1 Recursion

1.1 (Adapted from Fall 2013) Fill in the blanks in the implementation of `paths`, which takes as input two positive integers `x` and `y`. It returns a list of paths, where each path is a list containing steps to reach `y` from `x` by repeated incrementing or doubling. For instance, we can reach 9 from 3 by incrementing to 4, doubling to 8, then incrementing again to 9, so one path is `[3, 4, 8, 9]

```python
def paths(x, y):
    """Return a list of ways to reach y from x by repeated incrementing or doubling."""
    >>> paths(3, 5)
    [[3, 4, 5]]
    >>> sorted(paths(3, 6))
    [[3, 4, 5, 6], [3, 6]]
    >>> sorted(paths(3, 9))
    [[3, 4, 5, 6, 7, 8, 9], [3, 4, 8, 9], [3, 6, 7, 8, 9]]
    >>> paths(3, 3) # No calls is a valid path
    [[3]]
    ""
    if _________________:
        return ________________________________
    elif _________________:
        return ________________________________
    else:
        a = ________________________________
        b = ________________________________
        return ________________________________
```
1.2 We will now write one of the faster sorting algorithms commonly used, known as *merge sort*. Merge sort works like this:

1. If there is only one (or zero) item(s) in the sequence, it is already sorted!

2. If there are more than one item, then we can split the sequence in half, sort each half recursively, then merge the results, using the merge procedure described below. The result will be a sorted sequence.

Using the algorithm described, write a function `mergesort(seq)` that takes an unsorted sequence and sorts it.

Recall the merge procedure is as follows:

```python
def merge(s1, s2):
    """ Merges two sorted lists """
    if len(s1) == 0:
        return s2
    elif len(s2) == 0:
        return s1
    elif s1[0] < s2[0]:
        return [s1[0]] + merge(s1[1:], s2)
    else:
        return [s2[0]] + merge(s1, s2[1:])

def mergesort(seq):
```

*Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.*
2 Trees

2.1 Implement `long_paths`, which returns a list of all paths in a tree with length at least $n$. A path in a tree is a linked list of node values that starts with the root and ends at a leaf. Each subsequent element must be from a child of the previous value's node. The length of a path is the number of edges in the path (i.e. one less than the number of nodes in the path). Paths are listed in order from left to right. See the doctests for some examples.

```python
def long_paths(tree, n):
    """Return a list of all paths in tree with length at least n."

    >>> t = Tree(3, [Tree(4), Tree(4), Tree(5)])
    >>> left = Tree(1, [Tree(2), t])
    >>> mid = Tree(6, [Tree(7, [Tree(8)]), Tree(9)])
    >>> right = Tree(11, [Tree(12, [Tree(13, [Tree(14)])])])
    >>> whole = Tree(0, [left, Tree(13), mid, right])
    >>> for path in long_paths(whole, 2):
    ...    print(path)
    ...
    <0 1 2>
    <0 1 3 4>
    <0 1 3 4>
    <0 1 3 5>
    <0 6 7 8>
    <0 6 9>
    <0 11 12 13 14>
    >>> for path in long_paths(whole, 3):
    ...    print(path)
    ...
    <0 1 3 4>
    <0 1 3 4>
    <0 1 3 5>
    <0 6 7 8>
    <0 11 12 13 14>
    >>> long_paths(whole, 4)
    [Link(0, Link(11, Link(12, Link(13, Link(14)))))]
    """

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
2.2 Write a function that takes a Tree object and returns the elements at the depth with the most elements.

In this problem, you may find it helpful to use the second optional argument to sum, which provides a starting value. All items in the sequence to be summed will be concatenated to the starting value. By default, start will default to 0, which allows you to sum a sequence of numbers. We provide an example of sum starting with a list, which allows you to concatenate items in a list.

```python
def widest_level(t):
    """
    >>> sum([[1], [2]], [])
    [1, 2]
    >>> t = Tree(3, [Tree(1, [Tree(1), Tree(5)]),
    ...     Tree(4, [Tree(9, [Tree(2)])])])
    >>> widest_level(t)
    [1, 5, 9]
    """
    levels = []
x = [t]

    while ________________________________:
        ________________________________
        __________ = sum(__________________________, [])

    return max(levels, key=__________________________)
```

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3 Mutation

3.1 For each row below, fill in the blanks in the output displayed by the interactive Python interpreter when the expression is evaluated. Expressions are evaluated in order, and expressions may affect later expressions.

