# CS 1110 review session for prelim 2, April 20, 2017

## SOLUTIONS version

Questions chosen because the solutions would be interesting to present — meaning that this set of questions together would be probably too hard/long to be all on a single prelim. On that note, we only plan to cover the first couple of questions in class; we included more questions just in case we somehow miraculously got through more questions than expected.

1. [ points] **Classes and objects. From 2014 Spring** The three classes `Course`, `Student`, and `Schedule` that are printed on a separate handout are part of the Registrar's new course enrollment database, which keeps track of which courses each student is enrolled in, and also which students are enrolled in each course. Two methods are not implemented: `Student.add_course` (line 92), which updates the database to reflect a student enrolling in a course, and `Student.validate` (line 101), which checks a student's schedule to make sure it follows the rules.

   Read the code to become familiar with the design and operation of these classes. Note that helper methods and a unit test included, which may help in understanding how these classes are used and in solving the problems below.

   After reading the code, implement the two incomplete methods by filling in your code below. Write your answers on this sheet, not on the code printout (where there is no space to fit your answer).

```
class Student(object):
    ...

    def add_course(self, course):
        """See the code for the specification."""
```

Solution:

```
        self.schedules[0].courses.append(course)
        course.students.append(self)


    def validate(self, credit_limit):
        """See the code for the specification."""
```

Solution:

```
        current_sem = self.schedules[0]
        # check for overlaps, return False if any
        for prev in self.schedules[1:]:
            if current_sem.overlaps(prev):
                return False

        # Now we know there are no overlaps
        return current_sem.total_credits() <= credit_limit
```

2. [ points] **Iteration and recursion on a sequence. From 2013 Spring**

The motivation for this problem is analyzing patterns in a sequence. We would argue that this is a case where recursion is more natural and easier to implement than use of a for-loop.

Finish the implementation of the following function; note that we have started it off for you. Your implementation must use a loop to determine the length of the first run of zeroes in the list `data`, and then use recursion to determine the final answer.

```
def max_zrun_length(data):
    """Returns:  length of the longest run of zeroes in data, which is a
    list of ints (possibly empty).

    Examples:  max_zrun_length([0,0,1,0,0,0]) is 3
    max_zrun_length([2,0,4,0,5]) is 1
    max_zrun_length([3,-2]) is 0
    max_zrun_length([]) is 0
    """
    if 0 not in data:
        return 0

    # now data is guaranteed to contain at least one 0
    i = data.index(0) # i is the position of the first 0
```

Solution:

```
    # Inv: data[i..j-1] is known to be 0, so j is the next place to check
    j = i + 1
    while j < len(data) and data[j] == 0:
        j += 1

    firstlength = j - i  # length of first run of zeroes.
    return max(firstlength, max_zrun_length(data[j:]))
    # data[j:] is empty if j == len(data)

########   Alternate solution: ################
    # inv: firstlength is length of run seen so far;
    #      i is index of last zero seen, so i+1 is next place to check
    firstlength = 1
    while i+1 < len(data) and data[i+1] == 0:
        firstlength += 1
        i=i+1
    return max(firstlength, max_zrun_length(data[i+1:]))
```

3. [ points] **Recursion on nested lists. From Spring 2014 lecture.** The printed handout was missing some closing brackets.

```
def embed(theinput):
    """Returns: depth of embedding, or nesting,  in theinput.

    Examples:
        "the dog that barked" -> 0
        ["the", "dog", "that", "barked" ] -> 1
        ["the" ["dog", "that", "barked"]] -> 2
        ["the" ["dog", ["that", "barked"]], ["was bad"]] -> 3
        ["the" ["dog", ["that", ["barked"]]]] -> 4
        [[[["the"], "dog"], "that"], "barked"] -> 4

    Precondition: theinput is a string, or a potentially nested
    non-empty list of strings. No component list can be empty"""
```

Solution: Solution using `map`. Recall that `map(f, alist)` returns the list `[f(alist[0]), f(alist[1]), ..., f(alist[len(alist)-1])]`.

```
    if type(theinput) != list: # no sub-lists to check
        return 0
    else:
        return 1 + max(map(embed, theinput))
```

Solution using for-loop instead of `map`:

```
    if type(theinput) != list:
        return 0

    # sublists to account for
    sublist_max = 0
    for item in theinput:
        sublist_max = max(sublist_max, embed(item))
    return 1 + sublist_max
```

4. [ points] **Recursion on object structures. Modified from 2014 spring.** Assume we have written a definition for class Node where each node has a contacted_by attribute consisting of a (possibly empty) list of nodes that have contacted it.[1] This question asks you to add a new method for class Node; implement it according to its specification. Your solution must make effective use of recursion, though it can involve for-loops as well.

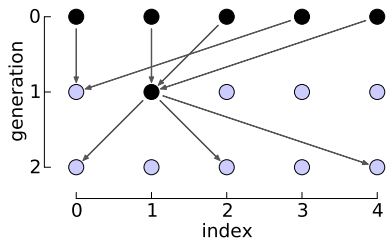
```
class Node(object):

    ...
    def is_downstream_from(self, older):
        """Returns True if: older is in this node's contacted_by list, OR if
           at least one of the nodes in this node's contacted_by list is
           downstream from older.  Returns False otherwise.
           Pre: older is a node.
        """
```

Solution:

```
if older in self.contacted_by:
    return True
else:
    # if self.contacted_by is [], the for-loop never happens
    for contacter in self.contacted_by:
        if contacter.is_downstream_from(older):
            return True
# If we get to this line, no contacter was downstream of older
return False
```

*Example:* In the figure below, (2,0) is downstream from (0,1), (0,2), (0,4), and (1,1), but no other nodes. (If you are looking at this after 2014 spring, note that you don't need to know what "generation" and "index" refer to in the figure.)




