### 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 61A midterm 1 study guide attached to the back of this exam.
- Mark your answers ON THE EXAM ITSELF. If you are not sure of your answer you may wish to provide a brief explanation.

<table>
<thead>
<tr>
<th>Last name</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>First name</td>
<td></td>
</tr>
<tr>
<td>SID</td>
<td></td>
</tr>
<tr>
<td>Email (<a href="mailto:...@berkeley.edu">...@berkeley.edu</a>)</td>
<td></td>
</tr>
<tr>
<td>Login (e.g., cs61a-ta)</td>
<td></td>
</tr>
<tr>
<td>TA &amp; section time</td>
<td></td>
</tr>
<tr>
<td>Name of the person to your left</td>
<td></td>
</tr>
<tr>
<td>Name of the person to your right</td>
<td></td>
</tr>
</tbody>
</table>

All the work on this exam is my own. (please sign)

---

<table>
<thead>
<tr>
<th>Q. 1</th>
<th>Q. 2</th>
<th>Q. 3</th>
<th>Q. 4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>/12</td>
<td>/12</td>
<td>/14</td>
<td>/12</td>
<td>/50</td>
</tr>
</tbody>
</table>

For staff use only
1. (12 points) Mutater-tot

For each of the expressions in the table below, write the output displayed by the interactive Python interpreter when the expression is evaluated. The output may have multiple lines. Expressions are evaluated in order, and expressions may affect later expressions.

Whenever the interpreter would report an error, write ERROR. If execution would take forever, write FOREVER.

Assume that you have started Python 3 and executed the following statements:

def ready(betty):
    print(len(betty))
    betty[0].append(betty)
    return betty[0:1]

def get_set(s):
    ready(s)
    return s.pop()

def go(on, up):
    if up:
        return go(on[0], up-1)
    else:
        return on

f = [1, [2]]
g = [[3, 4], [5], 6]
h = [g, g]

<table>
<thead>
<tr>
<th>Expression</th>
<th>Interactive Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>f.pop()</td>
<td>[2]</td>
</tr>
<tr>
<td>h[1].pop()</td>
<td>6</td>
</tr>
<tr>
<td>g[g[1][0]-g[0][1]]</td>
<td>[5]</td>
</tr>
<tr>
<td>len(ready(g))</td>
<td>2 1</td>
</tr>
<tr>
<td>g[0][2][0][1]</td>
<td>4</td>
</tr>
<tr>
<td>ready(get_set(h))[0][0]</td>
<td>2 3 3</td>
</tr>
<tr>
<td>[len(go(h, k)) for k in range(3)]</td>
<td>[1, 3, 4]</td>
</tr>
</tbody>
</table>
2. (12 points) Vulcans

(a) (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 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.

Remember: Do not add a new frame when calling a built-in function (such as abs). The built-in abs function is always written as func abs(...) [parent=Global].

```python
def live(long):
    def prosper(spock, live):
        nonlocal long
        if len(long) == 1:
            return spock+1
        long[1] = live(long[0])
        long = long[1:]
        prosper(long[0], abs)
        return spock[0]+1
    prosper(long, lambda trek: trek-3)
live([1, 4])
```

(b) (4 pt) Fill in the environment diagram that results from executing the code below after the entire program is finished. No errors occur during the execution of this example.
A complete answer will:

- Add all missing values created or referenced during execution.
- Show the return value for each local frame.

```python
def scramble(egg):
    return [egg, over(egg)]

def over(easy):
    easy[1] = [[easy], 2]
    return list(easy[1])

egg = scramble([12, 24])
```

Global frame

- `scramble` [func](parent=Global)
- `over` [func](parent=Global)
- `egg` [var]

f1: `scramble` [parent=Global]
- `egg` [var]
  - Return Value

f2: `over` [parent=Global]
- `easy` [var]
  - Return Value
3. (14 points) Will Code for Points

(a) (2 pt) Implement objectify, which takes a tree data abstraction and returns an equivalent Tree instance. Both the Tree class and the tree data abstraction appear on the midterm 2 study guide.
Warning: Do not violate the tree data abstraction! (Exams are flammable.)
def objectify(t):
    """Return a Tree instance equivalent to a tree represented as a list.
    >>> m = tree(2)
    >>> m
    [2]
    >>> objectify(m)
    Tree(2)
    >>> r = tree(3, [tree(4, [tree(5), tree(6)]), tree(7, [tree(8)])])
    >>> r
    [3, [4, [5], [6]], [7, [8]]]
    >>> objectify(r)
    Tree(3, [Tree(4, [Tree(5), Tree(6)]), Tree(7, [Tree(8)])])
    """
    return Tree(root(t), [objectify(b) for b in branches(t)])

(b) (2 pt) Circle the Θ expression that describes the number of Tree instances constructed by calling objectify on a tree with n nodes.
Θ(1) Θ(log n) Θ(n) Θ(n^2) Θ(2^n)

