TERM 1 EXAM
Science One Computer Science

December 16, 2015

TIME: 100 minutes

Name: ______________________________

Signature: ______________________________

Student number: ______________________________

- Make sure that this exam contains this cover page plus 10 pages of exam questions.
- No electronic devices of any kind may be used during the exam, including phones, laptops, calculators, or digital watches.
- Please be prepared to present, upon request, a student card for identification.
- If you need more space, use the back of a page. If your work on the back of a page forms part of your answer to a question, clearly indicate that we should turn the page and continue reading on the back.
- Make sure the indentation of your Python code is clear and unambiguous.
- In the interests of time, you do not need to add comments to your code unless you are explicitly asked to do so.
- You do not need to "show your work" on any of the questions; if you get the correct answer, you will receive full points.
- If anything is unclear or seems ambiguous, **state your assumptions**.

Question:	1	2	3	4	5	6	Total
Points:	30	4	20	15	20	11	100
Score:							

G O O D L U C K !!

Question 1. **(30 points)**

Determine and **clearly** indicate the output (exactly what is printed to the screen) of each of the following code snippets when executed with Python 2.7 (the version we have been using in this course), or write "ERROR" if executing the code would cause an error. Be careful – some of these questions are meant to be tricky.

1 pt (a)
```
print 5+2
```

1 pt (b)
```
print 5+2.0
```

1 pt (c)
```
print 5/2
```

1 pt (d)
```
print '5'+'2'
```

1 pt (e)
```
print 1.0+2.0==3.0
```

1 pt (f)
```
print 0.1+0.2==0.3
```

1 pt (g)
```
print 1.0+2.0=3.0
```

2 pts (h)
```
if 2 > 3 or 3 > 2:
    print 'Hello'
else:
    print 'Goodbye'
```

2 pts (i)
```
x = 2
if x < 5 and x > 8:
    x = x + 1
if x > 0:
    x = x + 1
print x
```

2 pts (j)
```
x = 2
if x < 5 and x > 8:
    x = x + 1
    if x > 0:
        x = x + 1
print x
```

3 pts (k)
```
x = 2
y = x
x = 3
print y
```

3 pts (l)
```python
def hello(a):
    return a + 5

a = 1
a = hello(a)
a = hello(a)
print a
```

1 pt (m)
```python
def hello(a):
    a = a + 5
    return a

a = 1
hello(a)
print a
```

4 pts (n)
```python
import numpy as np
N = 5
x = np.zeros(N)
x[0] = 1
x[1] = 1
n = 2
while n < N:
    x[n] = x[n-1] + x[n-2]
    n = n + 1
print x[N-1]
```

1 pt (o)
```python
import numpy as np
x = np.zeros(5)
print x[5]
```

2 pts (p)
```python
x = 0
for j in range(4):
    x = x + j
print x
```

3 pts (q)
```python
x = 0
for i in range(20):
    for j in range(50):
        x = x + 1
print x
```

Question 2. **(4 points)**

2 pts (a) What is the binary representation of the base-10 number 20?

2 pts (b) What is the base-10 representation of the binary number 1000011?

Question 3. **(20 points)**

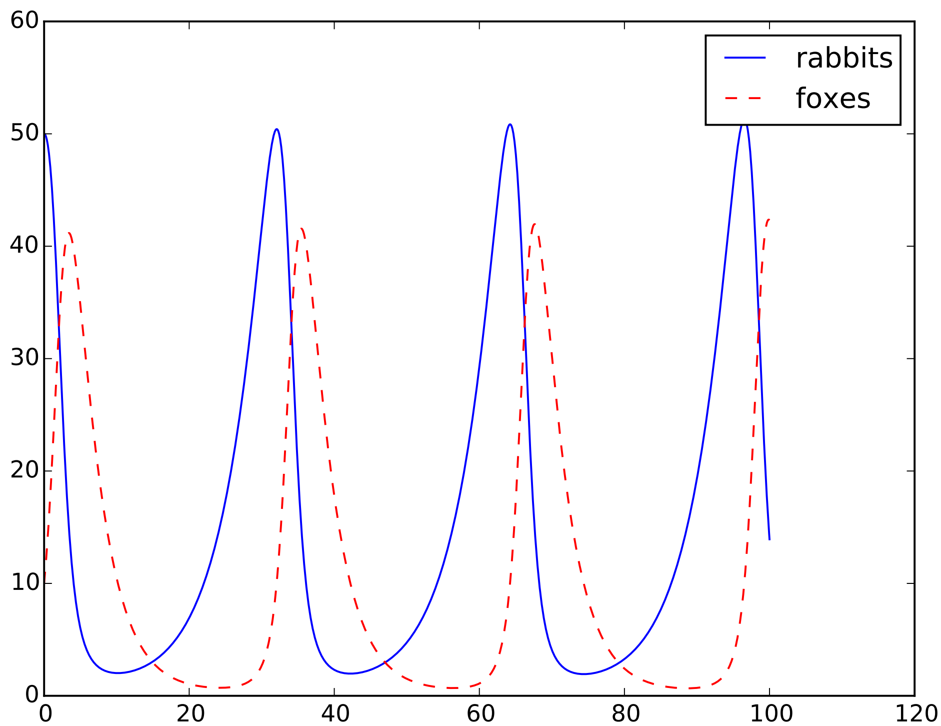
Let x be the number of rabbits and y be the number of foxes in a forest. We will model the interactions between these populations with the following differential equations:

