



The Mathematical Association of Victoria MATHEMATICAL METHODS (CAS)

Trial written examination 2

2007

Reading time: 15 minutes

Writing time: 2 hours

Student's Name:

QUESTION AND ANSWER BOOK

Structure of book

<i>Section</i>	<i>Number of questions</i>	<i>Number of questions to be answered</i>	<i>Number of marks</i>
1	22	22	22
2	4	4	58
			Total 80

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

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Working space

MULTIPLE CHOICE ANSWER SHEET

Student Name:

Circle the letter that corresponds to each correct answer

1	A	B	C	D	E
2	A	B	C	D	E
3	A	B	C	D	E
4	A	B	C	D	E
5	A	B	C	D	E
6	A	B	C	D	E
7	A	B	C	D	E
8	A	B	C	D	E
9	A	B	C	D	E
10	A	B	C	D	E
11	A	B	C	D	E
12	A	B	C	D	E
13	A	B	C	D	E
14	A	B	C	D	E
15	A	B	C	D	E
16	A	B	C	D	E
17	A	B	C	D	E
18	A	B	C	D	E
19	A	B	C	D	E
20	A	B	C	D	E
21	A	B	C	D	E
22	A	B	C	D	E

Working space

SECTION 1

Instructions for Section 1

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** for the question.

A correct answer scores 1, an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

Question 1

If $R \rightarrow R$, where $f(x) = 2x + 1$ and $g: R \setminus \{0\} \rightarrow R$, where $g(x) = \frac{1}{x^2}$ then the range of $f(g(x))$ is

- A. $R \setminus \{1\}$
- B. $(1, \infty)$
- C. $(0, \infty)$
- D. $R \setminus \{-\frac{1}{2}\}$
- E. $R \setminus \{0\}$

Question 2

If $h: (1, 2] \rightarrow R$, where $h(x) = (x - 1)^2(x + 2)$ and $f: [-1, 2) \rightarrow R$, where $f(x) = 1 - x$ then $g = hf$ is defined by

- A. $g: R \rightarrow R$, where $h(x) = -(x - 1)^3(x + 2)$
- B. $g: (1, 2) \rightarrow R$, where $h(x) = -(x - 1)^3(x + 2)$
- C. $g: (1, 2] \rightarrow R$, where $h(x) = -(x - 1)^3(x + 2)$
- D. $g: (1, 2) \rightarrow R$, where $h(x) = -(x - 1)^2(x + 2)(x + 1)$
- E. $g: [-1, 2] \rightarrow R$, where $h(x) = -(x - 1)^3(x + 2)$

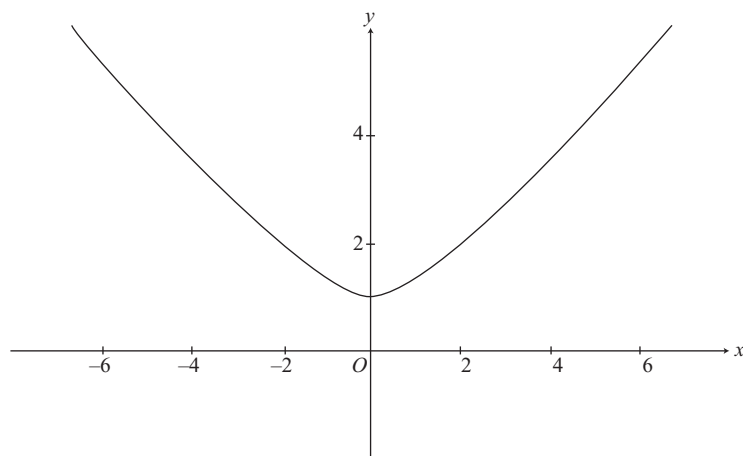
Question 3

The graph of $y = f(x)$ undergoes the following transformations:

- a translation of 5 units up, then
- a reflection in the y -axis, then
- a dilation by a scale factor of 3 from the x -axis, then
- a dilation by a scale factor of 2 from the y -axis.

