INSTRUCTIONS

• You have 2 hours to complete the exam.

• The exam is closed book, closed notes, closed computer, closed calculator, except two hand-written 8.5" × 11" crib sheets of your own creation and the two official CS 61A midterm study guides.

• Mark your answers on the exam itself. We will not grade answers written on scratch paper.

<table>
<thead>
<tr>
<th>Last name</th>
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<thead>
<tr>
<th>Student ID number</th>
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<tr>
<th>CalCentral email (<a href="mailto:_@berkeley.edu">_@berkeley.edu</a>)</th>
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<th>Name of the person to your left</th>
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<th>Name of the person to your right</th>
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<thead>
<tr>
<th>All the work on this exam is my own. (please sign)</th>
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1. (12 points)  By Any Other Name

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. The interactive interpreter displays the repr string of the value of a successfully evaluated expression, unless it is None. If an error occurs, write “Error”, but include all output displayed before the error. The first row has been provided as an example.

Assume that you have started python3 and executed the code shown on the left first, then you evaluate each expression on the right in order. Statements and expressions sent to the interpreter have a cumulative effect.

```python
class Plant:
    k = 1
    kind = "green"
    def __init__(self):
        self.k = Plant.k
        Plant.k = self.k + 1
        if self.k > 3:
            Plant.name = lambda t: "tree"
            Plant.k = 6
    def name(self):
        return kind
    def __repr__(self):
        s = self.name() + " 
        return s + str(self.k)

class Flower(Plant):
    kind = "pretty"
    def __repr__(self):
        s = self.smell() + " 
        return s + Plant.__repr__(self)
    def smell(self):
        return "bad"

class Rose(Flower):
    def name(self):
        return "rose"
    def smell(self):
        return "nice"

class Garden:
    def __init__(self, kind):
        self.name = kind
        self.smell = kind().smell
    def smell(self):
        return self.name.kind

f1 = Flower()
f2 = Flower()
```

<table>
<thead>
<tr>
<th>Expression</th>
<th>Interactive Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>[2, 3]</td>
<td>[2, 3]</td>
</tr>
<tr>
<td>(1 pt) f1.name()</td>
<td></td>
</tr>
<tr>
<td>(1 pt) f1.k</td>
<td></td>
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<tr>
<td>(1 pt) Plant().k</td>
<td></td>
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<tr>
<td>(1 pt) Rose.k</td>
<td></td>
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<tr>
<td>(2 pt) Plant()</td>
<td></td>
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<tr>
<td>(2 pt) Rose()</td>
<td></td>
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<tr>
<td>(2 pt) Garden(Flower).smell()</td>
<td></td>
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<tr>
<td>(2 pt) Garden(Flower).name()</td>
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</tbody>
</table>
2. (8 points) Buy Local

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 frames.
- Add all missing values created or referenced during execution.
- Show the return value for each local frame.
- Use box-and-pointer notation for list values. You do not need to write index numbers or the word “list”.

**Important:** The slash on line 11 means that the return expression continues on the next line.

```python
def f(L, x):
    L[1] = L

def g(c, h, b):
    nonlocal x
    x = c
    if c == 0:
        b.append(5)
        b = L + b
        return h
    else:
        return \
        g(c-1,
        lambda: [c, x],
        b)

p = g(1, None, [4])
x += 3
return p()

r = f([0, 0], 1)
```

Global frame

<table>
<thead>
<tr>
<th>Global frame</th>
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<tbody>
<tr>
<td>func f(L, x) [parent=Global]</td>
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</table>

f1:  

<table>
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<th>f1:</th>
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<tr>
<td>parent=</td>
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Return value

f2:  

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<th>f2:</th>
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<tbody>
<tr>
<td>parent=</td>
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</table>

Return value

f3:  

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<th>f3:</th>
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<tbody>
<tr>
<td>parent=</td>
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</table>

Return value

f4:  

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<th>f4:</th>
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<tbody>
<tr>
<td>parent=</td>
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Return value
3. (10 points) Pumpkin Splice Latte

(a) (2 pt) Implement splice, which takes two lists \( a \) and \( b \) and a non-negative integer \( k \) that is less than or equal to the length of \( a \). It returns the result of splicing \( b \) into \( a \) at \( k \). That is, it returns a new list containing the first \( k \) elements of \( a \), then all elements of \( b \), then the remaining elements of \( a \).

```python
def splice(a, b, k):
    """Return a list of the first \( k \) elements of \( a \), then all of \( b \), then the rest of \( a \)."

    >>> splice([2, 3, 4, 5], [6, 7], 2)
    [2, 3, 6, 7, 4, 5]
    """

    return ________________________________
```

(b) (3 pt) Implement all_splice, which returns a list of all the non-negative integers \( k \) such that splicing list \( b \) into list \( a \) at \( k \) creates a list with the same contents as \( c \). Assume that splice is implemented correctly.

```python
def all_splice(a, b, c):
    """Return a list of all \( k \) such that splicing \( b \) into \( a \) at position \( k \) gives \( c \).

    >>> all_splice([1, 2], [3, 4], [1, 3, 4, 2])
    [1]
    >>> all_splice([1, 2, 1, 2], [1, 2], [1, 2, 1, 2, 1, 2])
    [0, 2, 4]
    """

    return ________________________________
```

