Last Name…… First Name…… Student# …….

Short Python function/method descriptions:

__builtins__:

len(x) -> integer
Return the length of the list, tuple, dict, or string x.

max(L) -> value
Return the largest value in L.

min(L) -> value
Return the smallest value in L.

range([start], stop, [step]) -> list of integers
Return a list containing the integers starting with start and ending with stop - 1 with step specifying the amount to increment (or decrement). If start is not specified, the list starts at 0.
If step is not specified, the values are incremented by 1.

sum(L) -> number
Returns the sum of the numbers in L.

dict:

D[k] -> value
Return the value associated with the key k in D.

k in d -> boolean
Return True if k is a key in D and False otherwise.

D.get(k) -> value
Return D[k] if k in D, otherwise return None.

D.keys() -> list of keys
Return the keys of D.

D.values() -> list of values
Return the values associated with the keys of D.

D.items() -> list of (key, value) pairs
Return the (key, value) pairs of D, as 2-tuples.

float:

float(x) -> floating point number
Convert a string or number to a floating point number, if possible.

int:

int(x) -> integer
Convert a string or number to an integer, if possible. A floating point argument will be truncated towards zero.

list:

x in L -> boolean
Return True if x is in L and False otherwise.

L.append(x)
Append x to the end of list L.

L1.extend(L2)
Append the items in list L2 to the end of list L1.

L.index(value) -> integer
Return the lowest index of value in L.

L.insert(index, x)
Insert x at position index.

L.pop()
Remove and return the last item from L.
L.remove(value)
Remove the first occurrence of value from L.
L.sort()
Sort the list in ascending order.

Module random: randint(a, b)
Return random integer in range [a, b], including both end points.

str:
x in s -> boolean
Return True if x is in s and False otherwise.
str(x) -> string
Convert an object into its string representation, if possible.
S.count(sub[, start[, end]]) -> int
Return the number of non-overlapping occurrences of substring sub in string S[start:end]. Optional arguments start and end are interpreted as in slice notation.
S.find(sub[,i]) -> integer
Return the lowest index in S (starting at S[i], if i is given) where the string sub is found or -1 if sub does not occur in S.
S.split([sep]) -> list of strings
Return a list of the words in S, using string sep as the separator and any whitespace string if sep is not specified.

set:
{1, 2, 3, 1, 3} -> {1, 2, 3}
s.add(...)
Add an element to a set
set()
Create a new empty set object
x in s
True iff x is an element of s

list comprehension:
[<expression with x> for x in <list or other iterable>]

functional if:
<expression 1> if <boolean condition> else <expression 2>
-> <expression 1> if the boolean condition is True, otherwise <expression 2>

======Class Container ==========

```
class Container:
    """
    A data structure to store and retrieve objects.
    This is an abstract class that is not meant to be instantiated itself,
    but rather subclasses are to be instantiated.
    """
```

```
    def __init__(self):
        """
        Create a new and empty Container self.
        """
        self._content = None
        raise NotImplemented ("This is an abstract class, define or use its subclass")

    def add(self, obj):
        """
        Add object obj to Container self.
        :param obj: object to place onto Container self
        :type obj: Any
        :rtype: None
        """
        raise NotImplemented ("This is an abstract class, define or use its subclass")

    def remove(self):
        """
        Remove and return an element from Container self.
        Assume that Container self is not empty.
        :return an object from Container slef
        :rtype: object
        """
        raise NotImplemented ("This is an abstract class, define or use its subclass")

    def is_empty(self):
        """
        Return whether Container self is empty.
        :rtype: bool
        """
        return len(self._content) == 0

    def __eq__(self, other):
        """
        Return whether Container self is equivalent to the other.

        :param other: a Container
        :type other: Container
        :rtype: bool
        """
        return type(self)== type(other) and self._content == other._content

    def __str__(self):
        """
        Return a human-friendly string representation of Container.
        :rtype: str
        """
        return str(self._content)
```