$$\frac{dx}{dt} = 0.2x - 0.02xy$$
$$\frac{dy}{dt} = -0.3y + 0.02xy$$

Just like in the biology and physics tutorials, we can write down discrete versions of these equations using the Euler method with a finite time step Δt:

$$x(t + \Delta t) = x(t) + [0.2x(t) - 0.02x(t)y(t)]\,\Delta t$$
$$y(t + \Delta t) = y(t) + [-0.3y(t) + 0.02x(t)y(t)]\,\Delta t$$

In the space provided on the next page, write a program that simulates how these populations change over time. The first and last few lines of the program are already provided for you; to get full marks, you must make use of the provided code. Below is an example of what the output looks like for $N = 10000$, $\Delta t = 0.01$, $x(0) = 50$, and $y(0) = 10$.



```python
import sys
import numpy as np
import matplotlib.pyplot as plt

N  = int(sys.argv[1])    # number of iterations
dt = float(sys.argv[2])  # time step size
x0 = int(sys.argv[3])    # initial number of rabbits, x(0)
y0 = int(sys.argv[4])    # initial number of foxes, y(0)

t = np.zeros(N+1)
x = np.zeros(N+1)
y = np.zeros(N+1)

plt.plot(t, x, 'b')   # plots x vs. t with a solid blue line
plt.plot(t, y, '--r') # plots y vs. t with a dashed red line
plt.legend(('rabbits', 'foxes')) # adds a legend to the plot
plt.show()
```

Question 4. **(15 points)**

Write the `simulate` function from Assignment 2. As a reminder, this function takes as arguments S_0, σ, and T and returns an array of size $T+1$ containing the stock price at each time step. To generate the stock prices, the function simulates the geometric Brownian motion for T steps using the update rule

$$S_t = S_{t-1} \exp\left(-0.5\sigma^2 + \sigma Z\right) \,,$$

where Z is a random number drawn from a Gaussian distribution, which you can generate using `numpy.random.randn()`. You can assume `numpy` has already been imported somewhere above your function (and you can refer to it as either `numpy` or `np`). You do not need to write comments. As a reminder, $\exp(x)$ means e^x and can be computed with `numpy.exp(x)`.

Question 5. **(20 points)**

Alice, your collaborator in the Earth, Ocean and Atmospheric Sciences Department at UBC, has provided you with a Python function `simulate` that simulates the temperature in Vancouver based on certain parameters. You are not given the code for this function, but you can see the documentation (comment statement) that Alice wrote:

```
# Predicts the future temperatures in Vancouver using a climate simulation.
# Note: the simulation is random and will give different results each time.
# Inputs: carbon_dioxide (float), the carbon dioxide emission levels
#         green_seats    (int),   number of Green Party seats in parliament
#         initial_temp   (float), the initial temperature
#         num_years      (int),   number of years to simulate
# Output: the simulated temperature over time (array of size num_years+1)
```

Your job is to complete the partially written program on the next page so that it repeatedly calls the `simulate` function and computes the expected *change* in temperature after N years, averaged over the specified number of trials.

We will assume that Alice's function is contained in the `globalwarming` library. Therefore, the top of the program on the next page contains the statement `import globalwarming`. To call the function, use `globalwarming.simulate`. This is just like what you have done in the past, for example when you type `import numpy` and then use `numpy.exp` to access the `exp` function within the `numpy` library.

Here are some example runs showing what your program should print out. (You do not need to understand where the numbers come from, since you cannot see the `simulate` function.) Note that the output specifies whether the temperature increases or decreases; your program should do this too, depending on whether the final temperature is greater than or less than the initial temperature. You can ignore the case of the temperature staying exactly the same.

```
>> python VancouverTemp.py 0.1 1 20 10 1000
The temperature will INCREASE by 0.2 degrees Celsius.

>> python VancouverTemp.py 0.1 300 20 10 1000
The temperature will DECREASE by 25.0 degrees Celsius.
```

question continues on next page

```python
import sys
import numpy as np    # in case you want to use numpy
import globalwarming # gives us access to globalwarming.simulate

# read in the command-line arguments
CO2      = float(sys.argv[1]) # the carbon dioxide emission levels
green    = int(sys.argv[2])   # the number of Green Party seats
T_0      = float(sys.argv[3]) # the initial temperature
N        = int(sys.argv[4])   # the number of years
trials   = int(sys.argv[5])   # the number of trials

##############################
#### WRITE YOUR CODE BELOW ####
##############################
```

