INSTRUCTIONS

- You have 1 hour and 50 minutes 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.

- 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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<tbody>
<tr>
<td>First name</td>
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<td>CalCentral email (<a href="mailto:_@berkeley.edu">_@berkeley.edu</a>)</td>
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<td>Name of the person to your left</td>
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All the work on this exam is my own. (please sign)

POLICIES & CLARIFICATIONS

- If you need to use the restroom, bring your phone and exam to the front of the room.

- You may use built-in Python functions that do not require import, such as min, max, pow, len, and abs.

- You may not use example functions defined on your study guide unless a problem clearly states you can.

- For fill-in-the-blank coding problems, we will only grade work written in the provided blanks. You may only write one Python statement per blank line, and it must be indented to the level that the blank is indented.

- Unless otherwise specified, you are allowed to reference functions defined in previous parts of the same question.
1. (12 points) **What Would Python Display** *(All are in Scope: Lambdas, HOFs, WWPD)*

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. If an error occurs, write “Error”, but include all output displayed before the error. If evaluation would run forever, write “Forever”. To display a function value, write “Function”. The first two rows have been provided as examples.

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

Assume that you have first started `python3` and executed the statements on the left.

<table>
<thead>
<tr>
<th>Expression</th>
<th>Interactive Output</th>
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<tbody>
<tr>
<td><code>def mint(y):</code>&lt;br&gt; <code>return print(-2)</code></td>
<td></td>
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<tr>
<td><code>def snooze(e, f):</code>&lt;br&gt; <code>if e and f(): print(e)</code>&lt;br&gt; <code>if e or f(): print(f)</code>&lt;br&gt; <code>if not e:</code>&lt;br&gt; <code>print('naughty')</code></td>
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<tr>
<td><code>def lose():</code>&lt;br&gt; <code>return -1</code></td>
<td></td>
</tr>
<tr>
<td><code>def alarm():</code>&lt;br&gt; <code>print('Midterm')</code>&lt;br&gt; <code>1 / 0</code>&lt;br&gt; <code>print('Time')</code></td>
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<tr>
<td><code>def sim(b, a):</code>&lt;br&gt; <code>while a &gt; 1:</code>&lt;br&gt; <code>def sc(ar):</code>&lt;br&gt; <code>a = b + 4</code>&lt;br&gt; <code>return b</code>&lt;br&gt; <code>a, b = a // 2, b - a</code>&lt;br&gt; <code>print(a)</code>&lt;br&gt; <code>print(sc(b - 1), a)</code></td>
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<tr>
<td><code>pumbaa = lambda f: lambda x: f(f(x))</code></td>
<td></td>
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<tr>
<td><code>pumbaa = pumbaa(pumbaa)</code></td>
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<tr>
<td><code>rafiki = 1</code></td>
<td></td>
</tr>
<tr>
<td><code>timon = lambda y: y + rafiki</code></td>
<td></td>
</tr>
<tr>
<td><code>rafiki = -1</code></td>
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<table>
<thead>
<tr>
<th>Expression</th>
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</thead>
<tbody>
<tr>
<td><code>pow(10, 2)</code></td>
<td>100</td>
</tr>
<tr>
<td><code>print(4, 5) + 1</code></td>
<td>4 5</td>
</tr>
<tr>
<td><code>print(mint(print))</code></td>
<td></td>
</tr>
<tr>
<td><code>print(snooze(1, lose))</code></td>
<td></td>
</tr>
<tr>
<td><code>snooze(print(1), alarm)</code></td>
<td>snooze(print(1), alarm)</td>
</tr>
<tr>
<td><code>sim(3, 3)</code></td>
<td>sim(3, 3)</td>
</tr>
<tr>
<td><code>pumbaa(timon)(5)</code></td>
<td>pumbaa(timon)(5)</td>
</tr>
</tbody>
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2. (6 points) **Environmental Studies** *(All are in Scope: Lambdas, HOFs, Environment Diagram)*

Fill in the environment diagram that results from executing the code on the right 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.

```
1  def oski(oski):
2    x = 1
3    if oski(2) > x:
4      return oski
5      bear = lambda z: (lambda y: z+3)(x+4)
6      x, z = 11, 12
7      x = oski(bear)
```
3. (5 points) You Again (All are in Scope: HOFs, Control)

Implement again, which takes a function $f$ as an argument. The `again` function returns the smallest non-negative integer $n$ for which $f(n)$ is equal to $f(m)$ for some non-negative $m$ that is less than $n$. Assume that $f$ takes non-negative integers and returns the same value for at least two different non-negative arguments.

