CS 1110 Prelim 2, April 2023

This 90-minute closed-book, closed-notes exam has 7 questions worth a total of roughly 90 points (some point-total adjustment may occur during grading). Pace yourself accordingly.
You may separate the pages while working on the exam; we have a stapler available.

It is a violation of the Academic Integrity Code to look at any exam other than your own, to look at any reference material besides the reference provided in the exam itself, or to otherwise give or receive unauthorized help.
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Signature: ______________________________ Date ____________

Name (First Last): ______________________________

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This is a comprehensive reference sheet that might include functions or methods not needed for your exam.

String methods	
`s[i:j]`	Returns: if `i` and `j` are non-negative indices and `i` $\leq$ `j-1`, a new string containing the characters in `s` from index `i` to index `j-1`, or the substring of `s` starting at `i` if `j` $\geq$ `len(s)`
`s.count(s1)`	Returns: the number of times `s1` occurs in string `s`
`s.find(s1)`	Returns: index of first occurrence of string `s1` in string `s` (-1 if not found)
`s.find(s1,n)`	Returns: index of first occurrence of string `s1` in string `s` STARTING at position n. (-1 if `s1` not found in `s` from this position)
`s.index(s1)`	Returns: index of first occurrence of string `s1` in string `s`; raises an error if `s1` is not found in `s`.
`s.index(s1,n)`	Returns: index of first occurrence of string `s1` in string `s` STARTING at position n; raises an error if `s1` is not found in `s` from this position
`s.isalpha()`	Returns: `True` if `s` is *not empty* and its elements are all letters; it returns `False` otherwise.
`s.isdigit()`	Returns: `True` if `s` is *not empty* and its elements are all numbers; it returns `False` otherwise.
`s.islower()`	Returns: `True` if `s` is has at least one letter and all letters are lower case; returns `False` otherwise (*e.g.*, 'a123' is `True` but '123' is `False`).
`s.isupper()`	Returns: `True` if `s` is has at least one letter and all letters are upper case; returns `False` otherwise (*e.g.*, 'A123' is `True` but '123' is `False`).
`s.lower()`	Returns: a copy of `s`, all letters converted to lower case.
`s.join(slist)`	Returns: a string that is the concatenation of the strings in list `slist` separated by string `s`
`s.replace(a,b)`	Returns: a *copy* of `s` where all instances of `a` are replaced with `b`
`s.split(sep)`	Returns: a list of the "words" in string `s`, using `sep` as the word delimiter (whitespace if `sep` not given)
`s.strip()`	Returns: copy of string `s` where all whitespace has been removed from the beginning and the end of `s`. Whitespace not at the ends is preserved.
`s.upper()`	Returns: a copy of `s`, all letters converted to upper case.

List methods	
`lt[i:j]`	Returns: if `i` and `j` are non-negative indices and `i` $\leq$ `j-1`, a new list containing the elements in `lt` from index `i` to index `j-1`, or the sublist of `lt` starting at `i` if `j` $\geq$ `len(s)`
`lt.append(item)`	Adds `item` to the end of list `lt`
`lt.count(item)`	Returns: count of how many times `item` occurs in list `lt`
`lt.index(item)`	Returns: index of first occurrence of `item` in list `lt`; raises an error if `item` is not found. (There's no "find()" for lists.)
`lt.index(y, n)`	Returns: index of first occurrence of `item` in list `lt` STARTING at position `n`; raises an error if `item` does not occur in `lt`.
`lt.insert(i,item)`	Insert `item` into list `lt` at position `i`
`lt.pop(i)`	Returns: element of list `lt` at index `i` **and also removes that element from the list** `lt`. Raises an error if `i` is an invalid index.
`lt.remove(item)`	Removes the first occurrence of `item` from list `lt`; raises an error if `item` not found.
`lt.reverse()`	Reverses the list `lt` in place (so, `lt` is modified)
`lt.sort()`	Rearranges the elements of `x` to be in ascending order.