```python
>>> cats = [1, 2]
>>> dogs = [cats, cats.append(23), list(cats)]
>>> cats
```

```python
>>> dogs[1] = list(dogs)
>>> dogs[1]
```

```python
>>> dogs[0].append(2)
>>> cats
```

```python
>>> cats[1::2]
```

```python
>>> cats[:3]
```

```python
>>> dogs[2].extend([list(cats).pop(0), 3])
>>> dogs[3]
```

```python
>>> dogs
```
4 OOP

4.1 Fill in the classes Emotion, Joy, and Sadness below so that you get the following output from the Python interpreter.

```python
>>> Emotion.num
0
>>> joy = Joy()
>>> sadness = Sadness()
>>> Emotion.num # number of Emotion instances created
2
>>> joy.power
5
>>> joy.catchphrase() # Print Joy's catchphrase
Think positive thoughts
>>> sadness.catchphrase() # Print Sad's catchphrase
I'm positive you will get lost
>>> sadness.power
5
>>> joy.feeling(sadness) # When both Emotions have same power value, print "Together"
Together
>>> sadness.feeling(joy)
Together
>>> joy.power = 7
>>> joy.feeling(sadness) # Print the catchphrase of the more powerful feeling before the less powerful feeling
Think positive thoughts
I'm positive you will get lost
>>> sadness.feeling(joy)
Think positive thoughts
I'm positive you will get lost
```

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
```python
class Emotion(_______):
    def __init__(self):
        pass

    def feeling(self, other):
        pass

class Joy(_______):
    def catchphrase(self):
        pass

class Sadness(_______):
    def catchphrase(self):
        pass
```

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5 Mutable Linked Lists and Trees

5.1 Write a recursive function `flip_two` that takes as input a linked list `lnk` and mutates `lnk` so that every pair is flipped.

```python
def flip_two(lnk):
    """
    >>> one_lnk = Link(1)
    >>> flip_two(one_lnk)
    >>> one_lnk
    Link(1)
    >>> lnk = Link(1, Link(2, Link(3, Link(4, Link(5)))))
    >>> flip_two(lnk)
    >>> lnk
    Link(2, Link(1, Link(4, Link(3, Link(5)))))
    """
```
6 Generators

6.1 Write a generator function that yields functions that are repeated applications of a one-argument function \( f \). The first function yielded should apply \( f \) 0 times (the identity function), the second function yielded should apply \( f \) once, etc.

```python
def repeated(f):
    """
    >>> double = lambda x: 2 * x
    >>> funcs = repeated(double)
    >>> identity = next(funcs)
    >>> double = next(funcs)
    >>> quad = next(funcs)
    >>> oct = next(funcs)
    >>> quad(1)
    4
    >>> oct(1)
    8
    >>> [g(1) for _, g in
    ...     zip(range(5), repeated(lambda x: 2 * x))]
    [1, 2, 4, 8, 16]
    """

    g = ______________________________________________________________________

    while True:

        ______________________________________________________________________

        ______________________________________________________________________

    g = ______________________________________________________________________

while True:

    ______________________________________________________________________

    ______________________________________________________________________

    ______________________________________________________________________
```

6.2 Ben Bitdiddle proposes the following alternate solution. Does it work?

```python
def ben_repeated(f):
    g = lambda x: x
    while True:
        yield g
        g = lambda x: f(g(x))
```

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
6.3 Implement `accumulate`, which takes in an `iterable` and a function `f` and yields each accumulated value from applying `f` to the running total and the next element.

```python
from operator import add, mul

def accumulate(iterable, f):
    """
    >>> list(accumulate([1, 2, 3, 4, 5], add))
    [1, 3, 6, 10, 15]
    >>> list(accumulate([1, 2, 3, 4, 5], mul))
    [1, 2, 6, 24, 120]
    """
    it = iter(iterable)
    ...
```

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
7 Scheme

7.1 Implement the `append-stream` procedure, which takes in two streams and returns a stream with the two streams concatenated. (Note that if the first stream is infinite, the result will not contain any elements from the second stream.)

