NATIONAL UNIVERSITY OF SINGAPORE

Semester 1, 2014/2015

CS1010S - PROGRAMMING METHODOLOGY

Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

1. The assessment paper contains **FIVE (5) questions** and comprises **TWENTY-TWO (22) pages**.
2. Weightage of questions is given in square brackets. The maximum attainable score is 100.
3. This is a **CLOSED** book assessment, but you are allowed to bring **TWO** double-sided A4 sheets of notes for this exam.
4. Write all your answers in the space provided in this booklet.
5. **Please write your student number below.**

STUDENT NUMBER: ____________________

(this portion is for the examiner's use only)

Question	Marks	Remark
Q1		
Q2		
Q3		
Q4		
Q5		
Total		

Question 1: Warm Up [24 marks]

There are several parts to this problem. Answer each part **independently and separately**. In each part, one or more Python expressions are entered into the interpreter (Python shell). Determine the response printed by the interpreter for the final expression entered. If the interpreter produces an error message, or enters an infinite loop, explain why.

A.

```
x = [1,2,3]
if x is [1,2,3]:
    x = [x] + [4,5]
if len(x) <= 3:
    y = [x] + [6,7]
elif len(x) <= 5:
    y = [x] + [10,11]
print(y)
```

[4 marks]

B.

```
x = (1,2,3,4)
a = x[1::2]
if not a:
    print(a)
else:
    print(a+x)
```

[4 marks]

C.
```
a = 0
for i in range(2,7):
    if i%4 == 0:
        a /= 2
        i += 2
    else:
        a += i
        i += 1
print(a)
```

[4 marks]

D.
```
x = 1
y = 5
def foo(y):
    y = 10
    def bar(z):
        return x+y+z
    return bar(y)
print(foo(x))
```

[4 marks]

E.

```
x=[0,1]
def test(x):
    try:
        for i in range(2,6):
            x = x.append(i)
    except:
        print("Bad things!")
    else:
        print(x)
    finally:
        print("Finished!")
test(x)
```

[4 marks]

F.

```
x = [1,3,2]
def foo(x):
    x.sort()
    x = x + [4,5]
    x.extend([6,7])
foo(x)
print(x)
```

[4 marks]

Question 2: Lego Engineering++ [30 marks]

Once again, your baby brother comes running to you with his building blocks.

"Remember the staircases you showed me last time?" he asks.

"Uh huh. . . " you slowly nod as you search deep in your memory, vaguely recalling some `staircase` function you wrote.

"I was wondering," he continues. "what's the widest or shortest staircase I can build with my blocks?"

You vaguely recall writing this function for your baby brother some time ago.

"No worries," you boast. "Watch my Python skills."

For this question, you may assume that a function `staircases(n)` is given, that produces a list of tuples, where each tuple is a staircase, that can be built using n blocks, with at least 2 steps.

Sample Execution:

```
>>> staircases(2)
[]

>>> staircases(3)
[(1, 2)]

>>> staircases(4)
[(1, 3)]

>>> staircases(5)
[(1, 4), (2, 3)]

>>> staircases(6)
[(1, 2, 3), (1, 5), (2, 4)]

>>> staircases(7)
[(1, 2, 4), (1, 6), (2, 5), (3, 4)]

>>> staircases(8)
[(1, 2, 5), (1, 3, 4), (1, 7), (2, 6), (3, 5)]

>>> staircases(9)
[(1, 2, 6), (1, 3, 5), (1, 8), (2, 3, 4), (2, 7), (3, 6), (4, 5)]
```

A. Define the function `widest` that takes in the number of blocks n as an argument and returns the width of the widest staircase (i.e., the number of steps) that can be built with exactly n blocks. [5 marks]

Sample Execution:

```
>>> widest(5)
2

>>> widest(7)
3
```

```
def widest(n):
```

B. Define the function `shortest` that takes in the number of blocks n as an argument and returns the height of the shortest staircase that can be built from exactly n blocks. [5 marks]

Sample Execution:

```
>>> shortest(6)
3

>>> shortest(7)
4
```

```
def shortest(n):
```

C. "Can my staircase reach a certain height?" is the next question.

Define the function `can_reach(h, n)` which returns `True` if there exists a staircase of height h that can be built from n blocks, and `False` otherwise. [5 marks]

Sample Execution:

```
>>> can_reach(5, 7)
True

>>> can_reach(3, 7)
False
```

```
def can_reach(h, n):
```

"You know, some of these staircases are crazy," your brother grumbles. "The gap between the steps is too large."