Dictionary Operations	
`d[k] = v`	Assigns value `v` to the key `k` in `d`.
`d[k]`	If value `v` was assigned to the key `k` in `d`, `d[k]` evaluates to `v`.
`del d[k]`	Deletes the key `k` (and its value) from the dictionary `d`.
`d.keys()`	**Returns**: an iterator of all the keys in dictionary `d`.
`d.values()`	**Returns**: an iterator of all the values in dictionary `d`.

Other useful functions	
`s1 in s`	Returns: `True` if the substring `s1` is in string `s`; `False` otherwise.
`elem in lt`	Returns: `True` if the element `elem` is in list `lt`; `False` otherwise.
`y in d`	Returns: `True` if `y` is a key in dictionary `d`; `False` otherwise.
`y in d.values()`	Returns: `True` if `y` is a value in dictionary `d`; `False` otherwise.
`input(s)`	prompts user for a response using string `s`; returns the user's response as a string.
`isinstance(o, c)`	Returns: `True` if `o` is an instance of class `c`; `False` otherwise.
`len(s)`	Returns: number of characters in string `s`; it can be 0.
`len(lt)`	Returns: number of items in list `lt`; it can be 0.
`len(d)`	Returns: number of keys in dictionary `d`; it can be 0.
`list(range(n))`	Returns: the list `[0 .. n-1]`

1. [8 points] **Iteration over lists.** Implement this function, making effective use of for-loops.

```python
def floor_divide_lists(numers, denoms):
    """Performs floor division across two lists of ints.
    Returns a new list. Each element of this new list is the string of the
    floor division result of dividing each int in the numers (numerators)
    list by its corresponding int in the denoms (denominators) list.

    Recall that floor division -- `//` -- is an integer operation that
    yields the integer that is less than or equal to the standard
    division -- '/' -- result.
    Examples: 1//2 --> 0, 2//2 --> 1, 3//2 --> 1, 4//2 --> 2

    Note:
      - The new list should be a list of STRINGS; each string is the
        string representation of the int resulting from the floor division
      - In case of dividing by 0, put 'E' (for 'Error') at the corresponding
        position in the resulting list.

    Return: a (possibly empty) list of str

                Example 1                Example 2               Example 3
       numers is [0,  12,  4]      numers is [9,   1,   6]     numers is []
       denoms is [7,   3,  3]      denoms is [0,   3,   3]     denoms is []
       return   ['0', '4','1']     return   ['E', '0', '2']    return    []

    Preconditions:
       numers: a (possibly empty) list of int
       denoms: a (possibly empty) list of int
       len(numers) == len(denoms), length can be 0                    """
    # STUDENTS: assume preconditions are met. No need to assert them.
```

2. [12 points] **Iteration over dictionaries.** Implement this function, using for-loops effectively.

```
def invert_dict(input_dict):
    """ Given:
          `input_dict` with the following properties:
          - the keys are characters a-z and ' '
          - values are ints

    Returns: the inverse of input_dict
    a new dictionary with the following properties:
    - the keys are the int values found in `input_dict`
    - the values are lists of letters that correspond to that int in `input_dict`
      (the letters in the lists can be in any order)

    EXAMPLES:
    {'a': 2, 'b': 1, 'c': 3, ' ': 5} → {2: ['a'], 1: ['b'], 3: ['c'], 5: [' ']}
    {'a': 2, 'b': 2, 'c': 3, ' ': 5} → {2: ['a', ‘b’], 3: ['c'], 5: [' ']}
    {'a': 2, 'b': 2, 'c': 2, ' ': 2} → {2: ['a', 'b', 'c', ' ']}
    {} → {}

    Precondition: input_dict is a possibly empty dictionary that will only have:
    - characters a-z or space as keys
    - ints as values
    """
    # STUDENTS: assume preconditions are met. No need to assert them.
```

3. **Lists and indexing** The variable `mylist` is successfully initialized as follows:

```
mylist = [ [ [ [ 1 ], 1, 2, 3] ], [2, 5, 6], [7] ]
```

After this initialization, what do the following Python expressions evaluate to? Write ERROR if evaluating the expression causes Python to throw an error. Assume each expression is evaluated independently.

