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# MATHEMATICAL METHODS

## Written examination 1

Tuesday 17 November 2020

Reading time: 9.00 am to 9.15 am (15 minutes)

Writing time: 9.15 am to 10.15 am (1 hour)

### QUESTION AND ANSWER BOOK

#### Structure of book

<i>Number of questions</i>	<i>Number of questions to be answered</i>	<i>Number of marks</i>
8	8	40

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners and rulers.
- Students are NOT permitted to bring into the examination room: any technology (calculators or software), notes of any kind, blank sheets of paper and/or correction fluid/tape.

#### Materials supplied

- Question and answer book of 14 pages
- Formula sheet
- Working space is provided throughout the book.

#### Instructions

- Write your **student number** in the space provided above on this page.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

#### At the end of the examination

- You may keep the formula sheet.

**Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.**

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**Instructions**

Answer **all** questions in the spaces provided.

In all questions where a numerical answer is required, an exact value must be given, unless otherwise specified.

In questions where more than one mark is available, appropriate working **must** be shown.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

**Question 1** (3 marks)

- a. Let  $y = x^2 \sin(x)$ .

Find  $\frac{dy}{dx}$ .

1 mark

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- b. Evaluate  $f'(1)$ , where  $f: R \rightarrow R$ ,  $f(x) = e^{x^2-x+3}$ .

2 marks

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**Question 2** (3 marks)

A car manufacturer is reviewing the performance of its car model X. It is known that at any given six-month service, the probability of model X requiring an oil change is  $\frac{17}{20}$ , the probability of model X requiring an air filter change is  $\frac{3}{20}$  and the probability of model X requiring both is  $\frac{1}{20}$ .

- a. State the probability that at any given six-month service model X will require an air filter change without an oil change.

1 mark

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- b. The car manufacturer is developing a new model, Y. The production goals are that the probability of model Y requiring an oil change at any given six-month service will be  $\frac{m}{m+n}$ , the probability of model Y requiring an air filter change will be  $\frac{n}{m+n}$  and the probability of model Y requiring both will be  $\frac{1}{m+n}$ , where  $m, n \in \mathbb{Z}^+$ .

Determine  $m$  in terms of  $n$  if the probability of model Y requiring an air filter change without an oil change at any given six-month service is 0.05

2 marks

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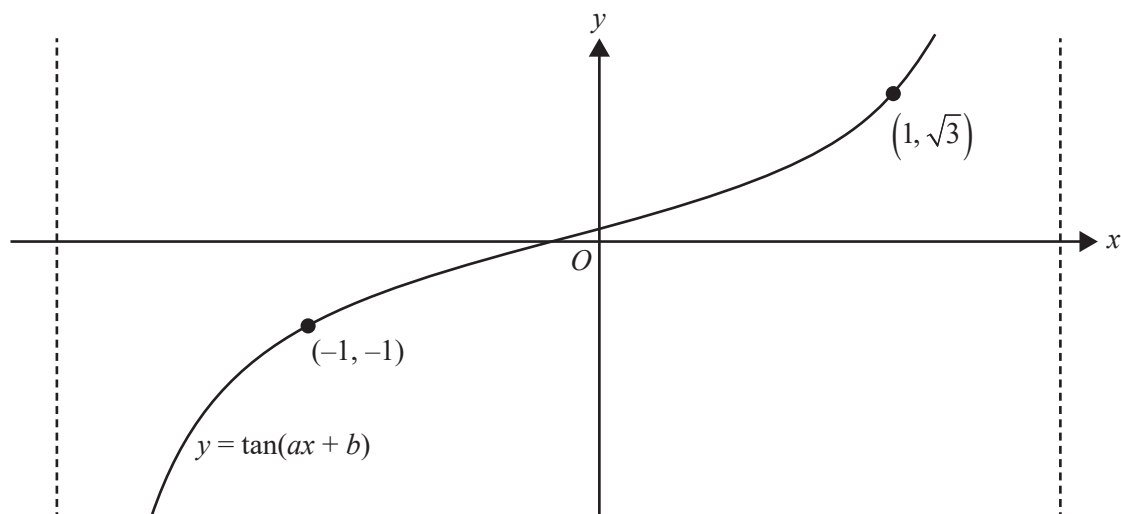
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**Question 3** (3 marks)

Shown below is part of the graph of a period of the function of the form  $y = \tan(ax + b)$ .



The graph is continuous for  $x \in [-1, 1]$ .

Find the value of  $a$  and the value of  $b$ , where  $a > 0$  and  $0 < b < 1$ .

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**Question 5** (4 marks)

For a certain population the probability of a person being born with the specific gene SPGE1 is  $\frac{3}{5}$ .

The probability of a person having this gene is independent of any other person in the population having this gene.

- a. In a randomly selected group of four people, what is the probability that three or more people have the SPGE1 gene? 2 marks

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- b. In a randomly selected group of four people, what is the probability that exactly two people have the SPGE1 gene, given that at least one of those people has the SPGE1 gene? Express your answer in the form  $\frac{a^3}{b^4 - c^4}$ , where  $a, b, c \in \mathbb{Z}^+$ . 2 marks

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**Question 6** (8 marks)

Let  $f: [0, 2] \rightarrow \mathbb{R}$ , where  $f(x) = \frac{1}{\sqrt{2}}\sqrt{x}$ .

