SCIE1000 Tutorial sheet 9

This tutorial contributes toward your final grade; see the Course Profile (https://www.uq.edu.au/study/course.html?course_code=SCIE1000). The tutorial will be marked out of 6, with 3 marks for completing the "Before class" work, and 3 marks for completing the "In class" assessment and working on the remaining "In class" questions until you finish them or the tutorial ends.

Goals: This week you will work through some calculation and discussion questions, mostly relating to blood alcohol concentration and forensic toxicology. As usual, the broad concepts and techniques are more important than the specific examples. Do not try to commit lots of facts to memory; instead, know **how** to do things, and **when** certain models and approaches are appropriate. The aim of the computing component of this tutorial is to understand the concept of *arrays* and how they can be used to store data in your Python programs. Many people find arrays to be a bit confusing when they first encounter them; ask your tutor if you are confused.

To be completed before class

Complete the following questions before class, write (or type if you wish) your answers on a sheet of paper, put your name and student number on the top of the paper, and hand it to your tutor as you enter the room. **If you do not hand in the answers at the start of the class, as you enter the room, then you will lose the marks for this component.** Note that in some cases there are no "right" or "wrong" answers.

Question (1)

1. In lectures and tutorials we have covered the Widmark formula, which is used to estimate blood alcohol concentrations (BACs). The Widmark formula is often used in court cases, when someone has been charged with drink driving (or *Driving Under the Influence, DUI*, or *Driving While Impaired, DWI*).

   There are many commercial websites that sell various tools, materials and services relating to legal defences in drink driving court cases, primarily within the USA. One such website is [here](https://www.jameseducationcenter.com/articles/attacking-widmark-calculations); please note that we are not endorsing or promoting the products offered on this website.

   Read the [linked article](https://www.jameseducationcenter.com/articles/attacking-widmark-calculations/) and take some useful notes. (There may be questions relating to this on the final exam.) You do not need to note down details, but instead what are some of the key messages? Do you agree with the mathematical claims and the "morality" of the legal approach? Did you find anything interesting? What new, broad ideas did you learn, if any? How did the article make you **feel**, and what did it make you **think**? Come along to class ready to discuss the answers to these questions.

2. In 2015, 1209 people died as the result of traffic accidents in Australia, with alcohol responsible for around 30 % of these deaths. All governments are very actively promoting road safety, and in particular trying to reduce the incidence of drink driving. The *Transport Accident Commission Victoria* has taken a very strong approach to advertising road safety over the last 20 years, including screening a number of fairly graphic and controversial television advertisements.

   In this question, we will ask you to watch a [_Transport Accident Commission Victoria_](https://www.tac.vic.gov.au/) video and respond to it. Note that the advertisement was played on free-to-air television in Victoria, has had more than 19 million views on youtube, is confronting and thought-provoking and perhaps behaviour-changing. There were reports that some viewers found it to be quite traumatic, including those who had previously been involved in a serious accident or who had lost close family members in such accidents. Hence we are asking you to make an informed and responsible judgement about how to approach this question. If you believe that you are OK to watch the video, then complete Part A below. We hope that most of you will select this option. If you are uncomfortable at the thought of watching the video, then complete Part B below. No-one will query your decision, but please only choose the Part B option if watching the video is likely to be distressing.

   A. (If you do this part, do not complete Part B.) Watch the [entire video](https://www.youtube.com/watch?v=Z2mf8DtWWd8), and take some notes about your **feelings** and **thoughts** as you watch it. Is it effective at getting across a message of road safety? Should it have been shown on television? Should it be compulsory viewing in schools? Come along to class ready to discuss the answers to these questions.

   B. (If you do this part, do not complete Part A.) Write down some thoughts about how better to promote road safety, and how to convince people more effectively to not drink drive.

3. Consider the web site you visited in Part 1, which was promoting methods to "beat drink driving charges". Have your feelings or thoughts about the website content and what they are proposing changed at all after completing Part 2? If so, briefly discuss the changes.

Question (2)

Over the past few decades, the annual number of road fatalities in Australia (https://en.wikipedia.org/wiki/List_of_motor_vehicle_deaths_in_Australia_by_year) (and in many other parts of the world) has shown a dramatic decline. The following Python cell contains a program which plots the annual number of road fatalities in Australia for years between 1982 and 2015, along with linear and exponential models.

1. Give some reasons why there may have been such a dramatic decline in the number of fatalities between 1982 and 2015, despite the fact that the population of Australia increased by around 50 %.

