### 

### Semester One Examination, 2023

### Question/Answer booklet

# MATHEMATICS METHODS

**UNIT 3**

## Section Two:

## Calculator-assumed

|  |  |
| --- | --- |
| **Your Name:** |  |
| **Your Teacher’s Name:** |  |

## Time allowed for this section

Reading time before commencing work: ten minutes

Working time: one hundred minutes

## Materials required/recommended for this section

***To be provided by the supervisor***

This Question/Answer booklet

Formula sheet (retained from Section One)

***To be provided by the candidate***

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: drawing instruments, templates, notes on two unfolded sheets of A4 paper, and up to three calculators approved for use in this examination

## Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Question | Marks | Max | Question | Marks | Max |
| 7 |  | 8 | 13 |  | 12 |
| 8 |  | 6 | 14 |  | 11 |
| 9 |  | 12 | 15 |  | 8 |
| 10 |  | 10 |  |  |  |
| 11 |  | 10 |  |  |  |
| 12 |  | 13 |  |  |  |

**Structure of this paper**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Section | Number of questions available | Number of questions to be answered | Working time (minutes) | Marks available | Percentage of examination |
| Section One:  Calculator-free | 6 | 6 | 50 | 51 | 35 |
| Section Two:  Calculator-assumed | 10 | 10 | 100 | 90 | 65 |
|  |  |  |  | **Total** | 100 |

**Instructions to candidates**

1. The rules for the conduct of the Western Australian Certificate of Education ATAR course examinations are detailed in the *Year 12 Information Handbook 2019*. Sitting this examination implies that you agree to abide by these rules.
2. Write your answers in this Question/Answer booklet.
3. You must be careful to confine your answers to the specific questions asked and to follow any instructions that are specific to a particular question.
4. Additional pages for the use of planning your answer to a question or continuing your answer to a question have been provided at the end of this Question/Answer booklet. If you use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number.
5. **Show all your working clearly.**Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning. Incorrect answers given without supporting reasoning cannot be allocated any marks. For any question or part question worth more than two marks, valid working or justification is required to receive full marks. If you repeat any question, ensure that you cancel the answer you do not wish to have marked.
6. It is recommended that you **do not use pencil**, except in diagrams.
7. The Formula sheet is **not** to be handed in with your Question/Answer booklet.

**Section Two: Calculator-assumed (90 Marks)**

This section has **ten** questions. Answer **all** questions. Write your answers in the spaces provided.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

● Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.

● Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question that you are continuing to answer at the top of the page.

Working time: 100 minutes.

**Question 7 (8 marks)**

mg of a radioisotope with a half-life of hours was injected into a patient before a CT scan. The mass of the radioisotope decays continuously so that hours after administration, the mass remaining is given by , where and are constants.

(a) Determine the value of the constants and . (3 marks)

|  |
| --- |
| Solution |
|  |
| Specific behaviours |
| ü states  ü equation for  ü value of |

(b) Determine the mass of the radioisotope that remains in the patient exactly days after their injection. (1 mark)

|  |
| --- |
| Solution |
|  |
| Specific behaviours |
| ü calculates mass |

(c) Eventually, the mass of the remaining radioisotope falls to mg.

(i) Determine how long after their injection that this occurs. (2 marks)

|  |
| --- |
| Solution |
|  |
| Specific behaviours |
| ü substitutes to form equation  ü uses CAS to solve for |

(ii) Determine the rate at which the radioisotope is decaying at this time. (2 marks)

|  |
| --- |
| Solution |
| Decay rate is |
| Specific behaviours |
| ü uses rate of change equation  ü correct rate |

**Question 8 (6 marks)**

A barrel is filled with balls numbered with the integers , but otherwise identical.

Let the random variable be the number on a ball drawn at random from the barrel.

(a) Explain why has a uniform distribution. (1 mark)

|  |
| --- |
| Solution |
| Every outcome is equally likely. |
| Specific behaviours |
| ü reasonable explanation indicating equally likely outcomes |

(b) Determine the expected value of . (1 mark)

|  |
| --- |
| Solution |
| Using the symmetry of a uniform distribution, |
| Specific behaviours |
| ü correct value |

Let the random variable take the value when and the value otherwise.

