CS 61A Fall 2018

Structure and Interpretation of Computer Programs

FINAL

INSTRUCTIONS

- You have 3 hours to complete the exam.
- The exam is closed book, closed notes, closed computer, closed calculator, except three hand-written $8.5" \times 11"$ crib sheet of your own creation and the official CS 61A midterm 1, midterm 2, and final study guides.
- Mark your answers on the exam itself. We will not grade answers written on scratch paper.

Last name	
First name	
Student ID number	
CalCentral email (_@berkeley.edu)	
TA	
Name of the person to your left	
Name of the person to your right	
All the work on this exam is my own. (please sign)	
(piease 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, abs, sum, next, iter, list, tuple, map, filter, zip, all, and any.
- You may not use example functions defined on your study guides 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.
- You may use the Tree, Link, and BTree classes defined on Page 2 (left column) of the Midterm 2 Study Guide.

1. (12 points) High Quality Air (All are in Scope: Object-Oriented Programming, WWPD, Lambda Expressions, Python Lists, Mutability)

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 first row is completed for you.

- If an error occurs, write **Error**, but include all output displayed before the error.
- To display a function value, write **FUNCTION**.
- To display an iterator value, write **ITERATOR**.
- If an expression would take forever to evaluate, write **FOREVER**.

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

Assume that you have started python3 and executed the code shown on the left first, then you evaluate each expression on the right in the order shown. Expressions evaluated by the interpreter have a cumulative effect.

from operator import sub
z = (lambda x: lambda y: 2 * (y-x))(3)
<pre>def breath(f, count=1): if count > 1: print(count) count += 1 return lambda x, y: f(x+1, y)</pre>
class Day:
aqi = 10
<pre>definit(self, aqi=0):</pre>
if aqi > self.aqi:
self.aqi = aqi
self.n = []
<pre>def mask(self, limit): def f(aqi):</pre>
if aqi > limit:
self.n.append(aqi-limit)
return self.mask(aqi)
return f
<pre>class Week(Day): aqi = 50</pre>
<pre>m, t = Day(), Week(199) t.mask(200)(100)(150)(160) Day.aqi = 140 t.aqi = 160</pre>

Expression	Output
print(None)	None
<pre>print(print(None), print)</pre>	
z(4)	
breath(breath(sub))(5, 3)	
[Day().aqi, m.aqi]	
[Week.aqi, t.aqi]	
.	
t.n	
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2. (8 points) Diagram Horror (All are in Scope: Python Lists, Mutability, Environment Diagrams, Lambda Expressions)

```
def get(out):
    out.pop()
    out = scary(lambda movie: out)
    return lambda: [out]

def scary(movie):
    out.append(movie)
    return movie(5)[:1]

out = [6]
get([7, 8])()
```

Fill in the environment diagram that results from executing the code on the left 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.
- Use box-and-pointer diagrams for lists and tuples.

Global	get		→ fund	get(out)	[pa	rent=Global]
	scary		→ fund	scary(mo	vie)	[parent=Global]
f1:	[parent=]				
	Return Value					
f2:	[parent=]				
	Return Value					
f3:	[parent=]				
	Return Value					
f4:	[parent=]				
	Return Value					

3. (16 points) Gainz

for x in t:

return True

Definition. A sequence is *near increasing* if each element beyond the second is larger than all elements preceding its previous element. That is, element i must be larger than elements i - 2, i - 3, i - 4, etc.

(a) (3 pt) (All are in Scope: Python Lists, Recursion) Implement is_near, which takes a sequence s and returns whether its elements form a near increasing sequence.

```
def is_near(s):
   """Return whether s is a near increasing sequence.
   >>> is_near([]) and is_near([1]) and is_near([1, 2]) and is_near(range(10))
   >>> is_near([4, 2]) and is_near((1, 4, 2, 5)) and is_near((1, 2, 4, 3))
   True
                               # 1 <= 3
   >>> is_near((3, 2, 1))
   False
   >>> is_near([1, 4, 2, 3, 5]) # 3 <= 4
   False
   >>> is_near([1, 4, 2, 5, 3]) # 3 <= 4
   False
   >>> is_near([1, 2, 4, 2, 5]) # 2 <= 2
   False
   11 11 11
   return all([______ > _____ for i in ______])
```

(b) (6 pt)(All are in Scope: Iterators, Recursion) Implement fast_near, which takes an iterable value and returns whether its elements form a near increasing sequence. fast_near must run in $\Theta(n)$ time and $\Theta(1)$ space (not including the input itself) for an iterable input with n elements. Assume that s has a finite number of elements. You may <u>not</u> call is_near.

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Alternative Definition. (Equivalent to the one on the previous page, but stated in a more useful way for the problem below.) A sequence is near increasing if each element but the last two is smaller than all elements following its subsequent element. That is, element i must be smaller than elements i + 2, i + 3, i + 4, etc.

(c) (6 pt)(All are in Scope: Lambda Expressions, Recursion) Implement near, which takes a non-negative integer n and returns the largest near increasing sequence of digits within n as an integer. The arguments smallest and d are part of the implementation; you must determine their purpose. You may <u>not</u> call is_near or fast_near. You may <u>not</u> use any values except integers and booleans (True and False) in your solution (no lists, strings, etc.).

def near(n, smallest=10, d=10): """Return the longest sequence of near-increasing digits in n. >>> near(123) 123 >>> near(153) 153 >>> near(1523) 153 >>> near(15123) 1123 >>> near(11111111) 11 >>> near(985357) 557 >>> near(14735476) 143576 >>> near(812348567) 1234567 11 11 11 if n == 0: return _____ no = near(n//10, smallest, d) if smallest > _____: yes = _______ return _____(yes, no)

(d) (1 pt) What is the largest possible integer that could ever be returned from the near function? Note: In general, integers in Python can be arbitrarily large.