- a. Find the domain and the rule for  $f^{-1}$ , the inverse function of  $f$ .

2 marks

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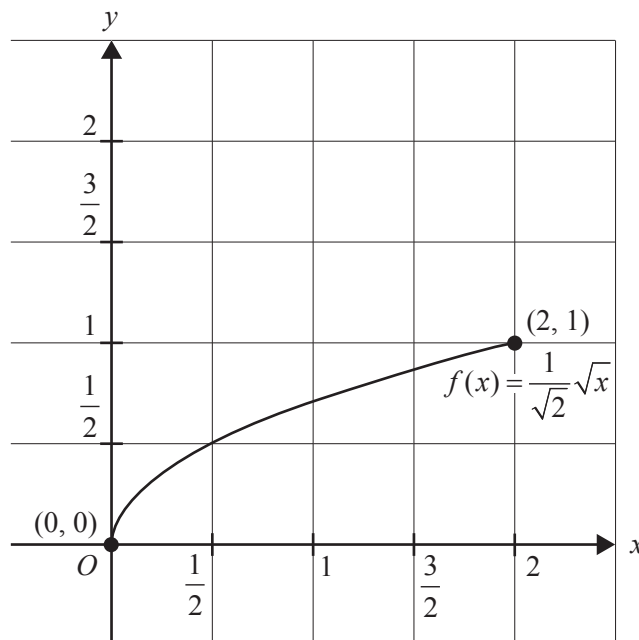


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The graph of  $y = f(x)$ , where  $x \in [0, 2]$ , is shown on the axes below.



- b. On the axes above, sketch the graph of  $f^{-1}$  over its domain. Label the endpoints and point(s) of intersection with the function  $f$ , giving their coordinates.

2 marks



- c. Find the total area of the two regions: one region bounded by the functions  $f$  and  $f^{-1}$ , and the other region bounded by  $f$ ,  $f^{-1}$  and the line  $x = 1$ . Give your answer in the form  $\frac{a - b\sqrt{b}}{6}$ , where  $a, b \in \mathbb{Z}^+$ . 4 marks

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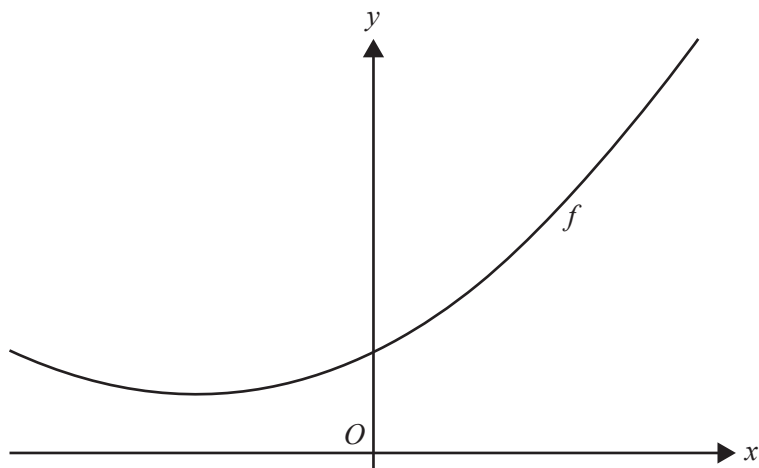
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**Question 7** (8 marks)

Consider the function  $f(x) = x^2 + 3x + 5$  and the point  $P(1, 0)$ . Part of the graph of  $y = f(x)$  is shown below.



- a. Show that point  $P$  is not on the graph of  $y = f(x)$ . 1 mark

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- b. Consider a point  $Q(a, f(a))$  to be a point on the graph of  $f$ .
- i. Find the slope of the line connecting points  $P$  and  $Q$  in terms of  $a$ . 1 mark

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- ii. Find the slope of the tangent to the graph of  $f$  at point  $Q$  in terms of  $a$ . 1 mark

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iii. Let the tangent to the graph of  $f$  at  $x = a$  pass through point  $P$ .

Find the values of  $a$ .

2 marks

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iv. Give the equation of one of the lines passing through point  $P$  that is tangent to the graph of  $f$ .

1 mark

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c. Find the value,  $k$ , that gives the shortest possible distance between the graph of the function of  $y = f(x - k)$  and point  $P$ .

