This 150-minute (2.5 hour) closed-book, closed-notes exam has 9 questions worth a total of roughly 115 points (some point-total adjustment may occur during grading).
You may separate the pages while working on the exam; we have a stapler available.

It is a violation of the Academic Integrity Code to look at any exam other than your own, to look at any reference material besides the reference provided in the exam itself, or to otherwise give or receive unauthorized help.
We also ask that you not discuss this exam with students who are scheduled to take a later makeup.

Academic Integrity is expected of all students of Cornell University at all times, whether in the presence or absence of members of the faculty. Understanding this, I declare I shall not give, use or receive unauthorized aid in this examination.

______________________________ Date ____________

Name (First Last):

______________________________

Cornell NetID, all caps: ________________________________
This is a comprehensive reference sheet that might include functions or methods not needed for your exam.

### String methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>s[i:j]</code></td>
<td>Returns: if i and j are non-negative indices and i ≤ j-1, a new string containing the characters in s from index i to index j-1, or the substring of s starting at i if j ≥ len(s)</td>
</tr>
<tr>
<td><code>s.count(s1)</code></td>
<td>Returns: the number of times s1 occurs in string s</td>
</tr>
<tr>
<td><code>s.find(s1)</code></td>
<td>Returns: index of first occurrence of string s1 in string s (-1 if not found)</td>
</tr>
<tr>
<td><code>s.find(s1, n)</code></td>
<td>Returns: index of first occurrence of string s1 in string s STARTING at position n. (-1 if s1 not found in s from this position)</td>
</tr>
<tr>
<td><code>s.index(s1)</code></td>
<td>Returns: index of first occurrence of string s1 in string s; raises an error if s1 is not found in s.</td>
</tr>
<tr>
<td><code>s.index(s1, n)</code></td>
<td>Returns: index of first occurrence of string s1 in string s STARTING at position n; raises an error if s1 is not found in s from this position</td>
</tr>
<tr>
<td><code>s.isalpha()</code></td>
<td>Returns: True if s is not empty and its elements are all letters; it returns False otherwise.</td>
</tr>
<tr>
<td><code>s.isdigit()</code></td>
<td>Returns: True if s is not empty and its elements are all numbers; it returns False otherwise.</td>
</tr>
<tr>
<td><code>s.islower()</code></td>
<td>Returns: True if s is has at least one letter and all letters are lower case; returns False otherwise (e.g., ‘A123’ is True but ‘123’ is False).</td>
</tr>
<tr>
<td><code>s.isupper()</code></td>
<td>Returns: True if s is has at least one letter and all letters are upper case; returns False otherwise (e.g., ‘A123’ is True but ‘123’ is False).</td>
</tr>
<tr>
<td><code>s.join(slist)</code></td>
<td>Returns: a copy of s where all instances of a are replaced with b</td>
</tr>
<tr>
<td><code>s.lower()</code></td>
<td>Returns: a copy of s, all letters converted to lower case.</td>
</tr>
<tr>
<td><code>s.replace(a, b)</code></td>
<td>Returns: a copy of s, all letters converted to lower case.</td>
</tr>
<tr>
<td><code>s.split(sep)</code></td>
<td>Returns: a list of the “words” in string s, using sep as the word delimiter (whitespace if sep not given)</td>
</tr>
<tr>
<td><code>s.strip()</code></td>
<td>Returns: copy of string s where all whitespace has been removed from the beginning and the end of s.</td>
</tr>
<tr>
<td><code>s.upper()</code></td>
<td>Returns: a copy of s, all letters converted to upper case.</td>
</tr>
</tbody>
</table>

### List methods

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td><code>lt[i:j]</code></td>
<td>Returns: if i and j are non-negative indices and i ≤ j-1, a new list containing the elements in lt from index i to index j-1, or the sublist of lt starting at i if j ≥ len(lt)</td>
</tr>
<tr>
<td><code>lt.append(item)</code></td>
<td>Adds item to the end of list lt</td>
</tr>
<tr>
<td><code>lt.count(item)</code></td>
<td>Returns: count of how many times item occurs in list lt</td>
</tr>
<tr>
<td><code>lt.index(item)</code></td>
<td>Returns: index of first occurrence of item in list lt; raises an error if item is not found. (There’s no “find()” for lists.)</td>
</tr>
<tr>
<td><code>lt.index(y, n)</code></td>
<td>Returns: index of first occurrence of item in list lt STARTING at position n; raises an error if item does not occur in lt.</td>
</tr>
<tr>
<td><code>lt.insert(i, item)</code></td>
<td>Insert item into list lt at position i</td>
</tr>
<tr>
<td><code>lt.pop(i)</code></td>
<td>Returns: element of list lt at index i and also removes that element from the list lt. Raises an error if i is an invalid index.</td>
</tr>
<tr>
<td><code>lt.remove(item)</code></td>
<td>Removes the first occurrence of item from list lt; raises an error if item not found.</td>
</tr>
<tr>
<td><code>lt.reverse()</code></td>
<td>Reverses the list lt in place (so, lt is modified)</td>
</tr>
<tr>
<td><code>lt.sort()</code></td>
<td>Rearranges the elements of x to be in ascending order.</td>
</tr>
</tbody>
</table>

