0.

    Raise an IndexError if i or j (or both) are too large (out of bounds for this list).

    NOTE: You don't need to create new nodes or change any "next" attributes.
    You can implement this method simply by assigning to the "item" attribute of existing nodes.

    >>> linky = LinkedList([10, 20, 30, 40, 50])
    >>> swap(linky, 0, 3)
    >>> str(linky)
    '[40 -> 20 -> 30 -> 10 -> 50]'
    """
```

Solution

```
    # Go to the node at index i.
    curr_i = lst._first
    curr_index = 0
    while curr_i is not None and curr_index < i:
        curr_i = curr_i.next
        curr_index += 1

    # Go to the node at index j.
    curr_j = lst._first
    curr_index = 0
    while curr_j is not None and curr_index < j:
        curr_j = curr_j.next
        curr_index += 1

    if curr_i is None or curr_j is None:
        # At least one of i and j is out of bounds
        raise IndexError
    else:
        # Both nodes are in bounds; swap their items.
        curr_i.item, curr_j.item = curr_j.item, curr_i.item
```

Marking scheme

- **2 marks** for using a loop to iterate to one of node i or node j correctly, when the index is in bounds.
- **1 mark** for iterating to the other node with a separate variable.
  - Don't give this mark if students assume $i < j$ (or vice versa), and so fail to iterate to the other node.
  - Also don't give this mark if students try to use the same variable to track both nodes (this won't lead to a correct solution, even if they store one or both *items* in variables).
- **2 marks** for raising an `IndexError` when appropriate.

  - Note that this can happen inside the loops or after them; multiple solutions exist.
  - Give **1 mark** if the logic is partially correct (e.g., only check out-of-bounds for one index).
- **2 marks** for doing a correct swap.
  - The actual code is quite simple. Though if students don't use multiple assignment then they must use a temporary variable to do the swap; otherwise, deduct at least **1 mark**.
  - You can give full marks if students create new nodes or mess around with links; however, such solutions will likely be more complicated, so we recommend leaving them aside at first.

Use this page for rough work. If you want work on this page to be marked, please indicate this clearly *at the location of the original question.*

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