[1] And we know that anything in a node's contacted_by list is from an earlier "generation". This is a technical condition that prevents the possibility of cycles in the node contacting.

5. [ points] **Broken invariant. From Spring 2013.**

The version on the printed handout was probably too difficult for where we are in class this semester. This version has been made easier.

Your friend gave you the following function, which is annotated with loop invariants and post-conditions.

```
def even_first_A(x):
    """Organize the list <x> so that even numbers precede odd numbers.
    Pre: x is a list of integers."""
    i = 0
    j = len(x)-1
    # Inv: x[..i-1] are all even; x[j+1..] are all odd
    while j != i+1:
        if x[i] % 2 == 0:
            i = i + 1
        else:
            x[i],x[j] = x[j],x[i]
            j = j - 1
    # Post: x[..i-1] are all even; x[i..] are all odd
```

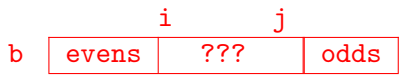
Your friend claims that their code is correct. Now, it is true that their invariants are fine. However, this code fails its test cases, and one potential issue is that it fails to conform to the invariant.

We guarantee that the body of the while-loop is correct. So either the initialization or the boolean expression in the while-loop is wrong with respect to the given invariant.

Your job: correct the function so that it agrees with the written invariant and postcondition, and thereby works correctly. Do so by changing **exactly one line**: cross out the offending line and then writing the correct version next to it.

Solution:

Here's a visualization of the invariant. The basic idea is that `i` and `j` are the next positions that need checking. (It's possible that `i` and `j` could be the same.)




So, the problem is that there is an incorrect stopping condition in the while-loop. For instance, we could have `i` being 6, and `j` being 7; in that case, we miss checking `x[6]` and `x[7]`.

Fix: change the loop "guard" in the while-loop to either `i<j+1`, or `i!=j+1` .

Note that "`i<=j+1`" as the loop condition fails on the empty list: at initialization we have $i = 0, j = -1$, so the loop would be entered, which we don't want.

Note that "`j != i`" as the loop condition *fails to agree with the postcondition*, even though the resultant code satisfies the spec! The issue is that there would be one position that we never

checked for even/odd-ness: `b[i]`. So, the post-condition would possibly be violated, because it could be that `x[i]` is even. That is, it's not necessarily the case that `x[i..]` are all odd, as stated by the post-condition. Or, to put it another way, with the line `while j!= 1`, the postcondition would actually be: `x[..i-1]` are all even; `x[i+1..]` are all odd

6. [ points] **Classes and Subclasses. Modified from Fall 2016 prelim 2.**

Meta-note, spring 2017: This problem isn't particularly interesting from a problem-solving standpoint. We included it on this handout simply so that you could see how Fall prelim questions of this sort would be modified for our semester.

You are to complete the skeleton of class ExoticPet, which is a subclass of Pet.

First, here are the specifications you need for class Pet; you don't need to know how its methods are implemented.

```
class Pet(object):
    """Instances represent a person's pet.

    MUTABLE ATTRIBUTES
        name:  The name of the pet [nonempty string]
        tag:  The license number for this pet [int >= -1]

    We use a tag value of -1 to indicate a pet without a license."""

    def __init__(self, name, tag = -1):
        """Initializer: Makes a pet have the given name and (optional) tag.

        Precondition: Parameter name is a nonempty string
        Precondition: Parameter tag is an int >= -1 (optional, default is
        -1)"""
        # Implementation omitted


    def __str__(self):
        """Returns:  A string representation of this pet.

        String is the pet name with the license number in parentheses.
        A pet with a tag of -1 is "unclaimed".

        Examples: 'Sparky (pet #43)' or 'Rover (unclaimed)'"""
        # Implementation omitted
```

What you have to do for the ExoticPet class definition:

1. Fill in the missing information in the class header.
2. Implement each method according to its specification.

```
class ExoticPet(          Pet          ):          # Fill in missing part
    """Instances represent a pet certified by a wild-life official.
    ATTRIBUTE (In addition to those from Pet):
        official:  The official certifying the pet [nonempty string] """


    def __init__(self, name, tag, official):
        """Initializer: Makes an exotic pet have name <name>, tag <tag>, and
        official <official>.
        In the case of an exotic pet, the tag is not optional and must be a
        value greater than -1.
        Precondition: Parameter name is a nonempty string
        Precondition: Parameter tag is an int >= 0
        Precondition: Parameter official is a nonempty string"""
        Pet.__init__(self,name,tag)
        self.official = official



    def __str__(self):
        """Returns: A string representation of this exotic pet
        The string is the same as for Pet, except that it also includes the
        official who certified the pet.
        Example: 'Tigger (pet #675); authorized by Sgt. O'Malley'"""
        result = Pet.__str__(self)
        result += '; authorized by ' + self.official
        return result
```