(a) [2 points] `mylist[0][0].index(1)` evaluates to

(b) [2 points] `mylist[1][2]` evaluates to

(c) [2 points] `mylist[1][1][1]` evaluates to

4. [14 points] **Recursion.** Let `Worker` be a class whose objects have the following two attributes:

```
name    [str] - unique non-empty name of worker
reports [list of Worker] - (possibly empty) workers who report directly
    to this worker instance, who acts as the manager for these reports.
```

A Implement the following **function** (not a class method), making effective use of recursion. For-loops are allowed as long as your solution is fundamentally recursive.

```
def calculate_salary(w):
    """Returns: the salary of worker `w` where workers make $50,000 by default,
    and managers make $10,000 more than the best paid worker that reports to them.

    Parameter w: the worker whose salary is to be calculated
    Precondition: w is an Worker object

    Example:                               Carlos
                                           /   \
    w1 = Worker("Ricky", [])             Rene  Draco
    w2 = Worker("Johnny", [w1])           |
    w3 = Worker("Rene", [w2])           Johnny
    w4 = Worker("Draco", [])              |
    w5 = Worker("Carlos", [w3, w4])     Ricky

    calculate_salary(w1) and calculate_salary(w4) Returns 50000
        because these 2 workers do not manage anyone (they have no reports)
    calculate_salary(w2) Returns 60000
    calculate_salary(w3) Returns 70000
    calculate_salary(w5) Returns 80000
        because Rene is the best paid of Carlos' 2 reports,
        so Carlos makes 10000 more than Rene                           """
    # STUDENTS: assume preconditions are met. No need to assert them.
```

5. [20 points] **Simulating Python Execution.** Diagram the execution of each line of code until Python reaches the comment `# STOP HERE` which would stop the code in the middle of the first iteration of the for loop. Draw the memory diagram as seen in class and Assignment 5. (As usual, do not draw the objects/folders for imported modules or for function definitions.) Include global variables, class folders, object folders and call frames. Pay attention to what goes in the **Global Space** / **Call Stack** / **Heap**. If a value changes, cross out the old value so that it remains legible. (Do not erase the old value.) This code runs without error. We have provided a skeleton of a Class and Object folder for you to use. Please use them.

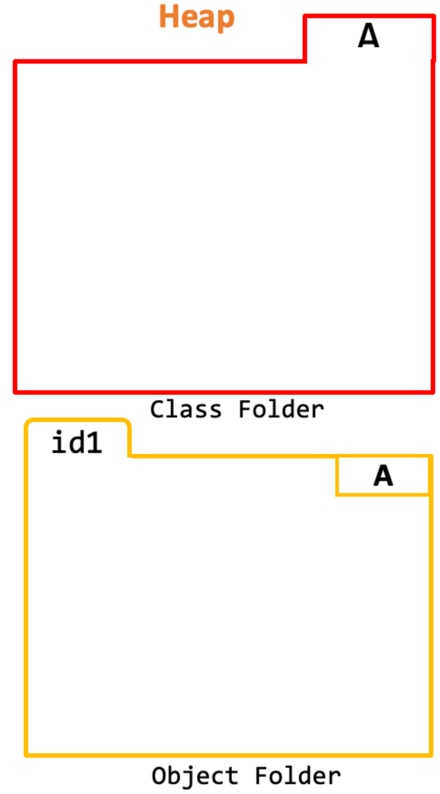
```python
class A:
    x = 1
    y = 10

    def __init__(self, x, y):
        self.x = y + 1
        A.y = x - 1
        z = self.y

    def g(self):
        silly = [self]
        for s in silly:
            x = s.x
            # STOP HERE
            s.x = y
        return s.y
x = 6
y = 4
e = A(y,x)
e.y = A.x
w = e.g()
```

Global Space

Heap



Call Stack

6. **Classes.** Consider the following class, defined as follows:

```
class LapTime:
    """Represents a runner's time for a single lap around a track.
    Each runner has at most one LapTime object for each lap they complete.

    Attributes:  name: [string] the name of the runner
                 lap:  [int] >= 0, representing the lap number
                 time: [float] >= 0.0, time taken to complete the lap in seconds
    """
    def __init__(self, name, lap_num, time):
        """Initializes a LapTime object
           Preconditions: name is a string,
                          lap_num is an int >= 0
                          time is a float >= 0.0                             """
        self.name = name
        self.lap = lap_num
        self.time = time
```