2 marks

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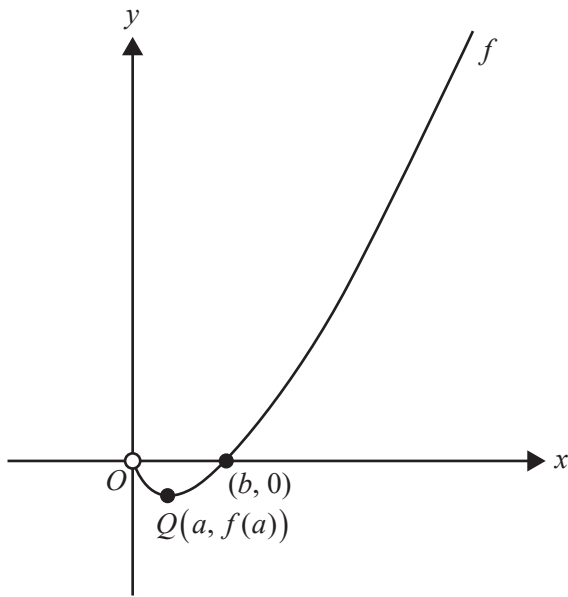
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**Question 8** (8 marks)

Part of the graph of  $y = f(x)$ , where  $f: (0, \infty) \rightarrow \mathbb{R}$ ,  $f(x) = x \log_e(x)$ , is shown below.



The graph of  $f$  has a minimum at the point  $Q(a, f(a))$ , as shown above.

- a. Find the coordinates of the point  $Q$ .

2 marks

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- b. Using  $\frac{d(x^2 \log_e(x))}{dx} = 2x \log_e(x) + x$ , show that  $x \log_e(x)$  has an antiderivative  $\frac{x^2 \log_e(x)}{2} - \frac{x^2}{4}$ . 1 mark

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- c. Find the area of the region that is bounded by  $f$ , the line  $x = a$  and the horizontal axis for  $x \in [a, b]$ , where  $b$  is the  $x$ -intercept of  $f$ . 2 marks

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d. Let  $g : (a, \infty) \rightarrow \mathbb{R}$ ,  $g(x) = f(x) + k$  for  $k \in \mathbb{R}$ .

i. Find the value of  $k$  for which  $y = 2x$  is a tangent to the graph of  $g$ .

1 mark

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ii. Find all values of  $k$  for which the graphs of  $g$  and  $g^{-1}$  do not intersect.

2 marks

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**Victorian Certificate of Education  
2020**

**MATHEMATICAL METHODS**

**Written examination 1**

**FORMULA SHEET**

**Instructions**

This formula sheet is provided for your reference.  
A question and answer book is provided with this formula sheet.

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## Mathematical Methods formulas

### Mensuration

area of a trapezium	$\frac{1}{2}(a+b)h$	volume of a pyramid	$\frac{1}{3}Ah$
curved surface area of a cylinder	$2\pi rh$	volume of a sphere	$\frac{4}{3}\pi r^3$
volume of a cylinder	$\pi r^2 h$	area of a triangle	$\frac{1}{2}bc \sin(A)$
volume of a cone	$\frac{1}{3}\pi r^2 h$		

### Calculus

$\frac{d}{dx}(x^n) = nx^{n-1}$	$\int x^n dx = \frac{1}{n+1} x^{n+1} + c, n \neq -1$		
$\frac{d}{dx}((ax+b)^n) = an(ax+b)^{n-1}$	$\int (ax+b)^n dx = \frac{1}{a(n+1)}(ax+b)^{n+1} + c, n \neq -1$		
$\frac{d}{dx}(e^{ax}) = ae^{ax}$	$\int e^{ax} dx = \frac{1}{a} e^{ax} + c$		
$\frac{d}{dx}(\log_e(x)) = \frac{1}{x}$	$\int \frac{1}{x} dx = \log_e(x) + c, x > 0$		
$\frac{d}{dx}(\sin(ax)) = a \cos(ax)$	$\int \sin(ax) dx = -\frac{1}{a} \cos(ax) + c$		
$\frac{d}{dx}(\cos(ax)) = -a \sin(ax)$	$\int \cos(ax) dx = \frac{1}{a} \sin(ax) + c$		
$\frac{d}{dx}(\tan(ax)) = \frac{a}{\cos^2(ax)} = a \sec^2(ax)$			
product rule	$\frac{d}{dx}(uv) = u \frac{dv}{dx} + v \frac{du}{dx}$	quotient rule	$\frac{d}{dx}\left(\frac{u}{v}\right) = \frac{v \frac{du}{dx} - u \frac{dv}{dx}}{v^2}$
chain rule	$\frac{dy}{dx} = \frac{dy}{du} \frac{du}{dx}$		



**Probability**

$\Pr(A) = 1 - \Pr(A')$	$\Pr(A \cup B) = \Pr(A) + \Pr(B) - \Pr(A \cap B)$
$\Pr(A B) = \frac{\Pr(A \cap B)}{\Pr(B)}$	

Probability distribution		Mean	Variance
Bernoulli	$\Pr(X = x) = \begin{cases} p & x = 1 \\ 1 - p & x = 0 \end{cases}$	$\mu = p$	$\sigma^2 = p(1 - p)$
binomial	$\Pr(X = x) = \binom{n}{x} p^x (1 - p)^{n-x}$	$\mu = np$	$\sigma^2 = np(1 - p)$
normal	$\Pr(X \leq a) = \int_{-\infty}^a \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} dx$	$\mu$	$\sigma^2$