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4. (11 points) Tree Time

Definition. A *runt node* is a node in a tree whose label is smaller than all of the labels of its siblings. A sibling is another node that shares the same parent. A node with no siblings is a runt node.

(a) (7 pt)(All are in Scope: Tree Recursion, Mutable Trees, Higher-Order Functions) Implement runts, which takes a Tree instance t in which every label is different and returns a list of the labels of all runt nodes in t, in any order. Also implement apply_to_nodes, which returns nothing and is part of the implementation. Do not mutate any tree. The Tree class is on the Midterm 2 Guide.

aeī	<pre>"""Return a list in any order of the labels of all runt nodes in t.</pre>
	>>> sorted(runts(Tree(9, [Tree(3), Tree(4, [Tree(5, [Tree(6)]), Tree(7)]), Tree(2)]))) [2, 5, 6, 9]
	<pre>result = [] def g(node):</pre>
	if:
	result.append()
	apply_to_nodes()
	return
def	<pre>apply_to_nodes(f, t): """Apply a function f to each node in a Tree instance t."""</pre>
	for b in t.branches:

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return t.label

5. (9 points) Run, Program, Run (All are in Scope: Scheme Lists)

Implement runs, a Scheme procedure that takes a list of integers s and returns a list of non-empty lists of integers t. Together, the lists in t should contain all elements of s in order. The first element in each list in t must be less than the last element in the previous list, if there is one. The rest of the elements in each list in t must be greater than or equal to the previous element.

Also implement and use next-run in your solution, which takes a non-empty list of integers s and returns a pair of lists: the longest non-decreasing prefix of s and the rest of s. Use the provided pair data abstraction. Your implementation should be correct even if the pair implementation were to change.

```
;; Return a list of non-decreasing lists that together contain the elements of s.
;; scm> (runs '(3 4 7 6 6 8 1 2 5 5 4))
;; ((3 4 7) (6 6 8) (1 2 5 5) (4))
;; scm> (runs '(4 3 2 3))
;; ((4) (3) (2 3))
(define (runs s)
  (if (null? s) _____
     (let ((p (next-run s)))
       _____))))
;; A data abstraction for a pair of a first run and the rest of a list.
(define (pair a b) (lambda (c) (if c a b)))
(define (first p) (p #t))
(define (rest p) (p #f))
;; Return a pair containing the first run in s (a list) and the rest of s (another list).
;; scm> (first (next-run '(4 5 1 3 2)))
;; (4 5)
;; scm> (rest (next-run '(4 5 1 3 2)))
;; (1 3 2)
(define (next-run s)
  (if (or ______
         _____)
     (pair _____)
     (begin
       (define p (next-run (cdr s)))
       (pair _____))))
```

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	6.	9 points) Generation	\mathbf{Z}
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(a) (4 pt) (All are in Scope: Generators, Linked Lists) Implement rev, a generator function that takes a Link instance and yields the elements of that linked list in reverse order. The Link class appears on Page 2 of the Midterm 2 Study Guide.

(b) (2 pt) (At least one of these is out of Scope: Scheme Lists, Streams) Using the provided add procedure, define not-three, an infinite stream of all positive integers that are not evenly divisible by 3. The not-three stream is increasing and begins with 1, 2, 4, 5, 7, 8, 10, 11, 13.

```
      (define (add k s) (cons-stream (+ k (car s)) (add k (cdr-stream s))))

      (define not-three ______)
```

(c) (3 pt) (All are in Scope: Macros) Implement infix, a Scheme macro that evaluates infix expressions. An infix expression is either a number or a three-element list containing an infix expression, a procedure, and another infix expression. The value of a compound infix expression is the value of its second element applied to the values of its first and third elements. Note: The last line begins with a quasiquote. If you cross out the quasiquote and solve the problem without using quasiquote or unquote, you can receive up to 2 out of 3 points (not recommended).

7.	(10 points)) SQL of Course	(All	are in	Scope:	SQL	, More S	QL)
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The courses table describes the course name, start time hour (h) and minute (m), and length in minutes (len) for different lectures. For example, 61A starts at 13:00 and lasts 50 minutes. The locations table describes the course name and location (loc) of these courses. Assume that each course name appears exactly once in each table. Write your SQL statements so that they would still be correct if the table contents changed.

each	i table.	Write yo	our SQL	stateme	ents s	so that they	would st	till be corr	ect if th	e table co	onter	its changed.	
SELECT " SELECT " SELECT " SELECT "	'1" AS 6 '2" '8" '10" '50AC" '61A"	course,	13 12 12 13 13	, 30 , 30 , 30 , 30 , 0	,	80 AS len 80 50 110 45 50;	UNION UNION UNION UNION	SEL SEL SEL SEL	ECT "1" ECT "2" ECT "10 ECT "50	AC" A"	e, " , " , "	AS "VLSB" AS loc "Dwinelle" "VLSB" "Wheeler" "Wheeler"; before 13:30.	UNIO UNIO UNIO
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	Dwinelle VLSB Wheeler	80											;
of	f time in nclude pa	n minute airs of co	s between surses w	en the e here the	nd ti e lect	me of the eaures do not	arlier cou overlap i	rse and the n time. N	ne start ote: The	time of tere are 60	the la	e, and the amou ater course. On nutes in an hou	$_{ m nly}$
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61A	1	10
8	1	40
8	2	10
8	50AC	10

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8. (0 points) Draw! (Optional) Draw a picture of some function or procedure.