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# CS 1110 Final December 7th, 2012

This 150-minute exam has **??** questions worth a total of **??** points. Scan the whole test before starting. Budget your time wisely. Use the back of the pages if you need more space. You may tear the pages apart; we have a stapler at the front of the room.

**It is a violation of the Academic Integrity Code to look at any exam other than your own, to look at any other reference material, or to otherwise give or receive unauthorized help.**

You will be expected to write Python code on this exam. We recommend that you draw vertical lines to make your indentation clear, as follows:

```
def foo():
    if something:
        do something
        do more things

    do something last
```

Unless you are explicitly directed otherwise, you may use anything you have learned in this course.

Run LaTeX again to produce the table

**The Important First Question:**

1. [2 points] Write your last name, first name, and Cornell NetId at the top of each page.

Throughout this exam, there are several questions on sequences (strings, lists, and tuples). All sequences support slicing. In addition, you may find the following expressions below useful (though not all of them are necessary).

| Expression | Description |
|---|---|
| `len(s)` | Returns: number of elements in sequence `s`; it can be 0. |
| `x in s` | Returns: `True` if `x` is an element of sequence `s`; `False` otherwise. |
| `s.index(x)` | Returns: index of the FIRST occurrence of `x` in `s`.<br>Raises a `ValueError` if `x` is not found. |
| `s.rindex(x)` | Returns: index of the LAST occurrence of `x` in `s`.<br>Raises a `ValueError` if `x` is not found. |
| `s.count(x)` | Returns: number of times `x` appears in `s`. Could be zero |
| `s.append(x)` | (**Lists Only**) Adds `x` to the end of list `s`, increasing length by 1. |

2. [**??** points total] **Classes and Subclasses**
In Assignment 7 you got experience with `GRectangle` and `GEllipse` which extended `GObject`. They did not have any new attributes beyond those in `GObject`, but behaved very differently. This question deals with three very similar classes: `Shape`, `Rectangle`, and `Circle`.

   These classes are similar to those in A7 except for two very important details. First of all, there is no drawing code. More importantly **they do not use the advanced keyword arguments used by Kivy**. The expression `**keyword` should not appear anywhere in your solution.

   (a) [8 points] The skeleton for class `Shape` is provided on the next page. The attributes are immutable; you are to implement properties that enforce this. In addition, you should complete the constructor and method `__str__` according to their specification. Your constructor must enforce all invariants.

   (b) [10 points] You are to create the classes `Rectangle` and `Circle`, each of which is a subclass of `Shape`. We have not provided you with any skeleton code for these classes; you are to implement everything yourself.

   The classes **have no new attributes** beyond those inherited from `GObject`. For each class implement a constructor and one other method, according to the following constraints.

   - The constructor for `Rectangle` should have an header that looks exactly like the constructor for `Shape`, includeing default values. The body of this constructor should be a single line call to `super`.
   - The constructor for `Circle` should have three parameters: `x`, `y`, and `radius`. Using `super`, it should set the `width` and `height` attributes to the diameter ($= 2r$).
   - Both classes should have a method `calculateArea()`, which returns the area of the shape. For class `Circle`, you may use the constant `PI` in module `math`. Remember that the area of a circle is $\pi r^2$.

