CS 61A Structure and Interpretation of Computer Programs
Spring 2020

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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<tr>
<td>Student ID number</td>
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<tr>
<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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<td>Name of the person to your right</td>
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</table>

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 lists, dictionaries, tuples, sets, or the := operator. These features have not been covered.
- 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. (8 points) What Would Python Display

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>
</tr>
</thead>
<tbody>
<tr>
<td>pow(10, 2)</td>
<td>100</td>
</tr>
<tr>
<td>print(4, 5) + 1</td>
<td>Error</td>
</tr>
<tr>
<td>print(print)(2020)</td>
<td></td>
</tr>
<tr>
<td>tik(50)</td>
<td></td>
</tr>
<tr>
<td>snap(2020)</td>
<td></td>
</tr>
<tr>
<td>q(20)</td>
<td></td>
</tr>
</tbody>
</table>

```
def tik(tok):
    tik = lambda: tok + 1
    while tok - tik() < 5:
        tok = tik() + 1
        if tok > 100:
            return tik()
    return tok

snap = lambda chat: lambda: snap(chat)
snap, chat = print, snap(2020)
```

```python
def q(q):
    if print(q, q):
        print(q + 1)
    if q:
        q = q + q
    if q > 0:
        return q
    print(q + 2)
```
2. (8 points) People’s Park

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.
Do not include frames for calls to built-in functions.
A complete answer will:

- Add all missing names and parents to all local frames.
- Add all missing values created or referenced during execution.
- Show the return value for each local frame.
- Cross out or erase all arrows and values that are not part of the final diagram.

```
def people(s):
    unit = 2
    park = s(unit, t) + 1
    s = (lambda t: park)(s)
    return lambda: abs(unit)

unit, t = 1, 3
def park(t, park):
    return unit - 2

unit = people(park)
```

<table>
<thead>
<tr>
<th>Global frame</th>
<th>people</th>
<th>func people(s) [parent=Global]</th>
</tr>
</thead>
<tbody>
<tr>
<td>f1: ________</td>
<td>[parent=_________]</td>
<td>Return Value</td>
</tr>
<tr>
<td>f2: ________</td>
<td>[parent=_________]</td>
<td>Return Value</td>
</tr>
<tr>
<td>f3: ________</td>
<td>[parent=_________]</td>
<td>Return Value</td>
</tr>
<tr>
<td>f4: ________</td>
<td>[parent=_________]</td>
<td>Return Value</td>
</tr>
</tbody>
</table>
3. (16 points) Digit Fidget

(a) (6 pt) Implement `same_digits`, which takes two positive integers. It returns whether they both become the same number after replacing each sequence of a digit repeated consecutively with only one of that digit. For example, in 1222321, the sequence 2222 would be replaced by only 2, leaving 12321.

Restriction: You may only write combinations of the following in the blanks:
- `a`, `b`, `end`, `10`, `%`, `if`, `while`, `and`, `or`, `==`, `!=`, `True`, `False`, and `return`. (No division allowed!)

```python
def same_digits(a, b):
    """Return whether a and b become the same number after removing adjacent repeats."

    >>> same_digits(2002200, 2202000) # Ignoring repeats, both are 2020
    True
    >>> same_digits(21, 12) # Digits must appear in the same order
    False
    >>> same_digits(12, 2212) # 12 and 212 are not the same
    False
    >>> same_digits(2020, 20) # 2020 and 20 are not the same
    False
    ""
    assert a > 0 and b > 0
    while a and b:
        if _____________________________________________________________________________:
            end = a % 10
            _____________________________________________________________________________:
            a = a // 10
            _____________________________________________________________________________:
            b = b // 10
        else:
            _____________________________________________________________________________
```

(b) (3 pt) Implement `no_repeats`, which takes a positive integer `a` and returns the smallest positive integer `b` for which `same_digits(a, b)` returns `True`. Assume `same_digits` is implemented correctly. Watch out for the `assert` statement in the implementation of `same_digits`! You may not call `set` or `str`.

```python
def no_repeats(a):
    """Remove repeated adjacent digits from a."

    >>> no_repeats(22000200)
    2020
    ""
    return search(____________________________________________________ , _______________)

def search(f, x):
    while not f(x):
        x += 1
    return x
```
(c) (4 pt) Implement unique_largest, which takes a positive integer \( n \). It returns whether the largest digit in \( n \) appears only once in \( n \). You may assign values to multiple names in an assignment statement.
You may not write call expressions or parentheses. You may not write lambda, if, max, set, and, or or.

```python
def unique_largest(n):
    """Return whether the largest digit in n appears only once."

    >>> unique_largest(132123) # 3 is largest and appears twice
    False
    >>> unique_largest(1321523) # 5 is largest and appears only once
    True
    >>> unique_largest(5)
    True
    """
    assert n > 0
    top = 0
    while n:
        n, d = n // 10, n % 10

        if _______________________________________________________________________________
        _____________________ = _____________________________________________
        elif d == top:
            unique = _____________________________________________________________________
        return unique
```

(d) (3 pt) Implement transitive, which takes a two-argument function \( p \) that returns True or False. The transitive function returns whether it is the case that for every three digits \( a, b, c \) for which \( p(a, b) \) and \( p(b, c) \) both return True, \( p(a, c) \) also returns True. A digit is an integer between 0 and 9, inclusive.
You may not write str, [ or ].

```python
def transitive(p):
    """Return whether p is transitive over non-negative single digit integers."

    >>> transitive(lambda x, y: x < y) # if a < b and b < c, then a < c
    True
    >>> transitive(lambda x, y: abs(x-y) == 1) # E.g., p(3, 4) and p(4, 5), but not p(3, 5)
    False
    """
    abc = 0
    while abc < 1000:
        a, b, c = abc // 100, ____________________________________________, abc % 10

        if p(a, b) ________________________________________________________________________:
            return False
        abc = abc + 1
    return True
4. (8 points) Composition

(a) (4 pt) Implement `compose`, which takes a positive integer `n`. It returns a function that, when called repeatedly on `n` one-argument functions `f_1, f_2, ..., f_n`, returns a one-argument function of `x` that returns `f_1(f_2(...f_n(x)...))`. You may **not** call the `compose1` function from the Midterm 1 Study Guide.

```python
def compose(n):
    """Return a function that, when called n times repeatedly on unary functions f1, f2, ..., fn, returns a function g(x) equivalent to f1(f2(... fn(x) ... ))."

    >>> add1 = lambda y: y + 1
    >>> compose(3)(abs)(add1)(add1)(-4) # abs(add1(add1(-4)))
    2
    >>> compose(3)(add1)(add1)(abs)(-4) # add1(add1(abs(-4)))
    6
    >>> compose(1)(abs)(-4) # abs(-4)
    4

    assert n > 0

    if n == 1:
        return __________________________________________________________________________

    def call(f):
        def on(g):
            return _____________________________(________________________________________)
        return on

    return call
```

(b) (4 pt) Complete the final expression below with **only integers and names** so it evaluates to 2020.

```python
from operator import add
c = lambda f: lambda x: lambda y: f(x, y)
twice = lambda z: 2 * z

compose(___________)(twice)(___________(___________)(10))(___________(pow)(10))(___________)
```