UNIVERSITY OF TORONTO
Faculty of Arts and Science

Midterm Test CSC148H1F

Duration: 110 min. Instructor(s): David Liu. **Examination Aids**: Provided aid sheet

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 **5** questions. There are a total of **10 pages, DOUBLE-SIDED**.
- **DO NOT** open or turn over the exam paper until the exam has started.
- You may always write helper functions unless asked not to.
- Documentation is *not* required unless asked for.
- Answer questions clearly and completely. Provide justification unless explicitly asked not to.

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		8
Q3		9
Q4		7
Q5		7
Total		40

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.*

1. **[9 marks] Short answer.** You may answer the following questions in either point form or full sentences; *you do not need to write much to get full marks*!

   (a) **[1 mark]** Name two different **immutable** data types in Python.

   (b) **[1 mark]** Name two different **mutable** data types in Python.

   (c) **[1 mark]** In Python, what convention do we use to indicate that an instance attribute or method is *private*?

   (d) **[1 mark]** Name one abstract class we have used in this course (e.g., from a lecture, lab, prep, or assignment).

   (e) **[1 mark]** Why should client code never instantiate an abstract class directly?

   (f) **[2 marks]** Suppose we have a variable `curr` that refers to a `_Node` in a linked list. Write a Python expression that evaluates to `True` if `curr` refers to the *second-last* node in a linked list, and `False` otherwise. (You should not assume anything about the linked list, other than `curr` refers to a node in it.)

   (g) **[2 marks]** Suppose in Python we have a built-in array-based list of length 1,000,000, and a linked list of length 1,000,000. If we insert a new item at index 500,000 into each list, would it be:

   - significantly faster for the array-based list
   - significantly faster for the linked list
   - roughly the same amount of time for both lists

   Circle one of the three options, and then **explain your answer**:

2. [**8 marks**] **Object-oriented design.** You are responsible for creating a class to represent a user in an online messaging system. In this system, every user has a username, email address, and a history of all of the messages they have received from each user, in the *reverse* order in which they were received. Here is an example of how we want to use this class.

```
>>> david = User('david123', 'david@gmail.com')
>>> diane = User('dianehorton', 'diane@gmail.com')
>>> jacqueline = User('the_chairman', 'jacqueline@gmail.com')
>>> david.message(diane, 'Hi, how are you?')  # david sends a message to diane.
>>> diane.message(david, 'I am great! How are you?')
>>> david.message(diane, 'Good---although I could use some more sleep.')
>>> diane.get_messages(david)  # The messages diane received from david, in reverse order.
['Good---although I could use some more sleep.', 'Hi, how are you?']
>>> diane.get_messages(jacqueline)
[]
```

Below and on the next page is a very incomplete class design. You have tasks marked `TODO` in the code:

(a) [**2 marks**] Document all the *instance attributes* of the `User` class. You may choose any reasonable way to store the necessary data, and may make all attributes public.

(b) [**3 marks**] Implement `User.__init__` so that it is compatible with the example code and your chosen attributes.

(c) [**3 marks**] Complete the implementations for `User.message` and `User.get_messages`.

You may assume that all usernames and email addresses are unique.

```
class User:
    """A user in an online messaging system.
    === Attributes ===
    # TODO: Describe all instance attributes here.







    """
    # TODO: Write type annotations for your attributes here.
    # TODO: Implement User.__init__ here.
    # The method header must include a type contract, but a docstring is NOT required.
```

```
    # TODO: Implement this method.
    def message(self, recipient: User, text: str) -> None:
        """Send a message from this user to <recipient> with the given text."""
```

```
    # TODO: Implement this method.
    def get_messages(self, sender: User) -> List[str]:
        """Return a list of the messages this user received from <sender>.

        The messages should be returned in the REVERSE order in which they were received.
        """
```

3. [**9 marks**] **Stacks and queues.**

   (a) [**1 mark**] Here is the docstring of a function that operates on a stack. Read it and complete the doctest.

```
def keep_top(stack: Stack) -> None:
    """Remove all items except the top one from the given stack.
    Precondition: <stack> has at least one item.

    >>> s = Stack()
    >>> s.push(10)
    >>> s.push(20)
    >>> s.push(30)
    >>> keep_top(s)
    >>> s.pop()       # TODO: fill in the return value of s.pop() here.



    >>> s.is_empty()
    True
```

   (b) [**2 marks**] Here is an *incorrect* implementation of this function.

```
def keep_top(stack: Stack) -> None:
    top_item = stack.pop()
    while not stack.is_empty():
        stack.pop()
        stack.push(top_item)
```

   Explain: **(1)** what happens when we run the above doctest using this implementation, and **(2)** why this occurs.

   (c) [**2 marks**] Here is another *incorrect* implementation of this function.

```
def keep_top(stack: Stack) -> None:
    new_stack = Stack()
    top_item = stack.pop()
    new_stack.push(top_item)
    stack = new_stack
```

   Explain: **(1)** what happens when we run the above doctest using this implementation, and **(2)** why this occurs.

(d) [**1 mark**] Suppose we have a `Queue` implementation that uses a Python (array-based) list, where the front of the list represents the front of the queue.