(c) State the particular name given to two-outcome random variables such as . (1 mark)

|  |
| --- |
| Solution |
| Bernoulli random variable. |
| Specific behaviours |
| ü correct name |

(d) Determine . (1 mark)

|  |
| --- |
| Solution |
|  |
| Specific behaviours |
| ü correct probability |

(e) Three balls are drawn at random from the barrel. Determine the probability that exactly two of the balls are marked with single digit numbers. (2 marks)

|  |
| --- |
| Solution |
| Alternative: |
| Specific behaviours |
| ü indicates correct method  ü correct probability |

**Question 9 (12 marks)**

A vertical cross section through the highest point of an inselberg, a mountain range that rises above a surrounding level plain, is shown in the figure below.

<EFOFEX>
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FXData:

</EFOFEX>

The height of the plain and the inselberg above sea level , in kilometres, is given by

is the horizontal displacement in kilometres from an arbitrary origin.

(a) Determine the value of and the value of , the displacements where the inselberg meets the surrounding plain. (2 marks)

|  |
| --- |
| Solution |
| Using CAS to solve results in and . |
| Specific behaviours |
| ü writes equation  ü states both values (correct to two decimal places) |

(b) Use calculus to determine the cross-sectional area of the inselberg shaded in the figure above. (3 marks)

|  |
| --- |
| Solution |
|  |
| Specific behaviours |
| ü correct integrand  ü correct bounds of integration  ü correct area, with units (must be ) |

(c) Use calculus to

(i) Using calculus determine and justify the maximum height of the inselberg above the surrounding plain. (7 marks)

|  |
| --- |
| Solution |
| Using CAS to solve gives .  As the sign of the second derivative at this stationary point is negative then the curve is concave down and thus a maximum.  Hence maximum height is m above sea level, which is m above plain. |
| Specific behaviours |
| ü obtains first derivative of  ü shows all solutions to  ü obtains and shows second derivative function  ü calculates second derivative of all stationary points  ü uses sign of second derivative for justification  ü calculates height of both maximums  ü confirms correct highest point above plain, with units |

Question 10 (10 marks)

(a) Use the quotient rule to show that . (3 marks)

|  |
| --- |
| Solution |
| Using the quotient rule: |
| Specific behaviours |
| ü correct derivatives for  ü clearly shows use of quotient rule  ü clear simplification steps to obtain required result |

(b) Use your result from part (a) to show that , where is a constant. (3 marks)

|  |
| --- |
| Solution |
| Hence |
| Specific behaviours |
| ü uses result from (a), wrapping integrals around terms  ü simplifies two integrals, including constant  ü rearranges for required integral and simplifies |

(c) The height of a plant, initially cm, is changing at a rate given by cm/day,  
for .

(i) Determine an equation to model the height of the plant as a function of time and hence determine its height after days. (3 marks)

|  |
| --- |
| Solution |
|  |
| Specific behaviours |
| ü uses result from (b)  ü evaluates constant  ü correct height |

(ii) According to the model, what height will the plant never exceed? (1 mark)

|  |
| --- |
| Solution |
| As , cm.  Height will not exceed cm. |
| Specific behaviours |
| ü correct height |

Question 11 (10 marks)

Initially a water tank contains 300 *Litres*.

Between and hours , water is pumped into the tank at the rate of

At the same time 50 is pumped from the tank.

(a) What is the total number of litres of water pumped into the tank during the first twelve hours.

(2 marks)

|  |  |  |
| --- | --- | --- |
|  | *Diagram, text  Description automatically generated* | |
| **Specific behaviours** | | **Mark allocation** |
| States correct integral with limits  States correct answer | | 1  1 |

(b) Is the level of water rising or falling when ?

(2 marks)

|  |  |  |
| --- | --- | --- |
| *,* water is being removed 50L per hour.  level is decreasing | *Text  Description automatically generated* | |
| **Specific behaviours** | | **Mark allocation** |
| Calculates correct rate  States level is falling | | 1  1 |

(c) How many litres are in the tank at ? (3 marks)

|  |  |  |
| --- | --- | --- |
| At t, the tank contains  300+ | *Text  Description automatically generated* | |
| **Specific behaviours** | | **Mark allocation** |
| States correct integral with limits  States correct answer | | 2  1 |

(d) When is the amount of the water in the tank at a minimum? (3 marks)

|  |  |  |
| --- | --- | --- |
| Amount of water at any time *t* is given by  A(t) =300+  Minimum occurs when  Solve  a minimum | Text  Description automatically generated  Text  Description automatically generated    *Diagram  Description automatically generated* | |
| **Specific behaviours** | | **Mark allocation** |
| States correct equation to solve  Finds correct value for t  Justifies answer (must show the evaluation of the second derivative or first derivative sign test) | | 1  1  1 |

Question 12 (13 marks)

A picture containing sky, outdoor, building, bridge

Description automatically generatedThe Lupu Bridge in Shanghai was the longest steel arch bridge when it opened in 2003.

