## Instructions

- You have 2 hours to complete the exam.
- The exam is closed book, closed notes, closed computer, closed calculator, except one hand-written 8.5” × 11” crib sheet of your own creation and the official CS 61A midterm 1 study guide and official CS 61A midterm 2 study guide.
- Mark your answers **on the exam itself.** We will *not* grade answers written on scratch paper.

<table>
<thead>
<tr>
<th>Last name</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>First name</td>
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<tr>
<td>Student ID number</td>
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<td>BearFacts email (@berkeley.edu)</td>
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<td>Name of the person to your left</td>
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<td>Name of the person to your right</td>
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</tbody>
</table>

_All the work on this exam is my own._

_(please sign)_
1. (10 points) Shut up and take my money

For each of the expressions in the tables below, write the output displayed by the interactive Python interpreter when the expression is evaluated. The output may have multiple lines. If an error occurs, write “Error”.

*Recall:* The interactive interpreter displays the value of a successfully evaluated expression, unless it is None.

Assume that you have started python3 and executed the following statements:

```python
class Singer:
    msg = 'Shut up and '
    count = 1
lst = []

    def __init__(self, name, x):
        self.x = x

    def sing(self):
        Singer.count = Singer.count + 1
        print(self.msg + self.x)
        self.lst.append(self.count)

class Group(Singer):
    def __init__(self, s1, s2):
        self.s1 = s1
        self.s2 = s2

    def sing(self):
        self.count = self.count + 1
        self.s1.sing()
        self.s2.sing()
        self.s1.x, self.s2.x = self.s2.x, self.s1.x
        self.lst.append(self.count)

def w_moon(x):
    return Singer('WALK THE MOON', x)

def rihanna(x):
    return Singer('Rihanna', x)

w_moon = w_moon('dance')
rihanna = rihanna('drive')
w_ri = Group(w_moon, rihanna)
w_ri.lst = []
```

For the following lines, assume they are executed in the same interactive session; the result of executing one line may affect the result of executing all following lines. The statements on the right are executed after the statements on the left.

<table>
<thead>
<tr>
<th>Expression</th>
<th>Interactive Output</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>pow(2, 3)</code></td>
<td>8</td>
</tr>
<tr>
<td><code>print(4, 5) + 1</code></td>
<td>4 5</td>
</tr>
<tr>
<td><code>w_moon.lst is w_ri.lst</code></td>
<td>False</td>
</tr>
<tr>
<td><code>w_moon.sing()</code></td>
<td>Shut up and dance</td>
</tr>
<tr>
<td><code>w_moon.count</code></td>
<td>2</td>
</tr>
<tr>
<td><code>Group.count</code></td>
<td>2</td>
</tr>
<tr>
<td><code>w_ri.s2.sing()</code></td>
<td>Shut up and drive</td>
</tr>
<tr>
<td><code>w_ri.sing()</code></td>
<td>Shut up and dance</td>
</tr>
<tr>
<td><code>w_ri.lst</code></td>
<td>[4, 5]</td>
</tr>
<tr>
<td><code>Group.sing(w_moon)</code></td>
<td>Error</td>
</tr>
<tr>
<td><code>Group.sing(w_ri)</code></td>
<td>Shut up and drive</td>
</tr>
<tr>
<td><code>min(rihanna.lst, key=lambda x: -x)</code></td>
<td>7</td>
</tr>
</tbody>
</table>
2. (15 points) Fly, you foos!

(a) (7 pt) Fill in the environment diagram that results from executing the code below until the entire program is finished, an error occurs, or all frames are filled. You only need to show the final state of each frame. You may not need to use all of the spaces or frames.

A complete answer will:
- Add all missing names and parent annotations to all local frames.
- Add all missing values created or referenced during execution.
- Show the return value for each local frame.

```python
ex = [1, 3, 5]
def foo(x):
    bar[x] = x
    bar.append(len(bar))
    return bar

bar = [1, [2]]
foo(0)
foo(2)
foobar = bar[:]
foobar[1][0] = foobar
```

Global Frame

```
Global Frame

Global Frame

Global Frame
```

```python
1
2
3
def foo(x):
4    bar[x] = x
5    bar.append(len(bar))
6    return bar
7
8    bar = [1, [2]]
9
10   foo(0)
11   foo(2)
12   foobar = bar[:]
13   foobar[1][0] = foobar
```
(b) (8 pt) Fill in the environment diagram that results from executing the code below until the entire program is finished, an error occurs, or all frames are filled. You only need to show the final state of each frame. You may not need to use all of the spaces or frames.