2. The population of Australia in 1982 was about 15.2 million. and in 2015 was about 23.8 million. If the rate of road fatalities per capita had remained unchanged between 1982 and 2015, approximately how many additional fatalities would have occurred in 2015 compared to the number that actually occurred.

3. The Python program includes a linear model of the annual number of fatalities. By reading the program, find the equation of the linear model, and briefly demonstrate mathematically how this model was obtained (your answer can be approximate).

4. The Python program also includes an exponential model. By reading the program, find the equation of the exponential model. Which model (linear or exponential) do you think is likely to give a more accurate prediction of the number of fatalities in 2030, and why? Predict the number of fatalities in 2030.

5. In the year 2014, total road fatalities in Australia were around 1150, then in 2015 there were around 1200 fatalities, and in 2016 there werre around 1300. Comment on these figures with respect to the linear and expoenntial models. Why might numbers be increasing?

In [ ]:
```
# Program to plot annual number of road fatalities in Australia
from pylab import *

deaths=array([3252,2755,2822,2941,2888,2772,2887,2801,2331,2113,1974,
1953,1928,2017,1970,1767,1755,1764,1817,1737,1715,1621,1583,1627,1602,
1603,1437,1488,1352,1291,1310,1193,1153,1209])

yrs = arange(0,34)
plot(yrs,deaths,'x',mew=3,markersize=8,label='Fatalities')
plot(yrs,3000-1800/33*yrs,"k--",linewidth=3,label='Linear model')
plot(yrs,950+2250*exp(-0.061*yrs),linewidth=3,label='Exponential model')
grid(True)
legend(loc='upper right')
xlabel("Years since 1982")
ylabel("Number of fatalities")
title("Annual number of road fatalities in Australia")
show()
```

Question (3)

Read and understand Section A.8 in the Python Appendix of the lecture notes, covering "Arrays". (This material is in the book of lecture notes, near the end.) On your sheet of paper, write a short paragraph explaining the importance, role and use of arrays in your programs.

To be completed in class

Complete the following questions in class. They involve a mix of individual work, and discussions with others. Make sure that you read the questions before class and think about how you might approach answering them. Don't rely on someone else doing all of the work. You need to work by yourself on the final exam, so it is important that you work hard now.

Feedback: Be proactive!

Australian government research shows that students often feel they don't receive adequate feedback on their work. In a class of 800 students, it is not possible for the course coordinator to give direct feedback to each student. Instead, tutorial classes are designed to be the place in which you can get feedback on your work from classmates and the tutors. You can ask for help, show them your answers, and discuss your understanding of any of the course material. As an adult learner, the onus is on **you** to seek feedback; tutors and classmates are happy to give it, if you want it.

Question (4)

Briefly discuss with a partner the role, use and importance of arrays. Ensure that you both agree on the key points. In particular, how are arrays similar to other variables, and how they are different? What is the purpose of the *index* of an entry in an array?

Question (5)

Your tutors will record the marks for the sheet of paper you submitted with the "Before class" work, and they will then return your sheet to you early in the class so you can work from it.

1. Discuss your notes on the DUI website and the road safety video (if you watched it) with your partner. If they have written something that you think may be important and that you missed, then update your notes.

2. Discuss the content of the website and video as a group, and update your notes appropriately.

Question (6)

1. By hand, find all of the output generated by the following partial Python program.

```
BACArray = zeros(5)
n = 0
while n<5:
   BACArray[n] = n
   n = n + 1
print(BACArray)
```

2. Show how to modify the program from Part 1 so that it instead:

- prompts the user to input a number of hours `t`; you may assume this is a whole number, larger than 5.
- creates an array called `BACArray` with $t + 1$ entries.
- for each hour number from 0 to 4, places the hour number in the corresponding entry of `BACArray`.
- for each hour number from 5 to `t`, places the number 10 in the corresponding entry of `BACArray`.

Question (7)

In forensic police investigations it is common to identify whether alcohol (ethanol) was present in a person prior to death, and to estimate the initial concentration accurately.

When a person dies with alcohol in their system, the alcohol gradually degrades after death. The rate of degradation depends on factors such as temperature and exposure to air. Because remains are typically exposed to variable preservation and storage conditions, determining pre-death blood alcohol concentrations in post-mortem tissue samples is difficult. (Also, alcohol is often a by-product of bacterial action during decomposition. Research suggests that the *vitreous humour* inside the eye is less contaminated by bacterial action, so is a good source of tissue for estimating pre-death blood alcohol concentrations.)