The main arch can be represented by the graph of the function

where is the distance, in metres, from the middle, and is the distance, in metres, above the Hangpu River.

The bridge is symmetrical about the vertical axis.

(a) Determine writing your answer in the form , where  
 is a rational number. (2 marks)

|  |  |
| --- | --- |
| **Solution** | **Specific behaviours** |
|  | * Correctly differentiates and . * Determines and writes answer in required form. |

(b) Using calculus, verify that the **maximum** height of the bridge is 100 m. (4 marks)

|  |  |
| --- | --- |
| **Solution** | **Specific behaviours** |
|  | * Uses first derivative to determine coordinate of stationary point. * Determines second derivative. * Determines to verify the stationary point is a maximum. * Concludes maximum height is 100 m. |

The graph below shows the Lupu Bridge and the road, which is 46 m above the river.

<EFOFEX>

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FXData:


</EFOFEX>

(c) Determine, correct to the nearest 100 m2, the cross-sectional area between the  
road, the bridge and water. (4 marks)

|  |  |
| --- | --- |
| **Solution** | **Specific behaviours** |
|  | * Determines intercepts of the bridge. * Determines coordinates of the points of intersection of the bridge and road. * Writes an integral to determine the area. * Determines the area, correct to the nearest 100 m2. |

An observation deck is positioned at the top of the bridge. To access the deck, visitors need to climb the arch. The distance, , travelled along the arch is given by

where is measured in metres, and is measured in seconds.

(d) Determine the speed, of the visitors, when they are minutes into  
their ascent. (3 marks)

|  |  |
| --- | --- |
| **Solution** | **Specific behaviours** |
|  | * Uses Fundamental Theorem to determine expression in terms of for . * Substitutes . * Determines speed and states correct units. |

**Question 13 (12 marks)**

A Mathematics teacher gives a student two fair six-sided dice. One die is coloured red and the other coloured blue.

The student rolls the two dice, and then writes down the following fraction:

(a) Show that the probability of getting a fraction less than is . (2 marks)

|  |  |
| --- | --- |
| **Solution** | **Specific behaviours** |
|  | * Recognises that number on red < number on blue. * Shows how to get probability of . |

The teacher draws up the following table on the board.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Fraction |  |  |  |  |  |
|  |  |  |  |  |  |

(b) Complete the table above, providing the missing probabilities. (2 marks)

|  |  |
| --- | --- |
| **Solution** | **Specific behaviours** |
|  | * Determines . * Determines . |

(c) Determine the probability that a student obtains a fraction that is at least ,  
given that the fraction is less than . (2 marks)

|  |  |
| --- | --- |
| **Solution** | **Specific behaviours** |
|  | * Determines correct numerator. * Determines correct denominator and obtains final answer. |

A Mathematics teacher asks each of her 20 students to write down the fraction they obtained from rolling the two dice.

(d) Determine the probability that at least half of the class obtained a fraction where the numerator is greater than or equal to the denominator. (3 marks)

|  |  |
| --- | --- |
| **Solution** | **Specific behaviours** |
|  | * Defines the appropriate random variable and states correct binomial distribution. * States the correct probability statement. * Determines the probability. |

(e) The teacher asks each student one-by-one what fraction they obtained. The teacher dismisses the class when *exactly* students have a fraction of less than .  
  
Determine the probability that the teacher will need to ask *exactly* ten students before dismissing the class. (3 marks)

|  |  |
| --- | --- |
| **Solution** | **Specific behaviours** |
|  | * Defines the appropriate random variable and states correct binomial distribution. * Determines probability of 4 out of 9 having a fraction < 1. * Determines the final probability. |

Question 14 (11 marks)

Jake works in a tyre factory. The number of damaged tires that he makes on a random day has the **cumulative** probability distribution

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | 0 | *1* | *2* | *3* | *4* |
|  | *0.4* | *0.58* | *0.83* | *0.96* | *1* |

(a) Determine the probability that Jake produces:

(i) more than two damaged tyres. (1 mark)

|  |  |
| --- | --- |
|  | |
| **Specific behaviours** | **Mark allocation** |
| States correct probability. | 1 |
|  |  |

(ii) three damaged tyres. (1 mark)

|  |  |
| --- | --- |
|  | |
| **Specific behaviours** | **Mark allocation** |
| States correct probability | 1 |
|  |  |

(b) Calculate

(3 marks)

|  |  |
| --- | --- |
|  | |
| **Specific behaviours** | **Mark allocation** |
| States correct conditional probability formula  Correct numerator  States correct answer | 1  1  1 |
|  |  |

(c) Determine the expected value of and interpret your answer in the context of this question.