(c) (4 pt) Implement closest, which takes a Tree of numbers t and returns the smallest absolute difference anywhere in the tree between an entry and the sum of the entries of its branches. The Tree class appears on the midterm 2 study guide. The built-in min function takes a sequence and returns its minimum value. Reminder: A branch of a branch of a tree t is not considered to be a branch of t.
def closest(t):
    """Return the smallest difference between an entry and the sum of the root entries of its branches.
    >>> t = Tree(8, [Tree(4), Tree(3)])
    >>> closest(t) # |8 - (4 + 3)| = 1
    1
    >>> closest(Tree(5, [t])) # Same minimum as t
    1
    >>> closest(Tree(10, [Tree(2), t])) # |10 - (2 + 8)| = 0
    0
    >>> closest(Tree(3)) # |3 - 0| = 3
    3
    >>> closest(Tree(8, [Tree(3, [Tree(1, [Tree(5)])])])) # 3 - 1 = 2
    2
    >>> sum([])
    0
    """
    diff = abs(t.entry - sum([b.entry for b in t.branches]))
    return min([diff] + [closest(b) for b in t.branches])
(d) (6 pt) Implement `double_up`, which mutates a linked list by inserting elements so that each element is adjacent to an equal element. The `double_up` function inserts as few elements as possible and returns the number of insertions. The `Link` class appears on the midterm 2 study guide.

```python
def double_up(s):
    """Mutate s by inserting elements so that each element is next to an equal."

    >>> s = Link(3, Link(4))
    >>> double_up(s) # Inserts 3 and 4
    2
    >>> s
    Link(3, Link(3, Link(4, Link(4))))
    >>> t = Link(3, Link(4, Link(4, Link(5))))
    >>> double_up(t) # Inserts 3 and 5
    2
    >>> t
    Link(3, Link(3, Link(4, Link(4, Link(5, Link(5)))))),
    >>> u = Link(3, Link(4, Link(3)))
    >>> double_up(u) # Inserts 3, 4, and 3
    3
    >>> u
    Link(3, Link(3, Link(4, Link(4, Link(3, Link(3))))))
    """
    if s is Link.empty:
        return 0
    elif s.rest is Link.empty:
        s.rest = Link(s.first)
        return 1
    elif s.first == s.rest.first:
        return double_up(s.rest.rest)
    else:
        s.rest = Link(s.first, s.rest)
        return 1 + double_up(s.rest.rest)
```
4. (12 points) What color is it?

(a) (6 pt) Implement the look method of the Dress class. The look method returns a Dress instance’s current color when the number of times that the instance’s look method has ever been invoked evenly divides the total number times that the look method of any Dress instance has ever been invoked. Otherwise, the instance’s color changes to the most recently returned color from any call to look, and None is returned.

class Dress:
    """What color is the dress?
    
    >>> blue = Dress('blue')
    >>> blue.look()
    'blue'
    >>> gold = Dress('gold')
    >>> gold.look()
    'gold'
    >>> blue.look()  # 2 does not evenly divide 3; changes to gold
    >>> Dress('black').look()
    'black'
    >>> gold.look()  # 2 does not evenly divide 5; changes to black
    >>> gold.look()  # 3 evenly divides 6
    'black'
    >>> Dress('white').look()
    'white'
    >>> gold.look()  # 4 evenly divides 8
    'black'
    >>> blue.look()  # 3 evenly divides 9
    'gold'
    ""
    seen = 0
    color = None

def __init__(self, color):
    self.color = color
    self.seen = 0

def look(self):
    Dress.seen += 1
    self.seen += 1

    if Dress.seen % self.seen == 0:
        Dress.color = self.color
        return self.color
    else:
        self.color = Dress.color
(b) (6 pt) Implement `decrypt`, which takes a string `s` and a dictionary `d` that contains words as values and their secret codes as keys. It returns a list of all possible ways in which `s` can be decoded by splitting it into secret codes and separating the corresponding words by spaces.

```python
def decrypt(s, d):
    """List all possible decoded strings of s.
    >>> codes = {
    ...     'alan ': 'spooky',
    ...     'al ': 'drink',
    ...     'antu ': 'your',
    ...     'turing': 'ghosts',
    ...     'tur ': 'scary',
    ...     'ing': 'skeletons',
    ...     'ring ': 'ovaltine'
    ... }
    >>> decrypt('alanturing', codes)
    ['drink your ovaltine', 'spooky ghosts', 'spooky scary skeletons']""

    if s == '':
        return []

    messages = []

    if s in d:
        messages.append(d[s])

    for k in range(1, len(s)+1):
        first, suffix = s[:k], s[k:]

        if first in d:
            for rest in decrypt(suffix, d):
                messages.append(d[first] + ' ' + rest)

    return messages
```

```