(a) [5 points] Override the following special method of `LapTime` according to its specification.

```
def __lt__(self, other):
    """Compares two LapTimes of the same lap around the track
    (LapTimes of the same lap have the same value for their lap attribute)

    Returns True if this LapTime is less than (i.e., faster than) the other
    LapTime or if the other LapTime is None. Otherwise returns False.

    Precondition: other is either a LapTime object representing the same
    lap around the track as as self or None                                """
    # STUDENTS: assume preconditions are met. No need to assert them.
```

(b) [5 points] Complete the following test which asserts a case for which your implementation of `__lt__` should return `True`.

```
t1 = LapTime(_________________________________________)

t2 = LapTime(_________________________________________)

expected = True
assert_equals(expected, __________________________________)
```

(Classes, cont'd) Now we introduce a second class, defined as follows:

```
class Tracker:
    """Records the best lap times of runners in a training session.
    Attributes:
    runner_times: dictionary whose keys are names of runners (string) and
                  values are lists of LapTime objects. Each LapTime object
                  corresponds to the runner's performance for a certain lap.
    best_times: a list with one entry per lap. The element at index i contains
                either None or the LapTime object of the best performance for
                Lap i (across all runners) that have been added to the Tracker.
    """
    def __init__(self, max_laps):
        """Initializes Tracker object self.
              runner_times: set to an empty dictionary
              best_times: a list of length max_laps, containing all Nones

           Precondition: max_laps is an int > 0                             """
        self.runner_times = {}
        self.best_times = []
        for i in range(max_laps):
            self.best_times.append(None)
```

(c) [12 points] Override the following class method of `Tracker` according to its specification.

```
    def add_laptime(self, t):
        """Modifies this Tracker given a LapTime object t

        Adds t to the end of the corresponding runner's list in
        runner_times, or creates a new entry and list if necessary.
        If t represents a faster performance for its lap than the current
        entry for that lap in best_times, t should be added to best_times
        at the appropriate index

        Precondition: t is a LapTime object                             """
        # STUDENTS: assume preconditions are met. No need to assert them.
```

7. **Debugging.** Consider the following two classes and 3 lines of code that use them:

```python
class Course:
    def __init__(self, name, n_credit):
        name = name
        n_credit = n_credit

class Student:
    max_credit = 20

    def __init__(self, netID, courses=None):
        self.netID = netID
        self.courses = courses if courses is not None else []
        # ^^ this line has no error and is also not important to the question
        for one_course in self.courses:
            self.n_credit += one_course.n_credit # Add up all the credits

    def enroll(new_course):
        if new_course.n_credit + self.max_credit <= Student.n_credit:
            self.courses.append(new_course)
            self.n_credit += new_course.n_credit

c1 = Course("CS 1110", 4)
s1 = Student("mep1")
s1.enroll(c1)
```

When the given code is run in Python, the following error is reported:

```
Traceback (most recent call last):
  File "college.py", line 23, in <module>
    s1.enroll(c1)
TypeError: enroll() takes 1 positional argument but 2 were given
```

(a) [2 points] What are the 2 positional arguments that were given?

first argument:

second argument:

(b) [2 points] Fix the code to remove only the above error. **Fix only the code that directly leads to the above error message.** Mark your fix(es) with the label **FIX1**.

Now that you have fixed the error, you rerun the code and now a new error is reported:

```
Traceback (most recent call last):
  File "college.py", line 23, in <module>
    s1.enroll(c1)
  File "college.py", line 17, in enroll
    if new_course.n_credit + self.max_credit <= Student.n_credit:
AttributeError: 'Course' object has no attribute 'n_credit'
```

(c) [2 points] Fix the above code to remove only this new error. **Fix only the code that directly leads to the new error message.** Mark your fix(es) with the label **FIX2**.

(d) [2 points] Will your fixed code now run to completion without any reported Python errors?

Circle One: Yes No

If you answered No, circle or underline the source(s) of the next error that Python will report in the code. Label this as **ERR3**.