======Class Stack ======================

```
from container import Container

class Stack(Container):
    """Last-in, first-out (LIFO) stack.
    """
    def __init__(self):
        """Create a new, empty Stack self.

        Overrides Container.__init__

        """
        self._content = []

    def add(self, obj):
        """ Add object obj to top of Stack self.

        Overrides Container.add

        :param obj: object to place on Stack
        :type obj: Any
        :rtype: None
        >>> s = Stack()
        >>> s.add(1)
        >>> s.add(2)
        >>> print(s)
        [1, 2]
        """
        self._content.append(obj)

    def remove(self):
        """
        Remove and return top element of Stack self.

        Assume Stack self is not empty.

        Overrides Container.remove

        :rtype: object
        >>> s = Stack()
        >>> s.add(5)
        >>> s.add(7)
        >>> s.remove()
        7
        """
        return self._content.pop()
```

======Class Queue ==========

```
from container import Container

class Queue (Container):
    """A first-in, first-out (FIFO) queue.
    """

    def __init__(self):
        """
        Create and initialize new Queue self.

        Overrides Container.__init__

        """
        self._content = []

    def add(self, obj):
        """
        Add object at the back of Queue self.

        Overrides Container.add

        :param obj: object to add
        :type obj: object
        :rtype: None
        >>> q = Queue()
        >>> q.add(1)
        >>> q.add(2)
        >>> print(q)
        [1, 2]
        """
        self._content.append(obj)

    def remove(self):
        """
        Remove and return front object from Queue self.

        Queue self must not be empty.

        Overrides Container.remove

        :rtype: object

        >>> q = Queue()
        >>> q.add(3)
        >>> q.add(5)
        >>> q.remove()
        3
        """
        return self._content.pop(0)
```

======Class LinkedListNode==========

```
class LinkedListNode:
    """
    Node to be used in linked lists

    === Public Attributes ===
    :param LinkedListNode next_: successor to this LinkedListNode
    :param object value: data this LinkedListNode represents
    """

    def __init__(self, value, next_=None):
        """
        Create LinkedListNode self with data value and successor next_.

        :param value: data of this linked list node
        :type value: object
        :param next_: successor to this LinkedListNode.
        :type next_: LinkedListNode|None
        """
        self.value, self.next_ = value, next_

    def __str__(self):
        """
        Return a user-friendly representation of this LinkedListNode.

        :rtype: str

        >>> n = LinkedListNode(5, LinkedListNode(7))
        >>> print(n)
        5 -> 7 ->|
        """
        s = "{} ->".format(self.value)
        cur_node = self
        while cur_node is not None:
            if cur_node.next_ is None:
                s += "|"
            else:
                s += " {} ->".format(cur_node.next_.value)
            cur_node = cur_node.next_
        return s

    def __eq__(self, other):
        """
        Return whether LinkedListNode self is equivalent to other.

        :param LinkedListNode self: this LinkedListNode
        :param LinkedListNode|object other: object to compare to self.
```

```
    :rtype: bool

    >>> LinkedListNode(5).__eq__(5)
    False
    >>> n1 = LinkedListNode(5, LinkedListNode(7))
    >>> n2 = LinkedListNode(5, LinkedListNode(7, None))
    >>> n1.__eq__(n2)
    True
    """
    self_node, other_node = self, other
    while (self_node is not None and type(self_node) is type(other_node) and
            self_node.value == other_node.value):
        self_node, other_node = self_node.next_, other_node.next_
    return self_node is None and other_node is None
```