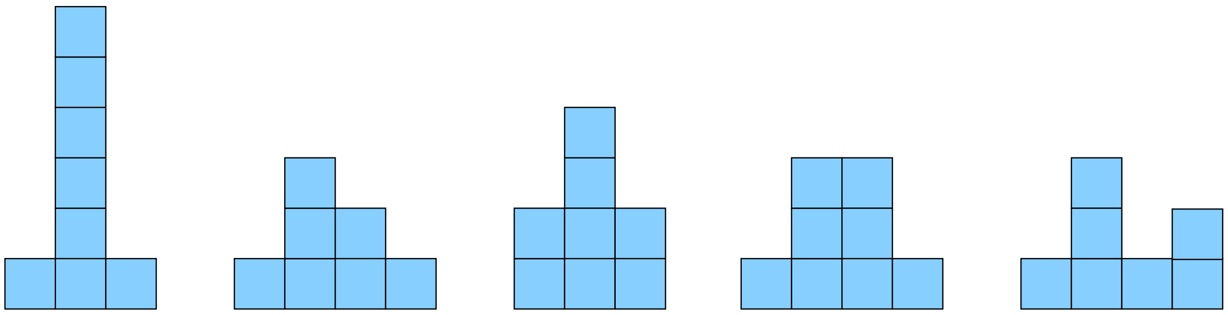
D. Define a function `better_stairs(max_gap, n)` that outputs a list of staircases of exactly n blocks, but no two consecutive steps are more than `max_gap` height apart. [6 marks]

Sample Execution:

```
>>> better_stairs(2, 9)
[(1, 3, 5), (2, 3, 4), (4, 5)]
```

```
def better_stairs(max_gap, n):
```

"What about pyramids?" your brother asks, showing you some of the pyramids he built.



"Ehh. . . not quite," you reply. "The first three can be considered pyramids but not the last two."

"You see, a pyramid is a sequence of steps s, such that all steps before the highest step are in strictly increasing height, and all steps after it are strictly decreasing."

In other words, for a sequence of steps $s_0, s_1, \ldots, s_n$

$$s_{j-1} < s_j < s_k \text{ and } s_k > s_i > s_{i+1} \text{ for all } 0 \leq j < k < i \leq n$$

"Let me fix them for you," you offer.

E. Define a function `is_pyramid` the takes in a sequence of steps and returns `True` if the steps form a pyramid, and `False` if not. You may assume that each step is an integer greater than 0 and there are at least two steps. **Note**: This definition is slightly different from that in the Practical Exam because a pyramid need not be symmetric. [5 marks]

```
def is_pyramid(steps):
```

F. Define a function `is_symmetric` that takes in a pyramid and returns `True` if the pyramid is symmetrical, and `False` if not. You may assume the input is a proper pyramid, i.e. that `is_pyramid` would return `True`. [4 marks]

```
def is_symmetric(steps):
```

Question 3: Espionage Deja Vu [18 marks]

You are working for a spy agency and you have been tasked with building a multi-level encryption system for the agency. Your job is to create a new class `SecretMessage` which is used to store a secret message that supports multiple levels of encryption. The initial `SecretMessage` object is initialized with an input messge (String) as an argument.