   You can assume that `math` is imported; you do not need to write an import statement in your code. Implement your classes on the blank page after the class `Shape`.

```
class Shape(object):
    """Instance is 2-dimensional geometric shape"""
    # IMMUTABLE ATTRIBUTES
    _x = 0.0 # x-coordinate of bottom-left corner; must be a float.
    _y = 0.0 # y-coordinate of bottom-left corner; must be a float.
    _width = 0.0 # shape width; must be a float >= 0.
    _height = 0.0 # shape height; must be a float >= 0.

    # DEFINE PROPERTY x for FIELD _x (specification not necessary)
    @property
    def x(self):
        return self._x


    # DEFINE PROPERTY y for FIELD _y (specification not necessary)
    @property
    def y(self):
        return self._y


    # DEFINE PROPERTY width for FIELD _width (specification not necessary)
    @property
    def width(self):
        return self._width


    # DEFINE PROPERTY height for FIELD _height (specification not necessary)
    @property
    def height(self):
        return self._height


    def __init__(  self, x=0.0, y=0.0, width=0.0, height=0.0  ):      # Fill in
        """Constructor: shape with given values x, y, width, and height (in order).
        Precondition: x, y, width, and height are floats with width, height >= 0.0.
        All parameters have a default of 0.0."""
        assert type(x) == float
        assert type(y) == float
        assert type(width) == float and width >= 0.0
        assert type(height) == float and height >= 0.0
        self._x = x
        self._y = y
        self._width = width
        self._height = height


    def __str__(self):
        """Returns: Description of shape geometry in format '[x,y,width,height]'.
        return ( '['+str(self.x)+sq,+str(self.y)+','+
                 str(self.width)+','+str(self.height)+']' )
```

(Answer Question ?? (??) here)

```
class Rectangle(Shape):
    """Instance is a rectangular shape"""
    def __init__(self, x=0.0, y=0.0, width=0.0, height=0.0):
        """Constructor: shape with given values x, y, width, and height (in order).
        Precondition: x, y, width, height are floats with width, height >= 0.0."""
        # Automatically enforces precondition
        super(Rectangle,self).__init__(x,y,width,height)


    def calculateArea(self):
        """Returns:  Area of this rectangle."""
        return self.width*self.height


class Circle(Shape):
    """Instance is a circular shape"""
    def __init__(self, x, y, radius):
        """Constructor: shape with given values x, y, and radius (in order).
        Precondition: x, y, radius are floats."""
        # Automatically enforces precondition
        super(Circle,self).__init__(x,y,radius*2,radius*2)


    def calculateArea(self):
        """Returns:  Area of this circle."""
        return math.pi*(self.width/2.0)*(self.width/2.0)
```

3. [?? points total] **Call Frames and Diagrams**

Suppose you were to modify class `Shape` to include the following method.

```
def contains(self,q):
    """Returns: True if point q is in this Rectangle; False otherwise.
    Precondition: q is a list [x,y]."""
    1   in_x = self.x < q[0] and q[0] < self.x+self.width
    2   in_y = self.y < q[1] and q[1] < self.y+self.height
    3   return in_x and in_y
```

Consider then the following python code.

```
rect = Rectangle(0.0,0.0,1.0,2.0)
circle = Circle(1.0,1.0,3.0)
shape = rect
p = [1.0, 2.0]
value = shape.contains(p)
```