```
scm> (define s (cons-stream 1 (cons-stream 2 nil)))
s
scm> (define a (append-stream s s))
a
scm> (car a)
1
scm> (car (cdr-stream a))
2
scm> (car (cdr-stream (cdr-stream a)))
1
scm> (car (cdr-stream (cdr-stream (cdr-stream a))))
2
```

```
(define (append-stream s1 s2)
  ; Implementation...
)
```
Now implement \texttt{subset-stream}, which takes in a normal Scheme list and returns a stream with every possible subset of that Scheme list.

It might help to use \texttt{map-stream}, which we've defined for you:

\begin{verbatim}
(define (map-stream f s)
  (if (null? s)
      nil
      (cons-stream (f (car s)) (map-stream f (cdr-stream s)))))
\end{verbatim}

\begin{verbatim}
scm> (define a (subset-stream '(1 2 3 4 5)))
a
scm> (car a)
(1 2 3 4 5)
scm> (car (cdr-stream a))
(1 2 3 4)
scm> (car (cdr-stream (cdr-stream a)))
(1 2 3 5)
scm> (car (cdr-stream (cdr-stream (cdr-stream a))))
(1 2 3)
\end{verbatim}

\begin{verbatim}
(define (subset-stream lst)
\end{verbatim}
7.3 Write a function that takes a procedure and applies to every element in a given
nested list.

The result should be a nested list with the same structure as the input list, but
with each element replaced by the result of applying the procedure to that element.

Use the built-in list? procedure to detect whether a value is a list.

\[
(\text{define} \ (\text{deep-map} \ \text{fn} \ \text{lst})
\]

\[
\text{scm}\> (\text{deep-map} \ (\text{lambda} \ (x) \ (* \ x \ x)) \ '(1 \ 2 \ 3))
\]
\[
(1 \ 4 \ 9)
\]

\[
\text{scm}\> (\text{deep-map} \ (\text{lambda} \ (x) \ (* \ x \ x)) \ '((4) \ 5) \ 9))
\]
\[
(1 \ ((16) \ 25) \ 81)
\]

7.4 Write a tail recursive function that takes in a Scheme list and returns the numerical
sum of all values in the list. You can assume that the list contains only numbers
(no nested lists).

\[
(\text{define} \ (\text{sum} \ \text{lst})
\]

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8 SQL

(Adapted from Fall 2019) The scoring table has three columns, a player column of strings, a points column of integers, and a quarter column of integers. The players table has two columns, a name column of strings and a team column of strings. Complete the SQL statements below so that they would compute the correct result even if the rows in these tables were different than those shown. Important: You may write anything in the blanks including keywords such as WHERE or ORDER BY. Use the following table called courses for the questions below:

CREATE TABLE scoring AS
    SELECT "Donald Stewart" AS player, 7 AS points, 1 AS quarter UNION
    SELECT "Christopher Brown Jr." , 7, 1 UNION
    SELECT "Ryan Sanborn", 3, 2 UNION
    SELECT "Greg Thomas", 3, 2 UNION
    SELECT "Cameron Scarlett", 7, 3 UNION
    SELECT "Nikko Remigio", 7, 4 UNION
    SELECT "Ryan Sanborn", 3, 4 UNION
    SELECT "Chase Garbers", 7, 4;

CREATE TABLE players AS
    SELECT "Ryan Sanborn" AS name, "Stanford" AS team UNION
    SELECT "Donald Stewart", "Stanford" UNION
    SELECT "Cameron Scarlett", "Stanford" UNION
    SELECT "Christopher Brown Jr.", "Cal" UNION
    SELECT "Greg Thomas", "Cal" UNION
    SELECT "Nikko Remigio", "Cal" UNION
    SELECT "Chase Garbers", "Cal";

8.1 Write a SQL statement to select a one-column table of quarters in which more than 10 total points were scored.

8.2 Write a SQL statement to select a two-column table of the points scored by each team. Assume that no two players have the same name.

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