A `SecretMessage` object supports for the following methods:

1. `read`(): returns the message stored in the `SecretMessage`, unless the message is encrypted, which would return the string `"*ENCRYPTED*"`.
2. `encrypt`(p_1,p_2,$\cdots$,p_k): which can take in an arbitrary number of passwords and encrypts the secret message using the passwords in order p_1, followed by p_2 and so forth.
3. `decrypt`(p_k,p_{k-1},$\cdots$,p_1): which can take in an arbitrary number of passwords and attempts to decrypts the secret message using the passwords in order p_k, followed by p_{k-1} and so forth. Note that to successfully decrypt and recover an encrypted message, `decrypt` must be applied in strict reverse order. If the wrong password is used in the decryption, the message will be messed up and any subsequent attempts to `read` it will return the string `"*GARBLED*"`. Attempts to decrypt a non-encrypted message will have no effect.
4. `copy`(): returns a copy of the secret message, that retains all encryption properties of the original message.

The following is a sample trace showing how `SecretMessage` works:

```
>>> m1 = SecretMessage("Congrats on surviving CS1010S!")
>>> m1
<__main__.SecretMessage object at 0x7fc600584110>

>>> m1.read()
Congrats on surviving CS1010S!

>>> m1.encrypt(12345)
<__main__.SecretMessage object at 0x7fc600584110>

>>> m1.read()
*ENCRYPTED*

>>> m2 = m1.copy()
>>> m1.decrypt(54321)
<__main__.SecretMessage object at 0x7fc600584110>

>>> m1.read()
*GARBLED*
```

```
>>> m2.read()
*ENCRYPTED*

>>> m2.decrypt(12345)
<__main__.SecretMessage object at 0x7fc600583322>

>>> m2.read()
Congrats on surviving CS1010S!

>>> m2.encrypt(54321)
<__main__.SecretMessage object at 0x7fc600583322>

>> m2.read()
*ENCRYPTED*

>>> m2.encrypt(12345)
<__main__.SecretMessage object at 0x7fc600583322>

>>> m2.read()
*ENCRYPTED*

>>> m3 = m2.copy()
>>> m2.decrypt(12345)
<__main__.SecretMessage object at 0x7fc600583322>

>>> m2.read()
*ENCRYPTED*

>>> m2.decrypt(54321)
<__main__.SecretMessage object at 0x7fc600583322>

>>> m2.read()
Congrats on surviving CS1010S!

>>> m2.decrypt(11111)
<__main__.SecretMessage object at 0x7fc600583322>

>>> m2.read()
Congrats on surviving CS1010S!

>>> m3.decrypt(54321)
<__main__.SecretMessage object at 0x7fc600584178>

>>> m3.read()
*GARBLED*
```

A. Describe how you will keep track of the state of a message and give a possible implementation of the `__init__` method for the `SecretMessage` object. [4 marks]

B. Please provide a possible implementation for the `read` method. [3 marks]

C. Please provide a possible implementation for the `encrypt` method that will encrypt the message according to Part (A) above and return the encrypted message. [4 marks]

D. Please provide a possible implementation for the `decrypt` method that will decrypt the message that was encrypted by the `encrypt` function in Part (C) above and return the decrypted message. [4 marks]

E. Please provide a possible implementation for the `copy` method. [3 marks]

Question 4: To Infinity and Beyond!! [24 marks]

So far, we have be dealing with finite objects in CS1010S. For example, when you work with tuples, lists or dictionaries, you can count the number of elements. But there are objects with an infinite number of elements. For example, consider the following series of natural numbers:

$$1, 2, 3, 4, 5, 6, 7, 8, \cdots$$

It turns out that it is possible to manipulate what are effectively infinite series by generating the required objects *on-the-fly*, since even if we had an infinite number of objects, we couldn't possibly be accessing them all at once. We can define *series* objects that support only one method `get` that will just produce the next term in a series. For example, the following `NaturalNumbers` class will generate all the natural numbers (i.e. positive integers) with a `get` method:

```
class NaturalNumbers:

    def __init__(self):
        self.count = 0

    def get(self):
        self.count += 1
        return self.count
```

For convenience, we can define the following function `get_terms` that will return a list of the first n elements for a series:

```
def get_terms(series, n):
    result = []
    for i in range(n):
        result.append(series.get())
    return result
```

The following is an example of how we can obtain a bunch of positive integers:

```
>>> pos_ints = NaturalNumbers()
>>> get_terms(pos_ints,10)
[1, 2, 3, 4, 5, 6, 7, 8, 9, 10]

>>> get_terms(pos_ints,10)
[11, 12, 13, 14, 15, 16, 17, 18, 19, 20]
```

