CS 61A Structure and Interpretation of Computer Programs

Fall 2022 MIDTERM 1

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 8.5" × 11" page of your own creation and the provided midterm 1 study guide.
- Mark your answers on the exam itself in the spaces provided. We will not grade answers written on scratch paper or outside the designated answer spaces.
- 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 `pow`, `len`, `abs`, `bool`, `int`, `float`, `str`, `max`, and `min`.
- You **may not** use example functions defined on your study guide unless a problem clearly states you can.
- Unless otherwise specified, you are allowed to reference functions defined in previous parts of the same question.
- You may not use ; to place two statements on the same line.

For questions with **circular bubbles**, you should select exactly *one* choice.

◯ You must choose either this option

◯ Or this one, but not both!

For questions with **square checkboxes**, you may select *multiple* choices.

☐ You could select this choice.

☐ You could select this one too!

Preliminaries

You can complete and submit these questions before the exam starts.

(a) What is your full name?

(b) What is your student ID number?

(c) What is your @berkeley.edu email address?

1. (4.0 points) What Would Python Display?

Assume the following code has been executed.

```
bear = -1
oski = lambda print: print(bear)
bear = -2

s = "Knock"
```

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

(a) (1.0 pt) `(3 and 4) - 5`

- ◯ -2
- ◯ -1
- ◯ 1
- ◯ 2
- ◯ Error

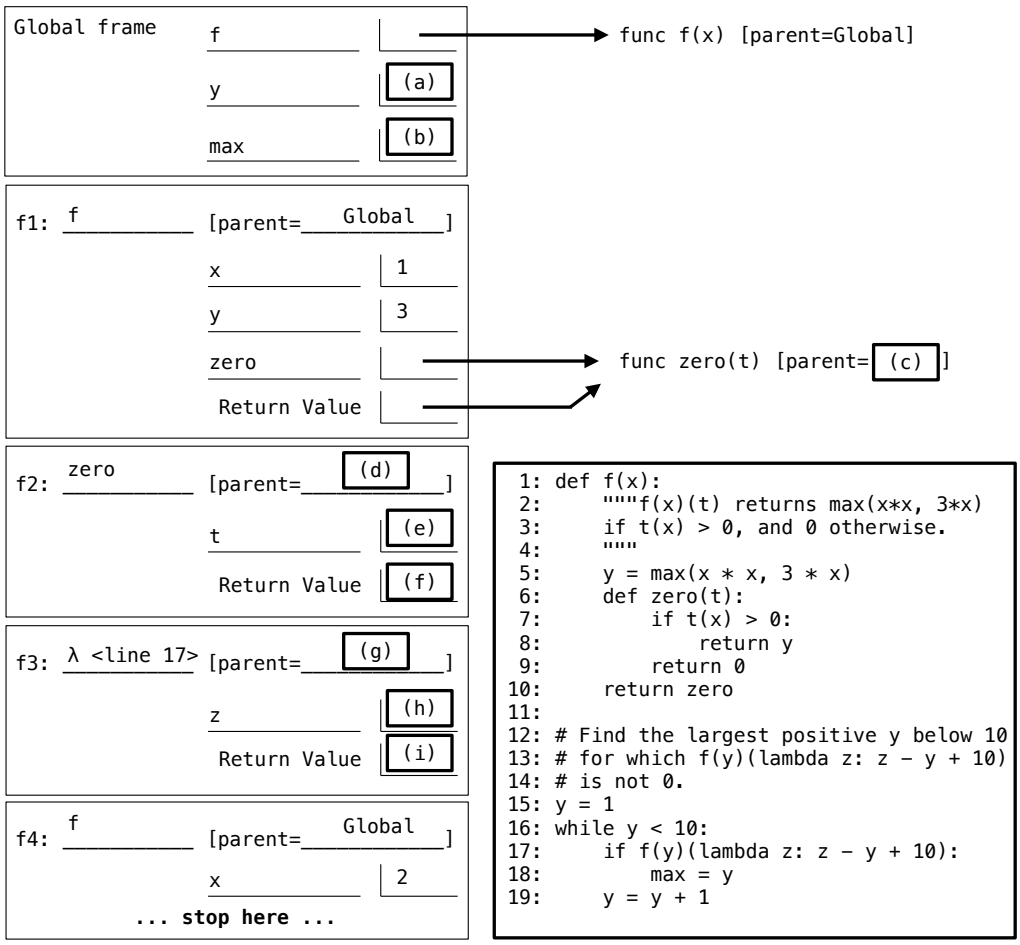
(b) (1.0 pt) `oski(abs)`

- ◯ -2
- ◯ -1
- ◯ 1
- ◯ 2
- ◯ Function
- ◯ Error

(c) (2.0 pt) `print(print(print(s, s) or print("Who's There?")), "Who?")`

2. (12.0 points) Don't Call Me, I'll Call You

When working on a large project, you get the error `'int' object is not callable` in the code below during the second call to `f`. Complete the environment diagram until the error occurs to identify the problem with the code. **If a blank contains an arrow to a function, write the function as it would appear in the diagram.**




```
 1: def f(x):
 2:     """f(x)(t) returns max(x*x, 3*x)