======Class (general) Tree=====================

```
class Tree:
    """A bare-bones Tree ADT that identifies the root with the entire tree.

    === Public Attributes ===
    :param object value: data for this binary tree node
    :param list[Tree] children: children of this binary tree node
    """

    def __init__(self, value=None, children=None):
        """Create Tree self with content value and 0 or more children

        :param value: value contained in this tree
        :type value: object
        :param children: possibly-empty list of children
        :type children: list[Tree]
        """
        self.value = value
        # copy children if not None
        self.children = children.copy() if children else []

    def __eq__(self, other):
        """Return whether this Tree is equivalent to other.

        :param other: object to compare to self
        :type other: object}Tree
        :rtype: bool

        >>> t1 = Tree(5)
        >>> t2 = Tree(5, [])
        >>> t1 == t2
        True
```

```
        >>> t3 = Tree(5, [t1])
        >>> t2 == t3
        False
        """
    return (type(self) is type(other) and self.value == other.value and self.children == other.children)

def descendants_from_list(t, list_, arity):
    """"Populate Tree t's descendants from list_, filling them in level order, with up to arity children per
    node. Then, return t.

    :param t: tree to populate from list_
    :type t: Tree
    :param list_: list of values to populate from
    :type list_: list
    :param arity: maximum branching factor
    :type arity: int
    :rtype: Tree

    >>> descendants_from_list(Tree(0), [1, 2, 3, 4], 2)
    Tree(0, [Tree(1, [Tree(3), Tree(4)]), Tree(2)])
    """
    q = Queue()
    q.add(t)
    list_ = list_.copy()
    while not q.is_empty():  # unlikely to happen
        new_t = q.remove()
        for i in range(0, arity):
            if len(list_) == 0:
                return t  # our work here is done
            else:
                new_t_child = Tree(list_.pop(0))
                new_t.children.append(new_t_child)
                q.add(new_t_child)
    return t
```

======Class BinaryTree======

```
class BinaryTree:
    """ A Binary Tree, i.e. arity 2.

    === Public Attributes ===
    :param object data: data for this binary tree node
    :param BinaryTree|None left: left child of this binary tree node
    :param BinaryTree|None right: right child of this binary tree node
    """

    def __init__(self, data, left=None, right=None):
        """
        Create BinaryTree self with data and children left and right.

        :param data: data of this node
        :type data: object
        :param left: left child
        :type left: BinaryTree|None
        :param right: right child
        :type right: BinaryTree|None
        """
        self.data, self.left, self.right = data, left, right

    def __eq__(self, other):
        """
        Return whether BinaryTree self is equivalent to other.

        :param other: object to check equivalence to self
        :type other: Any
        :rtype: bool

        >>> BinaryTree(7).__eq__("seven")
        False
        >>> b1 = BinaryTree(7, BinaryTree(5))
        >>> b1.__eq__(BinaryTree(7, BinaryTree(5), None))
        True
        """
        return (type(self) == type(other) and
                self.data == other.data and
                (self.left, self.right) == (other.left, other.right))

    def __repr__(self):
        """
        Represent BinaryTree (self) as a string that can be evaluated to
        produce an equivalent BinaryTree.

        @rtype: str
```

```
        >>> BinaryTree(1, BinaryTree(2), BinaryTree(3))
        BinaryTree(1, BinaryTree(2, None, None), BinaryTree(3, None, None))
        """
        return "BinaryTree({}, {}, {})".format(repr(self.data),
                                               repr(self.left),
                                               repr(self.right))

    def __str__(self, indent=""):
        """
        Return a user-friendly string representing BinaryTree (self)
        inorder.  Indent by indent.

        >>> b = BinaryTree(1, BinaryTree(2, BinaryTree(3)), BinaryTree(4))
        >>> print(b)
          4
        1
          2
            3
        <BLANKLINE>
        """
        right_tree = (self.right.__str__(indent + "    ") if self.right else "")
        left_tree = self.left.__str__(indent + "    ") if self.left else ""
        return (right_tree + "{}{}\n".format(indent, str(self.data)) + left_tree)

    def __contains__(self, value):
        """
        Return whether tree rooted at node contains value.

        :param value: value to search for
        :type value: object
        :rtype: bool

        >>> BinaryTree(5, BinaryTree(7), BinaryTree(9)).__contains__(7)
        True
        """
        return (self.data == value or
                (self.left and value in self.left) or
                (self.right and value in self.right))
```