### Dictionary Operations

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td><code>d[k] = v</code></td>
<td>Assigns value v to the key k in d.</td>
</tr>
<tr>
<td><code>d[k]</code></td>
<td>If value v was assigned to the key k in d, d[k] evaluates to v.</td>
</tr>
<tr>
<td><code>del d[k]</code></td>
<td>Deletes the key k (and its value) from the dictionary d.</td>
</tr>
<tr>
<td><code>d.keys()</code></td>
<td>Returns: an iterator of all the keys in dictionary d.</td>
</tr>
<tr>
<td><code>d.values()</code></td>
<td>Returns: an iterator of all the values in dictionary d.</td>
</tr>
</tbody>
</table>

### Other useful functions

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><code>s1 in s</code></td>
<td>Returns: True if the substring s1 is in string s; False otherwise.</td>
</tr>
<tr>
<td><code>elem in lt</code></td>
<td>Returns: True if the element elem is in list lt; False otherwise.</td>
</tr>
<tr>
<td><code>y in d</code></td>
<td>Returns: True if y is a key in dictionary d; False otherwise.</td>
</tr>
<tr>
<td><code>y in d.values()</code></td>
<td>Returns: True if y is a value in dictionary d; False otherwise.</td>
</tr>
<tr>
<td><code>input(s)</code></td>
<td>Prompts user for a response using string s; returns the user’s response as a string.</td>
</tr>
<tr>
<td><code>isinstance(o, c)</code></td>
<td>Returns: True if o is an instance of class c; False otherwise.</td>
</tr>
<tr>
<td><code>len(s)</code></td>
<td>Returns: number of characters in string s; it can be 0.</td>
</tr>
<tr>
<td><code>len(lt)</code></td>
<td>Returns: number of items in list lt; it can be 0.</td>
</tr>
<tr>
<td><code>len(d)</code></td>
<td>Returns: number of keys in dictionary d; it can be 0.</td>
</tr>
<tr>
<td><code>list(range(n))</code></td>
<td>Returns: the list [0 .. n-1]</td>
</tr>
</tbody>
</table>
1. [12 points] **Strings.** Implement the following function. Do not use iteration in your solution.

```python
def happify(s):
    """Returns a new string, that is the "happy version" of `s`

    the happy version is a copy of `s` with the following changes:
    1. the second word is replaced with the string `LOVE`
    2. the last character of the third word is replicated twice
       (this character can be a letter or punctuation)
    3. if it doesn't already, the string should end in an exclamation point

    Examples:
    happify('i like you lots!') returns 'i LOVE youuu lots!'
    happify('i like you. lots') returns 'i LOVE you... lots!'
    happify('I hate taking exams.') returns 'I LOVE takinggg exams.!'
    happify('a e i o!') returns 'a LOVE iii o!'

    Preconditions:
    `s` is a string of at least four words separated by spaces
    the only whitespaces in `s` are single spaces (' ')
    """

    # STUDENTS: assume preconditions are met. No need to assert them.
```
```
2. [12 points] **Dictionaries.** Implement this function according to its specification using any (and only) tools you learned in CS 1110.

```python
def merge_dict(input_dict):
    """ Given an `input_dict` with the following properties:
    - keys are strings of repeating letters ('aaa' or 'bbbbbbbbbb')
    - values are ints

    Returns: a new dictionary that is the merged version of the input_dict:
    - the keys are the 1 character version of input_dict's keys
    - the values are the combined values across all merged entries,
      weighted by the number of characters in the original key

    EXAMPLES:
    {'a': 6, 'aa': 5, 'aaa': 4} → {'a':28}
    1 x 6 + 2 x 5 + 3 x 4 =28
    {'bb':6 , 'aa': 5, 'aaa': 4} → {'b':12, 'a':22}
    2 x 6 =12
    2 x 5 + 3 x 4 =22
    {'a': 2, 'b': 2, 'c': 3} → {'a': 2, 'b': 2, 'c': 3}
    {'zzzzzzz': 1} → {'z': 7}
    {} → {}