 3:     if t(x) > 0, and 0 otherwise.
 4:     """
 5:     y = max(x * x, 3 * x)
 6:     def zero(t):
 7:         if t(x) > 0:
 8:             return y
 9:         return 0
10:     return zero
11:
12: # Find the largest positive y below 10
13: # for which f(y)(lambda z: z - y + 10)
14: # is not 0.
15: y = 1
16: while y < 10:
17:     if f(y)(lambda z: z - y + 10):
18:         max = y
19:     y = y + 1
```

(a) (1.0 pt) Fill in blank (a).

(b) (1.0 pt) Fill in blank (b).

(c) (1.0 pt) Which of these could fill in blank (c)?

- ◯ `Global`
- ◯ `f`
- ◯ `f1`

(d) (1.0 pt) Which of these could fill in blank (d)?

- ◯ `Global`
- ◯ `f`
- ◯ `f1`

(e) (2.0 pt) Fill in blank (e).

(f) (1.0 pt) Fill in blank (f).

(g) (1.0 pt) Which of these could fill in blank (g)?

- ◯ `Global`
- ◯ `f`
- ◯ `zero`
- ◯ `f1`
- ◯ `f2`

(h) (1.0 pt) Fill in blank (h).

(i) (1.0 pt) Fill in blank (i).

(j) (2.0 pt) Explain in 10 words or less why the `'int' object is not callable` error occurred.

3. (10.0 points) It's Perfect

Definitions. A *perfect* number is a positive integer `n` whose *proper factors* (the factors of `n` below `n`) sum to exactly `n`. A number `n` is *abundant* if the sum of `n`'s proper factors is greater than `n` and *deficient* if that sum is less than `n`.

(a) (4.0 points)

Implement `classify`, a function that takes an integer `n` **greater than** 1. It returns the string `'deficient'`, `'perfect'`, or `'abundant'` that correctly describes `n`.

```
def classify(n):
    """Return whether n > 1 is 'deficient', 'perfect', or 'abundant'.

    >>> classify(6)   # Proper factors 1, 2 and 3 sum to exactly 6.
    'perfect'
    >>> classify(24)  # Proper factors 1, 2, 3, 4, 6, 8, and 12 sum to 36.
    'abundant'
    >>> classify(23)  # Proper factor 1 sums to 1.
    'deficient'
    """
    total, k = 0, 1
    while __<BLANK 1>__:
        if __<BLANK 2>__:
            __<BLANK 3>__
        k = k + 1
    if total == n:
        return 'perfect'
    elif __<BLANK 4>__:
        return 'deficient'
    else:
        return 'abundant'
```

i. (1.0 pt) BLANK 1

- ◯ `k < n`
- ◯ `k <= n`
- ◯ `k < total`
- ◯ `k <= total`

ii. (1.0 pt) BLANK 2

iii. (1.0 pt) BLANK 3

iv. (1.0 pt) BLANK 4

(b) (6.0 points)