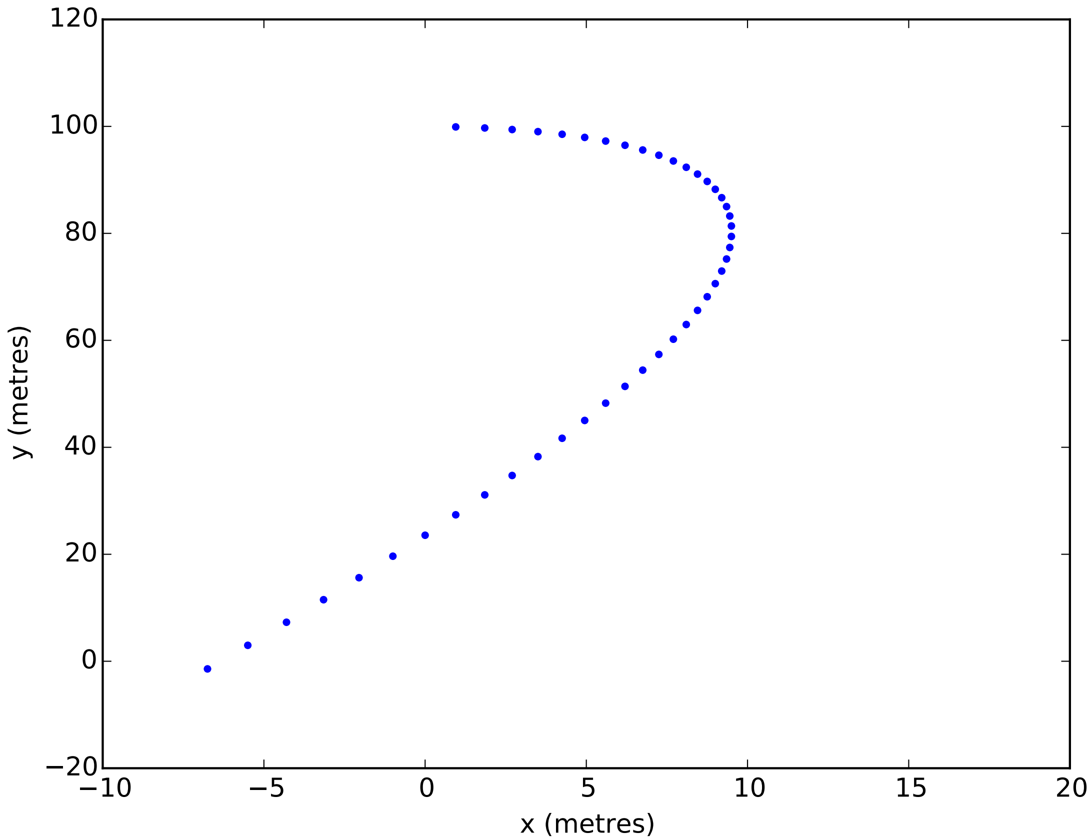
Question 6. **(11 points)**

A Science One student named James writes the following code for the Euler method tutorial. The lines are numbered along the left-hand side for your reference.

```
1  # Author:        James Charbonneau
2  # Description: Use the Euler method to simulate a parcel dropped
3  #              from an airplane moving in 2-D subject to drag
4  #              until it hits the ground.
5
6  import matplotlib.pyplot as plt
7  import math
8
9  dt    =  0.1   # step size (s)
10 g     = -9.8   # acceleration due to gravity (m/s^2)
11 gamma = 0.05   # drag coefficient (kg/m)
12
13 x = 0.0        # initial x-position (m)
14 y = 100.0      # initial y-position (m)
15
16 vx = 10.0      # initial horizontal velocity (m/s)
17 vy = 0.0       # initial vertical velocity (m/s)
18
19 # compute accelerations
20 v2 = vx*vx+vy*vy
21 v  = math.sqrt(v2)
22 ax = -gamma*v*vx
23 ay = g-gamma*v*vy
24
25 while y > 0:
26     # update velocities
27     vx = vx + ax*dt
28     vy = vy + ay*dt
29
30     # update positions
31     x = x + vx*dt
32     y = y + vy*dt
33
34     plt.plot(x, y, '.b')
35
36 plt.xlabel('x (metres)')
37 plt.ylabel('y (metres)')
38 plt.ylim(-20,120) # sets the y limits of the figure to [-20,120]
39 plt.xlim(-10, 20) # sets the x limits of the figure to [-10, 20]
40 plt.savefig('euler_buggy.pdf')
```

question continues on next page

However, when James runs his code, he obtains the following strange-looking plot:



3 pts (a) On the axes above, draw a curve representing what the plot should look like. You only need the very general shape; no need to spend time trying to get this curve just right.

4 pts (b) Briefly explain the problem with James's code (1 sentence maximum). You may refer to specific line numbers if that is helpful.

4 pts (c) What would happen if line 25 were changed to `while y != 0`? (1 sentence maximum.) As a reminder, the `!=` operator means "not equal to".