    Precondition: input_dict is a possibly empty dictionary that will only have:
    - strings of repeating lower case characters (a-z) as keys
    - ints as values
    """
    # STUDENTS: assume preconditions are met. No need to assert them.
```
3. [10 points] **Visualizing Inheritance.** For this question, you will be shown the state of memory before a single assignment statement is executed. Modify the drawing to show how memory changes after that single assignment statement has been executed. If at any point an error is thrown, please write **ERROR** next to the assignment statement; only draw the changes to memory that would occur before the error occurs.

Each part is independent.
Notice: there is no Call Stack.
To the right is an example:

```
>>> x = x + 1
```

---

```
>>> x = y.x
```

---

```
>>> z.x = B.x
```

---

```
>>> w = y.w
```
>>> a = z.w

>>> y.w = B.x
4. [7 points] **Visualizing Methods.** For this question, you will be shown the state of memory before a single Python statement is executed. Modify the drawing to show how memory changes after that single statement has been executed. If at any point an error is thrown, please write **ERROR** next to the assignment statement; only draw the changes to memory that would occur before the error occurs. Do not worry about changing the Program Counter in the top right corner of the call frame. (Since we are not showing you the code, you can’t know what the next line of executable code will be). Once again, each part is independent. Notice that there is a call stack: each line being executed exists inside a method.

execute line 4 of fun1:  \( \text{self.y} = x \)

execute line 5 of fun1:  \( z = \text{self.x} \)

execute line 5 of fun1:  \( \text{return y.x == self.x} \)
5. [16 points] **Recursion.** Let **Person** be a class as defined below:

```python
class Person:
    """An instance represents a person who may or may not be CPR certified. (CPR certification is useful during a medical emergency.)"

    Instance attributes:
    name [str] - unique non-empty name of a person
    cert [bool] - whether the person is CPR certified or not
    ec1 [Person or None] - emergency contact 1
    ec2 [Person or None] - emergency contact 2
    """
    def __init__(self, name, cert=False, c1=None, c2=None):
        """Create new Person with a name, CPR certification status, and up to 2 emergency contacts"
        self.name = name
        self.cert = cert
        self.ec1 = c1
        self.ec2 = c2
```

*Question begins on the next page.*
Implement the Person class’ instance method can_help, making effective use of recursion.

```python
def can_help(self):
    """Returns: True if the person has someone who is CPR certified in their emergency contact network. This means either they or someone they can reach through their emergency contacts are CPR certified. Otherwise returns False.

Examples:

p1 = Person("Ailee", True) / \ p4:HyunA-F p5:Tzuyu-F
p2 = Person("Jisoo", False, p1, p2) / \ p3:Jisoo-F
p3 = Person("BoA", False) / \ p1:BoA-F p2:Ailee-T
p4 = Person("HyunA", False, p3) / \ ^^ certified!
p5 = Person("Tzuyu", False) / \ p6:HyunA-F p5:Tzuyu-F
p6 = Person("Irene", False, p4, p5) / \

==IMPORTANT==
p1.can_help() and p5.can_help() return False; they have no emergency contacts and are not themselves CPR certified
p2.can_help(), p3.can_help(), p4.can_help(), p6.can_help() all return True because they or someone they can reach via their emergency contacts are CPR certified
""
```

# STUDENTS: assume all Person objects are well formed with attributes
# as described above
```python
class Course:
    def __init__(self, name, n_credit):
        """
        Precondition: name is unique string identifier
        n_credit is an int
        """
        self.name = name
        self.n_credit = n_credit

class Student:
    max_credit = 20

    def __init__(self, netID, courses):
        """
        Precondition: netID is unique string identifier
        courses is a list of Course
        """
        self.netID = netID
        self.courses = courses
        # Add up credits
        for one_course in self.courses:
            self.n_credit += one_course.n_credit

    def enroll(self, new_course):
        """
        Precondition: new_course is a Course
        """
        if new_course.n_credit + self.n_credit <= self.maxcredit:
            self.courses.append(new_course)
            self.n_credit += new_course.n_credit

    def drop(self, course_name):
        """
        Precondition: course_name is the name of the course to drop
        """
        for one_course in self.courses:
            if one_course.name == course_name:
                self.n_credit -= one_course.n_credit
                self.courses.remove(one_course)

    c1 = Course("CS 1110", 4)
    c2 = Course("HADM 1810", 3)
    s1 = Student("mep1", [c1])  # enroll in first course
    s1.enroll(c2)  # enroll in second course
    assert len(s1.courses) == 2  # enroll in second course
    s1.drop(c1)  # drop a course
    assert len(s1.courses) == 1  # should be down to 1 course...
```
6. **Debugging.** On the previous page is the code for two new classes and 7 lines of code that use them. Keep in mind that specifications are always correct and should not be changed.

When the given code is run in Python, the following error is reported:

```
Traceback (most recent call last):
  File "college.py", line 43, in <module>
    s1 = Student("mep1", [c1])   # enroll in first course
  File "college.py", line 22, in __init__
    self.n_credit += one_course.n_credit
AttributeError: 'Student' object has no attribute 'n_credit'
```

(a) [2 points] Fix the code to remove only the above error. **Fix only the problem that directly causes the above error message.** Mark your fix(es) with the label **FIX1**.

Now that you have fixed the error, you rerun the code and now a new error is reported:

```
Traceback (most recent call last):
  File "college.py", line 44, in <module>
    s1.enroll(c2)   # enroll in second course
  File "college.py", line 28, in enroll
    if new_course.n_credit + self.n_credit <= self.maxcredit:
AttributeError: 'Student' object has no attribute 'maxcredit'
```

(b) [2 points] Fix the code to remove only this new error. **Fix only the problem that directly causes to the new error message.** Mark your fix(es) with the label **FIX2**.

Now that you have fixed the error, you rerun the code and now a new error is reported:

```
Traceback (most recent call last):
  File "college.py", line 47, in <module>
    assert len(s1.courses) == 1     # should be down to 1 course...
AssertionError
```

(c) [2 points] Is there a bug in the drop method?

Circle One: Yes No

(d) [2 points] If you answered No, explain what the problem is. If you answered Yes, fix the bug. Label this as **FIX3**.
7. Classes and Subclasses. Here are two classes FoodItem and Cart.

class FoodItem:
    ""
    Represents some food available for sale at a store.
    
    Instance attributes:
    name (str): name of the food item
    weight (float): how much the food weighs (in pounds); based on how
        much of the item there is.
    price (float): how much the food costs
    flat_price (bool): indicates whether the price is the total price
        for the food item (if True) or the price per pound (if False).
    ""
    def __init__(self, name, weight, price, flat_price=True):
        self.name = name
        self.weight = weight
        self.price = price
        self.flat_price = flat_price

class Cart:
    ""
    Represents a shopping cart which holds food items.
    
    Instance attributes:
    contents (list of FoodItem): (possibly empty) list of all FoodItems
        in the cart.
    ""
    def __init__(self):
        self.contents = []

Question begins on the next page.
(Continued from previous page.)

(a) [5 points] Implement the `add_item` method of class `Cart` so that it meets its specification.

```python
def add_item(self, name, weight, price, flat_price=True):
    """This function makes a new FoodItem object (with name `name`,
    weight `weight`, price `price`, and flat_price `flat_price`) then
    adds the new FoodItem to the contents of the cart.
   "
    Parameters:
    `name`: name of the FoodItem being created/added
    `weight`: the weight of the FoodItem being created/added
    `price`: the price of the FoodItem being created/added
    `flat_price`: flat_price value for the FoodItem

    """
```

(b) [9 points] Implement the `calculate_total` method of class `Cart` so that it meets its specification.

```python
def calculate_total(self):
    """Calculates the total cost to purchase all food items in the cart.

    The total should correctly account for the price of all items,
    including calculating the cost based on the weight of food items
    as necessary.

    Returns: the total cost (as a float; doesn't need to be rounded)

    """
```
(Continued from previous page.)

Consider a subclass of Cart called MembersCart, which offers discounts to those who have purchased a store membership.

class MembersCart(Cart):
    """ Represents a shopping cart belonging to a customer who is a member,
    and has a corresponding membership discount rate on all items. """

discount = 0.10  # membership discount rate

(c) [8 points] Implement class MembersCart’s calculate_total method so that it meets specification.

def calculate_total(self):
    """
    Calculates the total cost to purchase all food items in the cart.
    The total should correctly account for the price of all items,
    including calculating the cost based on the weight of food items
    as necessary.

    Additionally, apply the membership discount rate to adjust the total
    cost. (ie: if the discount is 0.25, the total should be 25% less)

    Returns: the discounted total cost (as a float; no rounding needed)
    """

(d) [2 points] Will your calculate_total method work correctly, even though the MembersCart class
does not have its own __init__ method?

    Circle One: Yes  No

(e) [2 points] Explain.
8. [12 points] **While loops.** Implement this function, using a while-loop. Do not use `break`.