The transformation $T: R^2 \rightarrow R^2$, which maps the curve with equation $y = f(x)$ onto its image could be

- A. $T\left(\begin{bmatrix} x \\ y \end{bmatrix}\right) = \begin{bmatrix} -2 & 0 \\ 0 & 3 \end{bmatrix} \left(\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} 0 \\ 5 \end{bmatrix}\right)$
- B. $T\left(\begin{bmatrix} x \\ y \end{bmatrix}\right) = \begin{bmatrix} -\frac{1}{2} & 0 \\ 0 & 3 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} 0 \\ 5 \end{bmatrix}$
- C. $T\left(\begin{bmatrix} x \\ y \end{bmatrix}\right) = \begin{bmatrix} 2 & 0 \\ 0 & -3 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} 0 \\ -5 \end{bmatrix}$
- D. $T\left(\begin{bmatrix} x \\ y \end{bmatrix}\right) = \begin{bmatrix} 3 & 0 \\ 0 & -2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} 5 \\ 0 \end{bmatrix}$
- E. $T\left(\begin{bmatrix} x \\ y \end{bmatrix}\right) = \begin{bmatrix} -2 & 0 \\ 0 & \frac{1}{3} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} 0 \\ 5 \end{bmatrix}$

Question 4

The graph shown above passes through the point $(2, 2)$. A possible equation for this graph could be

- A. $y = x^{\frac{4}{3}} + 1$
- B. $y = x^{\frac{2}{3}} + 1$
- C. $y = x^{\frac{5}{3}} + 1$
- D. $y = x^2 + 1$
- E. $y = \left(\frac{x}{2}\right)^{\frac{4}{3}} + 1$

Question 5

A system of simultaneous linear equations is represented by the matrix equation

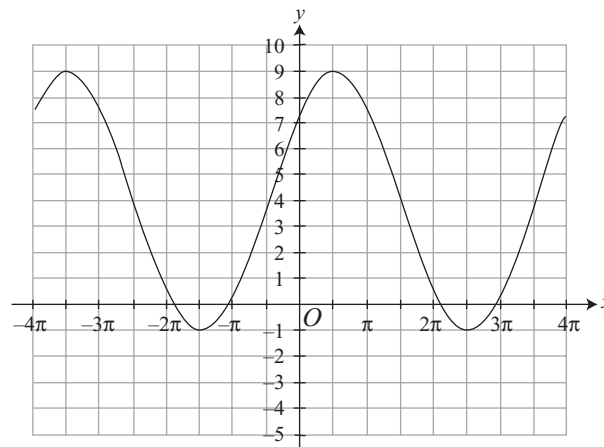
$$\begin{bmatrix} 0 & -k & 1 \\ 1 & -1 & k \\ 1 & 1 & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 3 \\ 1 \\ 5 \end{bmatrix}, \text{ where } k \text{ is a real constant.}$$

The system of equations has a unique solution for

- A. $k \in \mathbb{R}$
- B. $k \in \mathbb{R} \setminus \{0\}$
- C. $k \in \mathbb{R} \setminus \{\pm 1\}$
- D. $k \in \mathbb{R} \setminus \{2\}$
- E. $k \in \mathbb{R} \setminus \{\pm\sqrt{2}\}$

Question 6

The diagram below shows the graph of a circular function.