Based on this implementation, which operation do we generally expect to take *longer* (circle one):

`Queue.enqueue` `Queue.dequeue`

Explain (answers without an explanation will not receive credit):

(e) [**3 marks**] Consider the following function:

```
def send_to_back(queue: Queue, k: int) -> None:
    """Send the first <k> items in the given queue to the end of the queue.

    Preconditions:
        k >= 1, and <queue> has at least k items
    """
    for i in range(k):
        item = queue.dequeue()
        queue.enqueue(item)
```

Suppose we use the same `Queue` implementation as described in part (d). Let n be the size of `queue`. Calculate the total number of times an item is shifted in a Python `list` when we call `send_to_back(queue, k)`, in terms of n and/or k. *Answers without an explanation will not receive credit.*

Note: We will not deduct marks for off-by-one errors here.

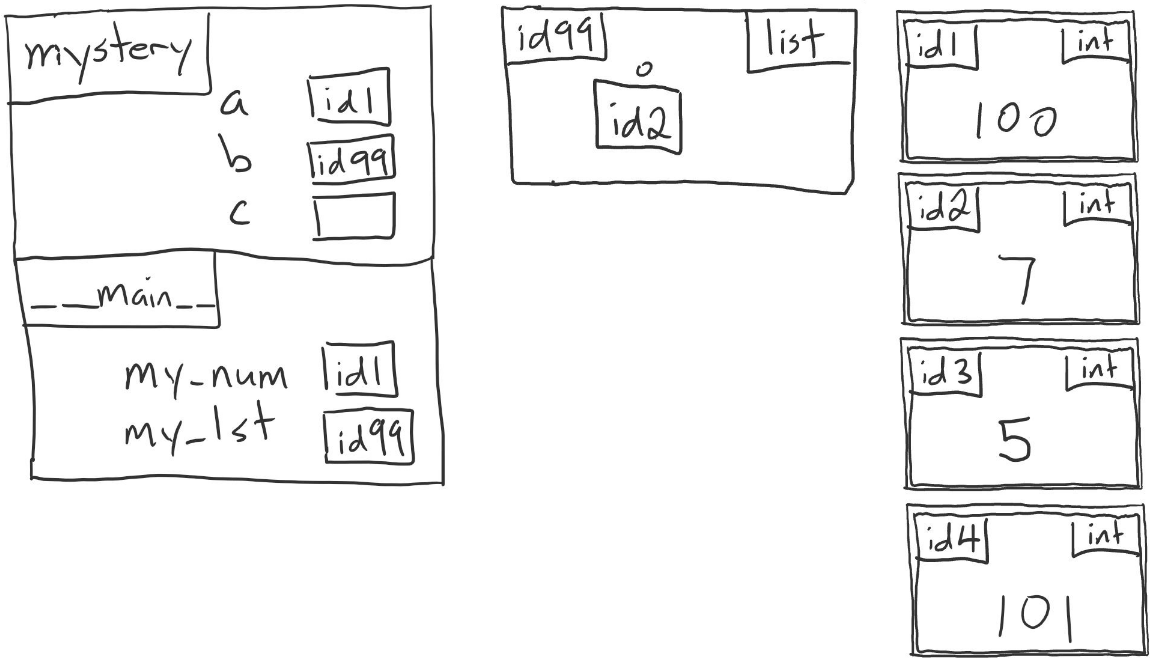
4. [**7 marks**] **Memory model diagrams.** Here is a short Python program.

```
def mystery(a: int, b: List[int]) -> None
    c = b
    c.append(a)
    a = a + 1
    b = [5]

if __name__ == '__main__':
    my_num = 100
    my_lst = [7]
    mystery(my_num, my_lst)
```

(a) [**5 marks**] The memory model diagram below shows the state of this program's memory when `mystery` is called, but before the first line of its body has been executed.

Modify this diagram to show the state of this program's memory *immediately before the function returns* (i.e., just after executing `b = [5]`). We have provided all the `int` objects you should need for your diagram.



(b) [**2 marks**] Write down the values of `my_num` and `my_lst` *after* `mystery` returns. (We're asking for their *values*, not their ids!)

`my_num`

`my_lst`

5. **[7 marks] Linked lists.** Implement each of the following `LinkedList` methods. You may not use *any* `LinkedList` methods in your implementation; we are looking for you to work with nodes directly.

   Please refer to the provided aid sheet for documentation for the `LinkedList` and `_Node` classes.

   For each method, we have provided a part of the implementation for you already. You *must* use this as a starting point for your solution.

   (a) **[3 marks]**

```
def average(self) -> float:
    """Return the average of the numbers in this linked list.

    Preconditions:
        - this linked list is not empty
        - all items in this linked list are numbers

    >>> lst = LinkedList([10, 15])
    >>> lst.average()
    12.5
    """
    curr = self._first

    # Initialize any other variables here.



    while curr is not None:



        curr = curr.next

    # Return the average after the loop ends.
    # (You may need to do some other calculations first.)



    return
```

(b) [**4 marks**] For this method, you can, and should, create new `_Node` objects.

```
def intersperse(self, other: LinkedList) -> None:
    """Insert the items of <other> in between the items of this linked list.

    Each item in <other> is inserted immediately after the corresponding item in <self>.
    Do not mutate <other> (this includes any of its nodes).
    See the doctest below for an example.

    Precondition: <self> and <other> have the same length.

    >>> lst1 = LinkedList([1, 2, 3])
    >>> lst2 = LinkedList([10, 20, 30])
    >>> str(lst1)                        # before
    '[1 -> 2 -> 3]'
    >>> lst1.intersperse(lst2)
    >>> str(lst1)                        # after
    '[1 -> 10 -> 2 -> 20 -> 3 -> 30]'
    """
    curr1 = self._first
    curr2 = other._first


    # NOTE: You should do all of your work *inside* the while loop.
    # It is up to you to complete the while loop condition and its body.


    while









        curr1 =


        curr2 =
```