(2 marks)

|  |  |
| --- | --- |
| Usually, he damages approximately 1 tyre per day. | |
| **Specific behaviours** | **Mark allocation** |
| Calculates correct answer  Makes a suitable statement interpreting the answer. | 1  1 |
|  |  |

(d) Calculate the Standard deviation of .

(2 marks)

|  |  |
| --- | --- |
| Variance =  Std deviation | |
| **Specific behaviours** | **Mark allocation** |
| Uses correct equation for variance  Calculates correct answer | 1  1 |
|  |  |

(e)

The factory owner decides to introduce a points scheme using the rule

Find the points Jake will expect to receive and state the variance of his points score.

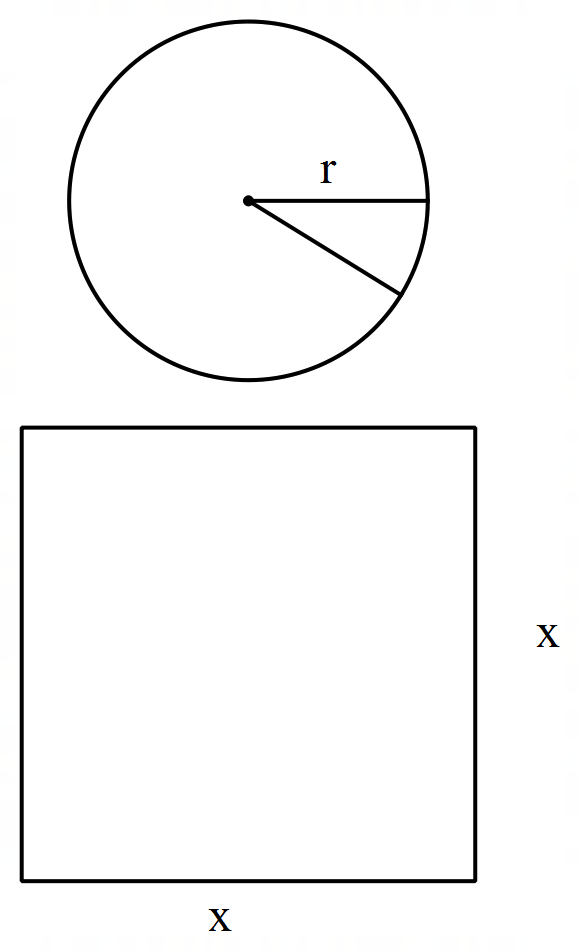
(Give your answers to the nearest unit)

(2 marks)

|  |  |
| --- | --- |
| Variance | |
| **Specific behaviours** | **Mark allocation** |
| Calculates new Expected Value correctly  Calculates correct answer for variance | 1  1 |
|  |  |

Question 15 (8 marks)

Thediagram below shows a logo which includes a circle of radius cm and a square with side cm.



Before construction, a stencil was made, and the total perimeter of both figures was found to be 60cm.

(a) By expressing in terms of , show that the total area of both shapes is given by:

(4 marks)

|  |  |  |
| --- | --- | --- |
|  |  | |
| **Specific behaviours** | | **Mark allocation** |
| Creates equation for Perimeter  Rearranges r in terms of x  Substitutes into Area  Simplifies for correct answer | | 1  1  1  1 |

(b) Using calculus determine the value of which minimises the area.

(4 marks)

|  |  |  |
| --- | --- | --- |
| Solve using CAS:  Minimum value | Diagram, text  Description automatically generatedText  Description automatically generated | |
| **Specific behaviours** | | **Mark allocation** |
| Correctly calculates derivative  Uses CAS to solve for correctly  Calculates second derivative  Justifies answer | | 1  1  1  1 |

Additional working space

Question number: \_\_\_\_\_\_\_

Additional working space

Question number: \_\_\_\_\_\_\_\_

Additional working space

Question number: \_\_\_\_\_\_\_\_