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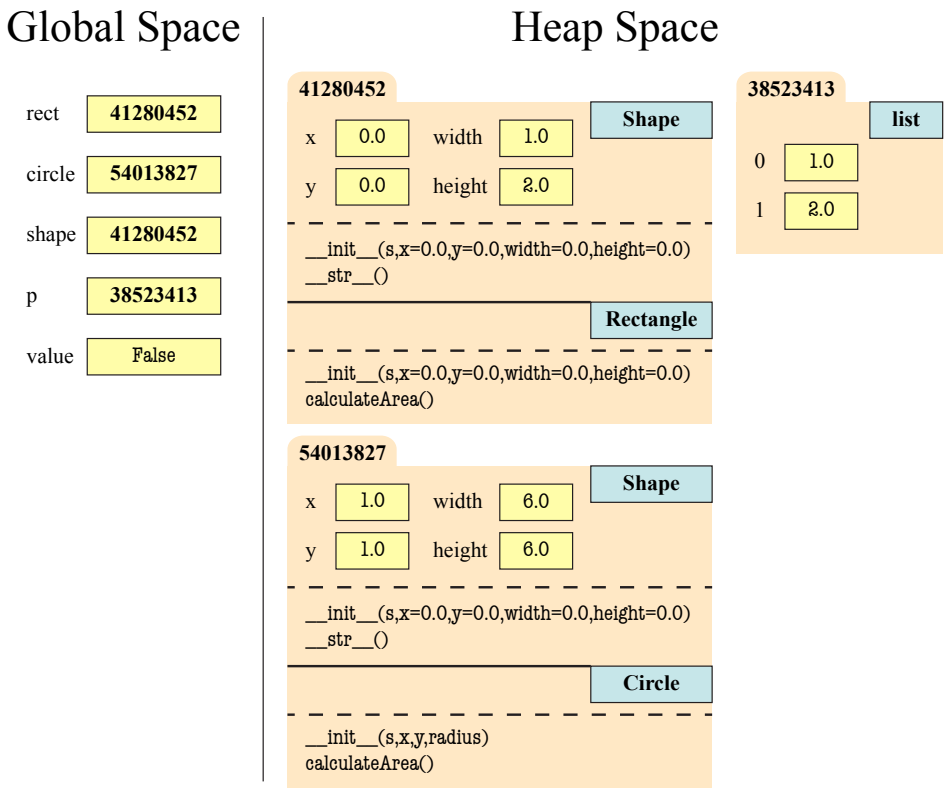
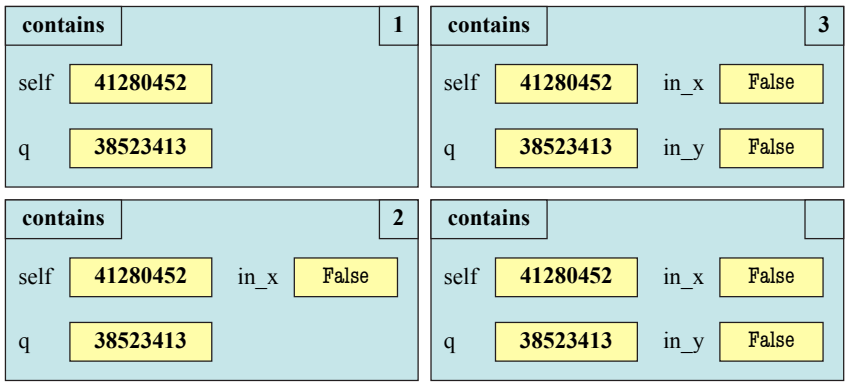
(a) [10 points] Execute the code on the previous page in global space. In other words you should draw all the variables in global space, as well as any folders created in heap space. Do not worry about call frames (yet). You do not have to draw the `object` partitions.




(b) [10 points] Draw your execution of the call `shape.contains(p)`. You will draw what the call frame looks like at four points in time: when the function starts, and once after it completes each of the line in the function. You do not need to redraw the folders for `shape` and `p`; simply use the folder names for your answer in part (`??`).



4. [14 points] **Recursion**

We want to compress strings that have long sequences of equal characters. For example, we want to compress `'bbbbaaa$$$$$$$$$$$$$$$d'` to `'b4a3$16d1'`. In the compression, each sequence of equal characters is given by the character followed by the length of the sequence. Write the function `compress` to do this. Use no loops; use only recursion. You may use the function `eq_chars` specifed below as a helper. **Do not implement** `eq_chars`.

**Hint**: The base case is not necessarily a string with one character.

```
def eq_chars(s,i):
    """Returns: length of sequence of equal characters starting at s[i].
    Examples: eq_chars('aaaxxyx',0) is 3 and eq_chars('aaaxxyx',5) is 1
    Precondition:  s is a string, 0 <= i < len(s)."""
```

```
def compress(s):
    """Returns: the compression of s, as explained above.
    Precondition:  s a nonempty string with no digits 0..9."""
    num = eq_chars(s,0)

    # BASE CASE
    if num == len(s):    # Only one character type
        return s[0]+str(num)


    # RECURSIVE CASE
    return s[0]+str(num)+compress(s[num:])
```

5. [?? points total] **Exceptions and Dispatch-on-Type**

In all of the questions below, you may assume that `ValueError` and `TypeError` are subclasses of `StandardError`, but neither is a subclass of the other.