A complete answer will:

- Add all missing names and parent annotations to all local frames.
- Add all missing values created or referenced during execution.
- Show the return value for each local frame.
3. (5 points) Counter intuitive

(a) (3 pt) Implement the \_\_init\_\_ method of the Counter class. The constructor for Counter takes in a list of strings and stores a dictionary called counts whose keys are elements of the list and whose values are the number of times each element appeared.

See the doctests for an example. Your solution should not require more than 5 additional lines, and your solution does not need to use all 5 lines.

class Counter:
    """
    >>> dog = Counter([‘this’, ‘is’, ‘spot’, ‘see’, ‘spot’, ‘run’])
    >>> dog.counts[‘this’]
    1
    >>> dog.counts[‘spot’]
    2
    >>> ‘catdog’ in dog.counts
    False
    """

def \_\_init\_\_(self, lst):
    self.counts = {}
    for elem in lst:
        if elem not in self.counts:
            self.counts[elem] = 1
        else:
            self.counts[elem] += 1
(b) (2 pt) It would be convenient if we could use indexing notation on our Counter objects instead of having to access its counts attribute:

```python
>>> sappy = Counter([ 'romeo', 'romeo', 'wherefore', 'art', 'thou', 'romeo'])
>>> sappy[ 'romeo']
3
>>> sappy[ 'thou']
1
>>> sappy[ 'paris']
0
```

Notice that, because 'paris' did not appear as an element in the input to Counter, we get 0 when we use it as a key (instead of getting a KeyError).

Implement the __getitem__ method to support this sort of behavior for Counter objects. You may assume that the __init__ method is implemented correctly.

Your solution should not require more than 4 lines, and your solution does not need to use all 4 lines.

```python
class Counter:
    # Code from previous question
    def __getitem__(self, key):
        """
        >>> hamlet = Counter([ 'to', 'be', 'or', 'not', 'to', 'be'])
        >>> hamlet[ 'be']
        2
        >>> hamlet[ 'not']
        1
        >>> hamlet[ 'whiny']
        0
        """
        if key not in self.counts:
            return 0
        return self.counts[key]
```
4. (7 points) Trees? What a reLEAF!

(a) (4 pt) Implement `find_and_replace(t, old, new)`, where `t` is an instance of the `Tree` class. The function `find_and_replace` mutates `t` such that every entry that is equal to `old` is replaced with `new`.

The `Tree` class has been provided for you below. Your solution should not require more than 7 lines, and you do not need to use all 7 lines.

```python
class Tree:
    def __init__(self, entry, subtrees=[]):
        self.entry = entry
        self.subtrees = list(subtrees)
    def is_leaf(self):
        return not self.subtrees
    def find_and_replace(t, old, new):
        if t.entry == old:
            t.entry = new
        for subtree in t.subtrees:
            find_and_replace(subtree, old, new)
```

`t`, an instance of `Tree`

`find_and_replace(t, 3, 42)` mutates `t` to look like this.
(b) (3 pt) Implement `is_bst(b)`, which takes an instance of the `BinaryTree` class and returns `True` if it is a valid binary search tree. By definition, an empty `BinaryTree` is a valid binary search tree.

You may use the provided `tree_max` function (which calculates the largest element in a `BinaryTree`) and `tree_min` function (which calculates the smallest element in a `BinaryTree`). The input tree to `tree_max` and `tree_min` is not allowed to be empty.

The `BinaryTree` class has also been provided for you below.

class BinaryTree:
    empty = ()
    def __init__(self, entry, left=empty, right=empty):
        self.entry = entry
        self.left = left
        self.right = right

def tree_max(b):
    """Returns the largest element in a non-empty BinaryTree.""
    # Implementation omitted.

def tree_min(b):
    """Returns the smallest element in a non-empty BinaryTree.""
    # Implementation omitted.

def is_bst(b):
    if b is BinaryTree.empty:
        return True
    elif b.left is not BinaryTree.empty and b.entry < tree_max(b.left):
        return False
    elif b.right is not BinaryTree.empty and b.entry > tree_min(b.right):
        return False
    return is_bst(b.left) and is_bst(b.right)
5. (13 points) The weakest link

(a) (2 pt) For the following questions, assume that the following generator function is defined:

```python
def naturals():
    i = 1
    while True:
        yield i
        i += 1
```

Implement a generator function called `filter(iterable, fn)` that only yields elements of `iterable` for which `fn` returns `True`.