Implement `nearest_perfect`, which takes an integer `n` above 5. It returns the nearest perfect number to `n`. If two perfect numbers are equally close to `n`, return the larger one. A number `a` is nearer to `n` than another number `b` if `abs(a - n) < abs(b - n)`. Assume `classify` is implemented correctly.

```
def nearest_perfect(n):
    """Return the nearest perfect number to n. In a tie, return the larger one.

    >>> nearest_perfect(8)   # 6 is perfect and 2 away from 8.
    6
    >>> nearest_perfect(20)  # 28 is perfect and 8 away from 20.
    28
    >>> nearest_perfect(17)  # Both 6 and 28 are 11 away from 17.
    28
    >>> nearest_perfect(6)   # 6 is perfect and 0 away from 6.
    6
    """
    k = 0
    while True:
        if __<BLANK 5>__:
            __<BLANK 6>__
        if __<BLANK 7>__:
            k = -k
        else:
            __<BLANK 8>__
```

i. (2.0 pt) BLANK 5

ii. (1.0 pt) BLANK 6

- ◯ `n = n + k`
- ◯ `n = n + 1`
- ◯ `n = n - k`
- ◯ `n = n - 1`
- ◯ `return n + k`
- ◯ `return n`
- ◯ `return k`

iii. (1.0 pt) BLANK 7

iv. (2.0 pt) BLANK 8

4. (4.0 points) Super Powers

Definition. A *function power*, written $f^n(x)$, describes repeated application of a function f to x. $f^2(x) = f(f(x))$, $f^5(x) = f(f(f(f(x))))$, and so on.

(a) (2.0 pt) Choose **all** correct implementations of `funsquare`, a function that takes a one-argument function `f`. It returns a one-argument function `f2` such that `f2(x)` has the same behavior as `f(f(x))` for all `x`.

```
>>> triple = lambda x: 3 * x
>>> funsquare(triple)(5)  # Equivalent to triple(triple(5))
45
```

```
A:  def funsquare(f):
        return f(f)
```

```
B:  def funsquare(f):
        return lambda: f(f)
```

```
C:  def funsquare(f, x):
        def g(x):
            return f(f(x))
        return g
```

```
D:  def funsquare(f):
        return lambda x: f(f(x))
```

```
E:  def funsquare(f, x):
        return f(f(x))
```

```
F:  def funsquare(f):
        def g(x):
            return f(f(x))
        return g
```

☐ A

☐ B

☐ C

☐ D

☐ E

☐ F

(b) (1.0 pt) Fill in the blank to assign `quadruple` to a function that takes a number x and returns $4x$.

```
>>> quadruple = funsquare(__<BLANK 1>__)
>>> quadruple(3)  # 4 * 3
12
```

BLANK 1

(c) (1.0 pt) Fill in the blank to assign `funfourth` to a function that takes a one-argument function $f(x)$ and returns a one-argument function $f^4(x)$. **You may not use a lambda expression.**

```
>>> funfourth = __<BLANK 2>__
>>> funfourth(triple)(10)  # 10 * 3 * 3 * 3 * 3 (triple is defined near the top of the page)
810
```

BLANK 2

5. (0.0 points) A+ Question 1: Busy Beaver

This A+ question is not worth any points. It can only affect your course grade if you have a high A and might receive an A+. Finish the rest of the exam first!

To receive an A+ in CS 61A, you need at least 300 points in the course overall and must solve 2 A+ questions. To receive credit for this A+ question, you must answer all parts of it entirely correctly.

Introduced by Tibor Radó in 1962, the *Busy Beaver Game* aims to find the terminating program of a given length that produces the most possible output. Here, we'll explore one approach to generating a lot of output.

Implement `b`, which takes a zero-argument function `f` that returns `None`. The `b` function calls its argument `f` 64 times and returns `None`.

- You may not use any numbers or strings or any expressions that evaluate to numbers or strings.
- You may not import any functions, but may use built-in functions that do not need to be imported.
- You may not use lists, tuples, or dictionaries.
- Your answer for blank 2 must be no longer than 50 characters, ignoring whitespace.

```
def b(f):
    """Evaluate f() 64 times.

    >>> a = lambda: print('A', end='')
    >>> b(a)
    AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
    """
    (lambda g: g(g(g(g(g(g(g(__<BLANK 1>__)))))))(__<BLANK 2>__)__<BLANK 3>__
```

(a) (0.0 pt) `BLANK 1`

◯ `f`

◯ `g`

◯ `f()`

◯ `g()`

(b) (0.0 pt) `BLANK 2` (**Your answer must not be longer than 50 characters, ignoring whitespace.**)

(c) (0.0 pt) `BLANK 3`

◯ `()`

◯ `(f)`

◯ `(g)`