**Constraints:**

- Lines numbered 2, 4, and 5 must begin with either `while` or `if`.
- Lines numbered 6 and 7 must contain either `return` or `=`.

```python
def parabola(x):
    """A parabola function (for testing the again function).""
    return (x-3) * (x-6)

def vee(x):
    """A V-shaped function (for testing the again function).""
    return abs(x-2)

def again(f):
    """Return the smallest non-negative integer $n$ such that $f(n) = f(m)$ for some $m < n$."
    
    >>> again(parabola)  # parabola(4) == parabola(5)
    5
    >>> again(vee)       # vee(1) == vee(3)
    3
    """
```

```python
n = 1

--------:

m = 0

--------:

--------:

--------:

n = n + 1
```
4. (17 points) Ups and Downs

**Definition.** Two adjacent digits in a non-negative integer are an *increase* if the left digit is smaller than the right digit, and a *decrease* if the left digit is larger than the right digit.

For example, $61127$ has 2 increases ($1 \to 2$ and $2 \to 7$) and 1 decrease ($6 \to 1$).

You may use the `sign` function defined below in all parts of this question.

```python
def sign(x):
    if x > 0:
        return 1
    elif x < 0:
        return -1
    else:
        return 0
```

(a) (5 pt) *(All are in Scope: Control)* Implement `ramp`, which takes a non-negative integer $n$ and returns whether it has more *increases* than *decreases* when reading its digits from left to right (see the definition above).

```python
def ramp(n):
    ""
    Return whether non-negative integer N has more increases than decreases.
    ""

    >>> ramp(123)  # 2 increases (1 -> 2, 2 -> 3) and 0 decreases
    True
    >>> ramp(1315)  # 2 increases (1 -> 3, 1 -> 5) and 1 decrease (3 -> 1)
    True
    >>> ramp(176)  # 1 increase (1 -> 7) and 1 decrease (7 -> 6)
    False
    >>> ramp(5)  # 0 increases and 0 decreases
    False
    ""

    n, last, tally = ______________________________ , _______________________________ , 0
    while n:
        n, last, tally = n // 10, n % 10, ______________________________

    return ____________________________________________
```
(b) (3 pt) (All are in Scope: Lambda, HOFs) Implement `over_under`, which takes a number `y` and returns a function that takes a number `x`. This function returns 1 if `x` is greater than `y`, 0 if `x` equals `y`, and -1 if `x` is less than `y`.

You may not use `if`, `and`, or `or`.

```python
def over_under(y):
    """Return a function that takes X and returns:
    -1 if X is less than Y
    0 if X is equal to Y
    1 if X is greater than Y"

    return ____________________________

>>> over_under(5)(3)  # 3 < 5
-1
>>> over_under(5)(5)  # 5 == 5
0
>>> over_under(5)(7)  # 7 > 5
1
"""
```

return ____________________________
**Read this first.** The `process` function below uses `tally` and `result` functions to analyze all adjacent pairs of digits in a non-negative integer `n`. A `tally` function is called on each pair of adjacent digits.

```python
def process(n, tally, result):
    """Process all pairs of adjacent digits in N using functions TALLY and RESULT.""
    while n >= 10:
        tally, result = tally(n % 100 // 10, n % 10)
        n = n // 10
    return result()
```

(c) (6 pt) *(All are in Scope: Self-Reference, HOFs)* Implement `ups`, which returns two functions that can be passed as `tally` and `result` arguments to `process`, so that `process` computes whether a non-negative integer `n` has exactly `k` increases.

**Hint:** You can use `sign` from the previous page and the built-in `max` and `min` functions.

```python
def ups(k):
    """Return tally and result functions that compute whether N has exactly K increases.
    >>> f, g = ups(3)
    >>> process(1200849, f, g) # Exactly 3 increases: 1 -> 2, 0 -> 8, 4 -> 9
    True
    >>> process(94004, f, g) # 1 increase: 0 -> 4
    False
    >>> process(12233445, f, g) # 4 increases: 1 -> 2, 2 -> 3, 3 -> 4, 4 -> 5
    False
    >>> process(0, f, g) # 0 increases
    False
    """
    def f(left, right):
        return ________________
    return ______________________ , ______________________
```

(d) (3 pt) *(All are in Scope: Control)* Implement `at_most`, which returns `True` if the number of `increases` in a non-negative integer `n` is less than or equal to `k`, and `False` otherwise. Assume `ups` is implemented correctly. You may use any of the functions from previous parts of this question: `sign`, `ramp`, `over_under`, and `process`. 
def at_most(n, k):
    """Return whether non-negative integer N has at most K increases.
    >>> at_most(567, 3)
    True
    >>> at_most(567, 2)
    True
    >>> at_most(567, 1)
    False
    ""
    result = ..........................................................
    while k >= 0:
        a, b = ups(k)
        k, result = k - 1, .............................................
    return result