The paper *Kinetics of ethanol degradation in forensic blood samples* (http://www.sciencedirect.com/science/article/pii/S0379073806003525) models the post-mortem level of alcohol $A(t)$ remaining in a tissue sample at time t after death using the equation

$$A(t) = A_0 e^{-kt}$$

where A_0 is the level of alcohol present at death, and k is the rate of alcohol degradation after death. The value of k depends on factors such as storage conditions. For example, the paper shows that if tissue is stored at a temperature of 25 °C and is exposed to air, then $k \approx 1.11 \times 10^{-3}$ hour^{-1}.

Consider the following hypothetical scenario. Police discover the body of a male driver killed in a car accident on an isolated road. Investigations show that:

- the mass of the man was 80 kg, and his body shape was typical so his Widmark r value is 0.7;
- the fatal accident occurred **exactly** 72 hours earlier;
- the man ceased consuming alcohol 3 hours before death and commenced driving 1 hour before death; and
- his tissue sample shows an alcohol concentration of 0.047 %.

A timeline of relevant events is as follows:

Time (hours)	event	BAC (%)
0	ceased drinking	?
2	commenced driving	?
3	fatal accident	?
75	post morterm conducted	0.047 %

The police, coroner and insurance company need to know the extent (if any) to which alcohol was a contributing factor to the accident.

1. Assuming the temperature had been a constant 25 $^{\circ}$C, was the man over the legal blood alcohol level of 0.05 % for driving at the time of his death?

2. Estimate his blood alcohol concentration when he commenced driving. (Hint: note that after consuming alcohol, a living person's blood alcohol content will reduce by 0.015 % per hour.)

3. Witnesses state that the man was a responsible and careful driver, and had consumed "about 3 standard drinks". Investigate the witness statements.

Question (8)

You will now write a program that performs calculations similar to those you did in Question 7, which a forensic scientist could use to predict the BACs of people killed in car accidents.

Paste the following partial program into the Python cell below, and modify the program so that it meets these specifications:

- Your program should prompt the user to enter the following (for simplicity, assume that all times are in whole numbers of hours, and that $t = 0$ at the time of ceasing alcohol consumption):
  - the time (in **hours**) at which a person died;
  - the time (in **hours**) at which a post-mortem tissue sample was analysed; and
  - the measured BAC in the post-mortem tissue sample.

- Your program should:
  - Print the victim's BAC at the time of ceasing alcohol consumption and at the time of death.
  - Produce a graph of the victim's BAC from $t = 0$ until the time at which the tissue is analysed. The program should assume that post-mortem, the tissue is stored at 25 $^\circ$C and is exposed to air. (Hint: note that alcohol is metabolised at a *linear* rate prior to death and then degrades at an *exponential* rate after death.)

```
# Program to calculate BACs both pre and post mortem.
from pylab import *

# Input data
print("In all cases, t=0 when drinking ceased.")
tDeath = eval(input("At what time did death occur: "))
tPM = eval(input("At what time was the post mortem tissue sample analysed: "))
PMBAC = eval(input("What was the post mortem BAC: "))

# Calculate the BAC at time of death.
tDead = ......
deathBAC = .......

# Calculate the initial BAC (we assume alcohol is metabolised at 0.015 %/hr).
initBAC = ........

# Print BACs at t=0 and at time of death.
........

# Create array of times for graph and and empty array for BAC
timeArray = arange(0,tPM+1)
BACArray = ......
```

In [ ]:
```
# Paste and write your program here
```

Question (9)

This question is a required, in-class assessment piece. To receive the marks for this component, you and your partner must show your answers to a tutor during your tutorial.

Paste a copy of your program from Question (8) into the following Python cell, and modify your program so that it now also:

- prompts the user to enter the mass and gender of the person
- estimates the number of standard drinks consumed by the person. (Assume that the person has a typical body shape for their gender, so the Widmark factor r equals 0.7 for males and 0.6 for females.)
- is commented, has sensible variable names, includes useful output messages, and has appropriate formatting of the graph.