(c) (5 pt) Implement splink, which takes two Link instances \( a \) and \( b \) and a non-negative integer \( k \) that is less than or equal to the length of \( a \). It returns a Link instance containing the first \( k \) elements of \( a \), then all elements of \( b \), then the remaining elements of \( a \). The Link class is defined on the midterm 2 study guide. **Important:** You may not use len, in, for, list, slicing, element selection, addition, or list comprehensions.

```python
def splink(a, b, k):
    """Return a Link containing the first \( k \) elements of \( a \), then all of \( b \), then the rest of \( a \).

    >>> splink(Link(2, Link(3, Link(4, Link(5)))), Link(6, Link(7)), 2)
    Link(2, Link(3, Link(6, Link(7, Link(4, Link(5)))))
    """

    if ________________________________:

        return a

    elif ________________________________:

        return ________________________________

    return ________________________________
```
4. (11 points) Both Ways

(a) (4 pt) Implement both, which takes two sorted linked lists composed of Link objects and returns whether some value is in both of them. The Link class is defined on the midterm 2 study guide.

Important: You may not use len, in, for, list, slicing, element selection, addition, or list comprehensions.

```python
def both(a, b):
    """Return whether there is any value that appears in both a and b, two sorted Link instances."

    >>> both(Link(1, Link(3, Link(5, Link(7)))), Link(2, Link(4, Link(6)))))
    False
    >>> both(Link(1, Link(3, Link(5, Link(7)))), Link(2, Link(7, Link(9)))))  # both have 7
    True
    >>> both(Link(1, Link(4, Link(5, Link(7)))), Link(2, Link(4, Link(5)))))  # both have 4 and 5
    True
    """
    if ____________________________________________________________:
        return False
    if ____________________________________________________________:
        a, b = b, a
    return ______________________________________________________
```

(b) (2 pt) Circle the Θ expression that describes the minimum number of comparisons (e.g., <, >, <=, ==, or >= expressions) required to verify that two sorted lists of length n contain no values in common.

- Θ(1)
- Θ(log n)
- Θ(n)
- Θ(n^2)
- Θ(2^n)
- None of these

(c) (5 pt) Implement ways, which takes two values start and end, a non-negative integer k, and a list of one-argument functions actions. It returns the number of ways of choosing functions f_1, f_2, ..., f_j from actions, such that f_1(f_2(...(f_j(start)))()) equals end and j ≤ k. The same action function can be chosen multiple times. If a sequence of actions reaches end, then no further actions can be applied (see the first example below).

```python
def ways(start, end, k, actions):
    """Return the number of ways of reaching end from start by taking up to k actions."

    >>> ways(-1, 1, 5, [abs, lambda x: x+2])  # abs(-1) or -1+2, but not abs(abs(-1))
    2
    >>> ways(1, 10, 5, [lambda x: x+1, lambda x: x+4])  # 1+1+4+1, or 1+4+1+4
    3
    >>> ways(1, 20, 5, [lambda x: x+1, lambda x: x+4])
    0
    >>> ways([3], [2, 3, 2, 3], 4, [lambda x: [2]+x, lambda x: 2*x, lambda x: x[:-1]])
    3
    """
    if ____________________________________________________________:
        return 1
    elif ____________________________________________________________:
        return 0
    return ________([____________________________________________________ for f in actions])
```
5. (9 points) Autumn Leaves

Definition. A pile (of leaves) for a tree $t$ with no repeated leaf labels is a dictionary in which the label for each leaf of $t$ is a key, and its value is the path from that leaf to the root. Each path from a node to the root is either an empty tuple, if the node is the root, or a two-element tuple containing the label of the node’s parent and the rest of the path (i.e., the path to the root from the node’s parent).

(a) (5 pt) Implement pile, which takes a tree constructed using the tree data abstraction. It returns a pile for that tree. You may use the tree, label, branches, and is_leaf functions from the midterm 2 study guide.

```python
def pile(t):
    """Return a dict that contains every path from a leaf to the root of tree t."

    >>> pile(tree(5, [tree(3, [tree(1), tree(2)]), tree(6, [tree(7)])]))
    {1: (3, (5, ())), 2: (3, (5, ())), 7: (6, (5, ()))}

    p = {}

    def gather(______________________________________, ______________________________________):
        if is_leaf(u):
            1 2 7
            3
            6
            5

        for b in branches(u):

            3 6
            1 2 7

        return p

    return p
```

(b) (4 pt) Implement Path, a class whose constructor takes a tree $t$ constructed by tree and a leaf_label. Assume all leaf labels of $t$ are unique. When a Path is printed, labels in the path from the root to the leaf of $t$ with label leaf_label are displayed, separated by dashes. Assume pile is implemented correctly.

```python
class Path:
    """A path through a tree from the root to a leaf, identified by its leaf label."

    >>> a = tree(5, [tree(3, [tree(1), tree(2)]), tree(6, [tree(7)])])
    >>> print(Path(a, 7), Path(a, 2))
    5-6-7 5-3-2

    def __init__(self, t, leaf_label):
        self.pile, self.end = pile(t), leaf_label

    def __str__(self):
        path, s = ___________________________________ , _____________________________________

        while path:
            3 6
            1 2 7

            path, s = _________________________________ , ___________________________________

        return s
```