(a) [9 points] Suppose you are given the following function definitions.

```
def first(n):
    x = 0
    try:
        x = second(n)
    except StandardError:
        x = x+1
    return x
```

```
def second(n):
    y = 2
    try:
        y = third(n)
    except ValueError:
        y = y+5
    return y
```

```
def third(n):
    if n == 0:
        raise ValueError()
    elif n == 1:
        raise TypeError()
    return n+10
```

Give the value of each function call below. If there is no value (e.g. program crashes), tell us that. To get full credit, **explain how how the call recovers from errors, if it recovers at all, with the line numbers provided**.

i. first(0)
Answer is 7. Call raises `ValueError` at 14, caught at 10. Assigns y = 2+5 = 7.

ii. first(1)
Answer is 1. Call raises `TypeError` at 16, caught at 4. Assigns x = 0+1 = 1.

iii. first(2)
Answer is 12. Call successfully completes `third` with value 2+10 = 12.

(b) [7 points] The method `__eq__` is used to define `==` on objects. When sorting objects, we need the comparison operators (e.g. `<`, `>`, `<=`, and `>=`). We implement these via the method `__cmp__` specified below. Implement this method for the class `Cornellian`, paying special attention to how it should handle errors.

```
class Cornellian(object):
    """Instance is a person at Cornell."""
    name = ''  # Name of person; a string in format 'last, first'
    netid = '' # Netid of person; a string of 2-3 letters and a number
    ...
    def __cmp__(self,other):
        """Returns: -1, 0, 1 indicating whether self is less than, equal to, or
        greater than other (e.g. -1 means self < other).
        Raises a TypeError if other is not an instance of Cornellian.
        To compare self and other, first compare names as strings. If names are
        equal, compare netids as strings. (Recall we can always compare strings
        with < and >). If both attributes are equal, return 0."""

        # Check that other has right type
        if not isinstance(other,Cornellian):
            raise TypeError()

        # Check names
        if self.name < other.name:
            return -1
        elif self.name > other.name:
            return 1

        # Check netids
        if self.netid < other.netid:
            return -1
        elif self.netid > other.netid:
            return 1

        return 0
```

6. [16 points] **While-Loops and Lists**

A triangular array is a ragged list whose rows start (end) at size one and increase (decrease) by one each row. Examples of triangular arrays are shown to the right. These arrays have applications in scientific computation.

| | | | |
|---|---|---|---|
| 1 | | | |
| 2 | 0 | | |
| 5 | 6 | -1 | |
| 4 | -2 | 3 | 8 |

Triangular, Increasing

| | | | |
|---|---|---|---|
| 1 | 2 | 5 | 4 |
| 0 | 6 | -2 | |
| -1 | 3 | | |
| 8 | | | |

Triangular, Decreasing

As with images in Assignment A6, we can talk about the *transpose* of a triangular array. The transpose is a triangular array with rows and columns swapped with each other. The two triangular arrays shown to the right are the transpose of one another.

Complete the function `transpose`, which takes an increasing triangular array and returns the (decreasing) transpose of the original, by filling in the blanks below. Note that the loop invariants are given. **Solutions that do not preserve the invariant will lose points.**

```
def transpose(b):
    """Returns: a new list which is the transpose of b.
    Precondition: b is a list representing an increasing triangular array."""

    result = []

    i = 0

    # inv: result[0..i-1] contains rows 0..i-1 of the transpose

    while i < len(b):

        # Initialize whatever you need for inner invariant here

        k = 0

        row = []

        # inv: row[0..k-1] contains elements 0..k-1 of column being transposed

        while k < len(b)-i:

            row.append(b[k+i][i])

            k = k+1

        result.append(row)

        i = i +1

    return result
```