```python
def filter_and_sum(mylist, n):
    """Returns the sum of the elements in a list. This function stops adding the elements when the nth zero is reached.

Examples:
filter_and_sum([1,0,2,3,0,4,0,5], 1) returns 1
    (1 then stops when it encounters the 1st 0 @ index 1)
filter_and_sum([1,0,2,3,0,4,0,5], 2) returns 6
    (1+2+3 then stops when it encounters the 2nd 0 @ index 4)
filter_and_sum([1,0,2,3,0,4,0,5], 4) returns 15
    (1+2+3+4+5 reaches the end of the list, never sees 4 0s)
filter_and_sum([], 3) returns 0
filter_and_sum([0], 1) returns 0

 Preconditions:
    mylist: a (possibly empty) list of integers
    n: an int, value >= 1
"""
```
9. For each question, provide **only one answer**. If you provide 2, we will only grade the first.

(a) [2 points] Which of the following statements about types in Python is true?
   
   (A) Python will never automatically convert a value from a narrower type to a wider type. For example, from an `int` to an `float`.
   (B) An operator (like `+`), has the same meaning regardless of the types of the values it operates on.
   (C) Once a variable has a value of a certain type, it can only ever have a value of that type assigned to it.
   (D) A class is a user-defined type.
   (E) Variables have types.

   *Seriously, put your answer in the box.* Your Answer: 

(b) [2 points] Which of the following statements about testing and debugging is true?
   
   (A) A programmer should first make their code efficient and then test it for correctness.
   (B) Using `print` statements is a good way to find syntax errors in your code.
   (C) A good test suite will include test cases that violate the precondition.
   (D) Using `print` statements after `if` expressions is a good way to examine program flow.
   (E) A good test suite includes a test case for each possible input length.

   Your Answer: 

(c) [2 points] Which of the following statements about equality and identity is true?
   
   (A) The `==` operator should compare identity; the `is` operator should compare equality.
   (B) When used to compare two instances of a newly-defined class that has no overwritten version of the special method `.eq.`, the `==` operator will compare identity.
   (C) The `isinstance` method can be used interchangeably with the `type` method.
   (D) The `is` operator invokes the `.eq.` method.
   (E) The `==` operator invokes the `isinstance` method.

   Your Answer: 

(d) [2 points] Which of the following statements about **Linear Search** is true?
   
   (A) Linear Search is faster than Binary Search.
   (B) With each step of Linear Search, you can rule out half of the search space.
   (C) It’s always better to sort your list so you can use Binary Search over Linear Search.
   (D) In Linear Search, doubling the list size quadruples the expected time of the search.
   (E) Linear Search works on any list, sorted or not.
   (F) Binary Search’s complexity is on the order of $n^2$.

   Your Answer: 

Page 16
In class we looked at insertion sort and merge sort. Here is the implementation of a third sorting algorithm, called selection sort:

```python
def selection_sort(mylist):
    """Sorts a list of integers by repeatedly looking for the smallest integer from the unsorted part of the list (on the right) and swapping it with the integer at the beginning of the unsorted part. The sorted part of the list keeps growing until all of mylist is sorted."
    
n = len(mylist)

    for i in range(n):
        # Find the smallest element in the unsorted part of mylist
        min_idx = i
        for j in range(i+1, n):
            if mylist[j] < mylist[min_idx]:
                min_idx = j

        # swaps values of mylist[i] and mylist[min_idx]
        swap(mylist, i, min_idx)
```

(e) [2 points] If the size of the list that needs to sorted were to double, how would the work performed by selection sort change?

(A) The work would double, just like it does for insertion sort.
(B) The work would a little more than double, just like it does for insertion sort.
(C) The work would quadruple, just like it does for insertion sort.
(D) The work would double, just like it does for merge sort.
(E) The work would a little more than double, just like it does for merge sort.
(F) The work would quadruple, just like it does for merge sort.

(f) [2 points] How would you describe the space requirements of selection sort?

(A) Like insertion sort, selection sort sorts the list in place, so the space requirements are not costly.
(B) Like merge sort, selection sort sorts the list in place, so the space requirements are not costly.
(C) Like insertion sort, selection sort requires that you make many temporary, new lists, so the space requirements are costly.
(D) Like merge sort, selection sort requires that you make many temporary, new lists, so the space requirements are costly.

Your Answer: 