A male of mass 80 kg consumes alcohol at time $t = 0$, and dies in a motor vehicle accident three hours later (at time $t = 3$). A post-mortem tissue sample taken 72 hours after death (at $t = 75$ hours) shows an alcohol concentration of 0.047 %. Use your program to answer the following questions, which match those in Question (7):

- What was the BAC at time of death?
- What was the alcohol concentration when he ceased consuming alcohol?
- If the man commenced driving 1 hour prior to death, what was his BAC at that time?
- How many standard drinks had the man consumed?

```
In [ ]: # Paste and write your program here
```

Question (10)

In lectures we saw the following equation for BAC that takes into account the time for alcohol to be absorbed in the disgestive system:

$$B = \frac{A}{rM} \times \left(1 - e^{-kt}\right) \times 100\% - 0.015t$$

where k is the rate at which the body absorbs alcohol, with $k \approx 6$ hr^{-1} when the stomach contains no food, and $k \approx 2.3$ hr^{-1} when the stomach contains food. It is not too hard to show that

$$B'(t) = \frac{100Ak}{rM} e^{-kt} - 0.015.$$

1. Explain (in words) how to find the time t_{max} at which B reaches its maximum value, B_{max}.

2. Find the value of t_{max} for a male of mass 107 kg and height 1.88 m who consumes four standard drinks, with an empty stomach and with food in his stomach. (Hint: the Widmark factor r for this male is 0.67.)

3. Hence find B_{max} for this person for each scenario (food and no food), and comment on your answers.

Extra questions

Here are some extra practise questions, for you to do in class (if you have time), or outside class. You do not need to do them all, but may like to choose some to help with your preparation for the final exam.

Question (11)

By hand, find all of the output generated by each of the following partial Python programs. (The first program was on the midsemester examination in 2011, and worth 6 marks. Expected working time was about 6 minutes. The second program was on the deferred examination in 2011, and worth 8 marks. Expected working time was about 8 minutes.)

First program:

```
a=zeros(4)
d=zeros(4)
i=0
while i<4:
    a[i] = (i+4) * 10
    d[i] = 0.77*(a[i]-30)**2
    print(a[i],d[i])
    i = i+1
```

Second program:

```
t = array([0, 2, 4, 8, 10, 12])
p = array([600,1200,800,800,1000,1400])
tA = 0
a = zeros(6)
i = 1
while i<5:
    h = t[i] - t[i-1]
    a[i] = p[i] * h
    tA = tA + a[i]
    print("h = ",h," a[i] = ",a[i])
    i = i + 1
print("AUC = ", tA, "units. ")
```

Question (12)

The gas law for an ideal gas at temperature T (in kelvin, K), pressure P (in atmospheres, atm), and volume V (in litres, L) is $PV = nRT$, where n is the number of moles of the gas and $R = 0.0821$ L atm mol^{-1} K^{-1} is the ideal gas constant.

1. Consider a sample of ideal gas containing $n=10$ mol. At a certain time the sample is at pressure $P=8$ atm which is increasing at a rate of 0.1 atm min^{-1}, and volume $V=10$ L which is decreasing at a rate of 0.15 L min^{-1}. Find the rate of change of the temperature T with respect to t at that time. Include units in your answer.

   (Hint: you will need to recall the _product rule_ for differentiating, which you covered at school. If y, A and B are all functions of the same variable and $y = A \times B$, then $y' = A'B + AB'$.)

2. Do the units in vour answer to Part 1 "make sense"? Justifv vour answer brieflv.

Question (13)

By hand, find all of the output generated by each of the following partial Python programs.

First program:

```
cs = zeros(4)
i = 0
while i < 4:
    cs[i] = i**2
    print(i, cs[i])
    i = i+1
print("cs =", cs)
```

Second program:

```
A = array([1,2,3,4,5])
A[2] = A[4] - 3
A[4] = A[4] * A[3]
A[0] = 7
A = A * 2
print("A =",A)
```

Third program:

```
F = zeros(10)
F[0] = 1
F[1] = 1
i = 2
while i<6:
    F[i] = F[i-1]+F[i-2]
    i = i+1
print(F)
```

Question (14)

(This question was on the final examination in 2010, and worth 6 marks. Expected working time for this question was about 6 minutes.)

The function

$$f(t) = t^2 + e^{-t}$$

has a local minimum near $t = 0$. Find the approximate value of t at which the local minimum occurs.

(Hint: it may help to note that $f'(t) = 2t - e^{-t}$ and that $f''(t) = 2 + e^{-t}$. The local minimum occurs where $f'(t) = 0$. Use **one step** of Newton's method in your answer.)

Question (15)

By hand, find all of the output generated by the following partial Python program.

```
A = array([1, 2, 3, 4, 5])
print(A[1])
print(A[0])
print(A[4] * A[3])
print(A[A[0]])
print(A*3)
```