A. [**Warm Up**] Define a new `Series` class that will take as an argument a function f and return the following series using a `get` method like `NaturalNumbers`: [4 marks]

$$f(1), f(2), f(3), f(4), f(5), f(6), f(7), f(8), \cdots$$

Sample Execution:

```
>>> even_nums = Series(lambda x: 2*x)
>>> get_terms(even_nums,5)
[2, 4, 6, 8, 10]

>>> get_terms(even_nums,5)
[12, 14, 16, 18, 20]
```

```
class Series:
```

B. Suppose you are given the following definition of the Fibonacci function `fib`:

```
def fib(n):
    if n<=1:
        return n
    else:
        return fib(n-1) + fib(n-2)
```

Using `fib` and your definition of `Series` in Part (A), create an infinite series of Fibonacci numbers `fibs`, i.e. [4 marks]

```
>>> get_terms(fibs,10)
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34]
```

```
fibs =
```

C. What is the order of growth in both time and space for the expression `get_terms(fibs,n)` in terms of n for the definition of `fibs` from Part (B)? Explain. [4 marks]

D. Define a new series object `Fibs` that will produce a series of Fibonacci numbers in $O(n)$ time. For example, in the following code:

```
>>> faster_fibs = Fibs()
>>> get_terms(faster_fibs,5)
[0, 1, 1, 2, 3]

>>> get_terms(faster_fibs,5)
[5, 8, 13, 21, 34]
```

`get_terms(faster_fibs,n)` will run in $O(n)$ time. [4 marks]

```
class Fibs:
```

E. Like lists and tuples, we can also manipulate infinite series. One natural operation is a *filter* operation. Define a new series object `FilterSeries` that takes in a filter function f and another series s and returns a new series which contains terms from s that satisfy the filter f. [4 marks]

Sample Execution:

```
primes = FilterSeries(is_prime,NaturalNumbers())
>>> get_terms(primes,10)
[2, 3, 5, 7, 11, 13, 17, 19, 23, 29]
```

```
class FilterSeries:
```

F. Sometimes we might want to work with a limited series of numbers instead of an infinite series. Define a new series object `LimitedSeries` that takes in a series s and a number n and returns a new series which contains only the first n terms from s. After the first n terms are exhausted, `None` will be returned by the `get` function. [4 marks]

Sample Execution:

```
>>> first5 = LimitedSeries(NaturalNumbers(),5)
>>> get_terms(first5,8)
[1, 2, 3, 4, 5, None, None, None]
```

```
class LimitedSeries:
```

Question 5: 42 and the Meaning of Life [4 marks]

Either: (a) explain how you think some of what you have learnt in CS1010S will be helpful for you for the rest of your life and/or studies at NUS; or (b) write a short snippet of code that you think will convince the examiner that you have learnt Python well and hence deserve a good grade for CS1010S; or (c) tell us an interesting story about your experience with CS1010S this Semester.

Appendix

The following are some functions that were introduced in class:

```
def sum(term, a, next, b):
  if (a>b):
    return 0
  else:
    return term(a) + sum(term, next(a), next, b)

def fold(op, f, n):
  if n==0:
    return f(0)
  else:
    return op(f(n), fold(op, f, n-1))

def enumerate_interval(low, high):
    return tuple(range(low,high+1))

def filter(pred, seq):
    if seq == ():
        return ()
    elif pred(seq[0]):
        return (seq[0],) + filter(pred, seq[1:])
    else:
        return filter(pred, seq[1:])

def accumulate(fn, initial, seq):
    if seq == ():
        return initial
    else:
        return fn(seq[0], accumulate(fn, initial, seq[1:]))

def is_prime(x):
    if x == 1:
        return False
    else:
        for i in range(2, int(math.sqrt(x) + 1)):
            if x%i == 0:
                return False
        return True
```

— E N D O F P A P E R —

Scratch Paper

– H A P P Y   H O L I D A Y S ! –