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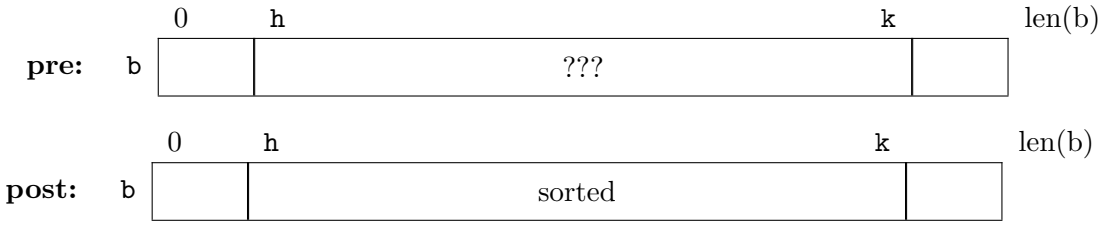
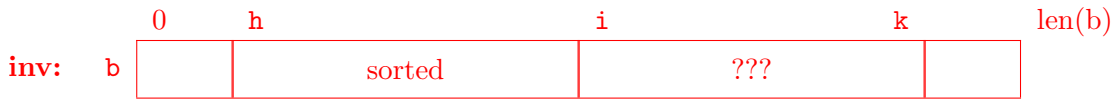
7. [?? points total] **Sorting**
The act of sorting is taking a list with given precondition, and rearranging the elements so that the list satisfies the following postcondition.




(a) [6 points] Give the loop invariant for sorting using **insertion sort**. You must write the invariant using our pictoral representation. Your placement of variables should be clear.




(b) [12 points] Implement the function `insertion_sort` below. You do not need to state the invariant above, but you must follow it. Answers that do not follow the invariant can get at most half-credit. If you need any helper functions, you must implement them as well (you do not need specifications or invariants for helpers).

```
def insertion_sort(b,h,k):
    """Uses insertion sort on the segment b[h..k]
    Precondition: b is a list, h <= k are positions in b""".
    i = h

    # inv:  b[h..i-1] is sorted
    while i <= k:
        push_down(b,i)
        i = i + 1
    # post:  b[h..k] is sorted


def push_down(b,h,n):
    j = n

    # inv:  b[j..n] is sorted
    while j > h:
        if b[j-1] > b[j]:
            swap(b,j-1,j)

        j = j - 1
    # post:  b[h..n] is sorted
```

(Helper function for Insertion Sort)

```
def swap(b,i,j):
    temp = b[i]
    b[i] = b[j]
    b[j] = temp
```

8. [?? points total] **Odds and Ends**.

(a) [3 points] What is an assertion? What is the relationship between an assertion and the `assert` statement?

An assertion is a property or statement (about code) that is either True or False. Assertions include preconditions, post conditions, and invariants. An `assert` statement is a way in Python of enforcing an assertion.

(b) [4 points] Describe the four steps that happen when you call a constructor.

When called, the constructor does the following:

- It creates a new object (folder) of the class, setting all the field values to their defaults.
- It puts the folder into heap space
- It executes the method `__init__` defined in the body of the class. In doing so, it
  - Passes the folder name to that parameter `self`
  - Passes the other arguments in order
  - Executes the commands in the body of `__init__`
- When done with `__init__` it returns the object (folder) name as final value of the expression (e.g. the constructor call).

(c) [3 points] Explain the difference between the command `import math` and the command `from math import *`.

When you use `import math`, it puts the contents of module `math` into a special namespace. To access any global variable, function, or class in `math`, you must first prefix it with `math.` When you use `from math import *`, it pulls the contents of `math` into the active namespace. In that case, you can use all of the contents of `math` without a prefix.

(d) [3 points] Below are three expressions. For each one, write its value. If evaluation leads to an error, just say BAD (do not tell us the exception)

```
True or (5/0 < 1)      (5/0 < 1) or True      3/2
```

`(True or (5/0 < 1))` is `True`. Python short-circuits the evaluation when it sees the first expression `True` (You only need on `True` in an `or` for it to be true).

`((5/0 < 1) or True)` is BAD. Division by zero raises an exception.

`3/2` is 1. Integer division always rounds down.

(e) [3 points] Consider the function `foo` defined below.

```
def foo():
    return 5
```

What is the difference between the contents of the variables `x` and `y` after the assignment statements below?

```
x = foo()
y = foo
```

`x` contains 5; `foo()` is a function call.

`y` contains the name of the function definition for `foo` in heap space.