See the doctests for expected behavior. **You may not use the built-in filter function or list comprehensions.**

Your solution should not require more than 3 lines, and you do not need to use all 3 lines.

```python
def filter(iterable, fn):
    """
    >>> is_even = lambda x: x % 2 == 0
    >>> list(filter(range(5), is_even))
    [0, 2, 4]
    >>> all_odd = (2 * y - 1 for y in range(5)) # Generator object
    >>> list(filter(all_odd, is_even))
    []
    >>> s = filter(naturals(), is_even)
    2
    >>> next(s)
    4
    """
    for elem in iterable:
        if fn(elem):
            yield elem
```
(b) (5 pt) Implement an iterator class called Filter. The \_\_init\_\_ method for Filter takes an iterable and a one-argument function that either returns \texttt{True} or \texttt{False}. The Filter iterator represents a sequence that only contains elements of the iterable for which the predicate function returns \texttt{True}.

See the doctests for expected behavior. \textbf{You may not use the built-in \texttt{filter} function or list comprehensions.}

Your solution should not require more than 6 lines, and you do not need to use all 6 lines.

class Filter:
    
    >>> is_even = lambda x: x % 2 == 0
    >>> for elem in Filter(range(5), is_even):
    ...     print(elem)
    0
    2
    4

    >>> all_odd = (2 * y - 1 for y in range(5))  # Generator object
    >>> for elem in Filter(all_odd, is_even):
    ...     print(elem)  # No elements are even!

    >>> s = Filter(naturals(), is_even)
    >>> next(s)
    2
    >>> next(s)
    4
    
    def \_\_init\_\_(self, iterable, fn):
        self.iterator = iter(iterable)
        self.fn = fn
    
    def \_\_iter\_\_(self):
        return self
    
    def \_\_next\_\_(self):
        candidate = next(self.iterator)
        while not self.fn(candidate):
            candidate = next(self.iterator)
        return candidate

    # Alternate implementation of \_\_next\_\_
    def \_\_next\_\_(self):
        candidate = next(self.iterator)
        if self.fn(candidate):
return candidate

return next(self)

# Alternate implementation for __next__

def __next__(self):
    for elem in self.iterator:
        if fn(elem):
            return elem
(c) (4 pt) Implement `trim(s, index)`, where `s` is an instance of the `Link` class and `index` is a non-negative integer. The `trim` function mutates `s` so that all elements that occur after the `index` are removed. The `trim` function should also return a linked list of all of the removed elements. If the `index` exceeds the linked list, raise an `IndexError`. Your solution must use recursion; you may not use iteration. You may NOT assume that `__getitem__` and `__len__` have been implemented. See the doctest for expected behavior. Your solution should not require more than 8 lines, and you do not need to use all 8 lines.

class Link:
    empty = ()
    def __init__(self, first, rest=empty):
        self.first = first
        self.rest = rest

def trim(s, index):
    """
    >>> s1 = Link(1, Link(2, Link(3)))
    >>> trim(s1, 0)
    Link(2, Link(3))
    >>> s1
    Link(1)

    >>> s2 = Link(1, Link(2, Link(3)))
    >>> trim(s2, 2) == Link.empty  # No elements after index 2
    True
    >>> s2
    Link(1, Link(2, Link(3)))

    >>> s3 = Link(1, Link(2, Link(3)))
    >>> trim(s3, 3)  # s3 has no index 3
    Traceback (most recent call last):
    ...
    IndexError
    """
    if s is Link.empty:
        raise IndexError
    elif index == 0:
        result = s.rest
        s.rest = Link.empty
        return result
    else:
        return trim(s.rest, index - 1)
(d) (2 pt) Consider the following linked list functions:

```python
def append(link, value):
    """Mutates link by adding value to the end of link."""
    if link.rest is Link.empty:
        link.rest = Link(value)
    else:
        append(link.rest, value)

def extend(link1, link2):
    """Mutates link1 so that all elements of link2 are added to the end
    of link1."""
    while link2 is not Link.empty:
        append(link1, link2.first)
        link2 = link2.rest
```

Circle the order of growth that best describes the runtime of calling `append`, where \( n \) is the number of elements in the input `link`.

- \( O(1) \)
- \( O(\log n) \)
- \( O(n) \)
- \( O(n^2) \)
- \( O(2^n) \)

Assuming the two input linked lists to `extend` both contain \( n \) elements, circle the order of growth that best describes the runtime of calling `extend`.

- \( O(1) \)
- \( O(\log n) \)
- \( O(n) \)
- \( O(n^2) \)
- \( O(2^n) \)

6. (0 points) A second chance

In each of the two boxes below, write a positive integer. If one of the numbers you pick is the lowest unique integer in the class, you get one extra credit point. In other words, you get two chances to write the smallest positive integer that you think no one else will write.

[Box 1] [Box 2]