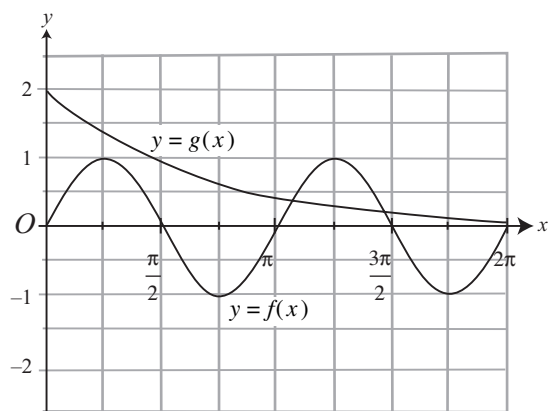


The **amplitude**, **period** and **rule**, respectively, of this graph are

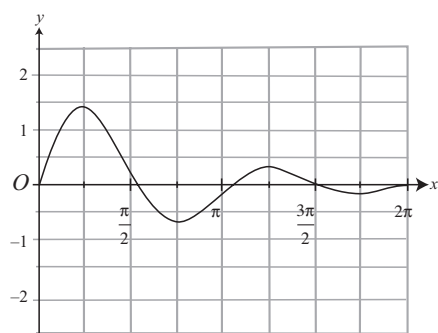
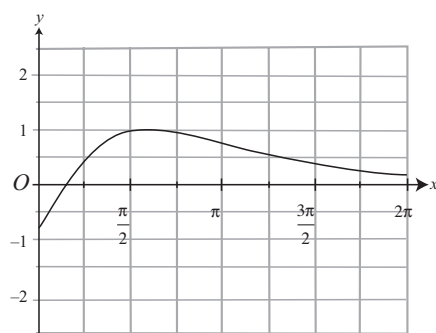
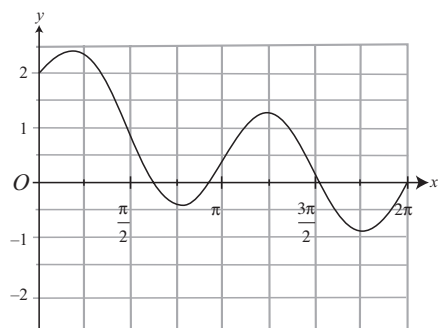
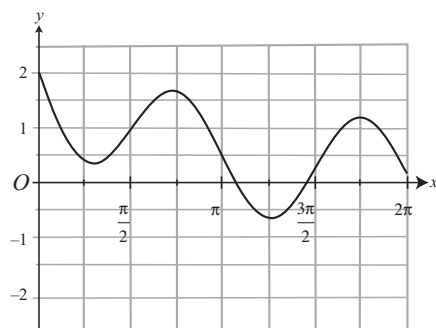
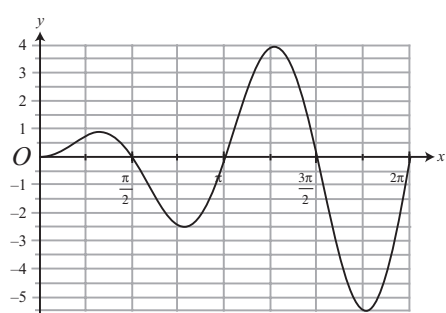
- A. $10, 8\pi, y = 10\cos\left(\frac{x}{2} - \frac{\pi}{2}\right) + 4$
- B. $5, 4\pi, y = 5\cos\left(\frac{x}{2} - \frac{\pi}{4}\right) + 4$
- C. $5, 4\pi, y = 5\cos\left(2x - \frac{\pi}{2}\right) + 4$
- D. $10, 4\pi, y = 10\cos\left(2x + \frac{\pi}{2}\right) + 4$
- E. $5, 8\pi, y = 5\cos\left(\frac{x}{4} - \frac{\pi}{2}\right) + 4$

Question 7

The diagram below shows the graphs of two functions, f and g .



Which one of the following could be the graph of the product function $y = (fg)(x)$?

A.**B.****C.****D.****E.**

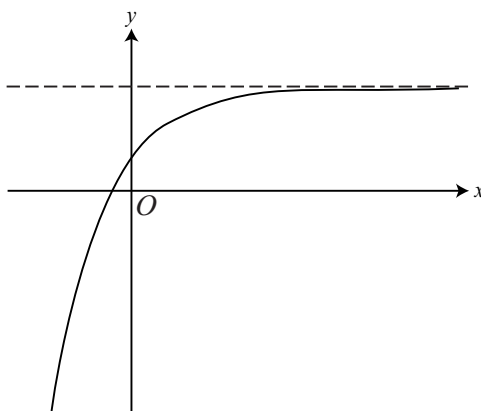
Question 8

Let $R \rightarrow R$, where $f(x) = e^{2(x-1)} + 3$. If the graph of g is the graph of f dilated by a factor of 3 from the x -axis then the graph of the inverse function g^{-1} has

- A. a vertical asymptote with equation $x = 9$.
- B. a horizontal asymptote with equation $y = 3$.
- C. a vertical asymptote with equation $x = 1$.
- D. a horizontal asymptote with equation $y = 1$.
- E. a vertical asymptote with equation $x = 3$.

Question 9

Part of the graph of an exponential function with rule $y = f(x)$ is shown below.



If $a > 0$, $b < 0$ and $k > 0$, the rule for f could be

- A. $y = ae^{bx} + k$
- B. $y = ae^{b(x-k)}$
- C. $y = -ae^{bx} + k$
- D. $y = ae^{-bx} + k$
- E. $y = ae^{bx} - k$

Question 10

A function f satisfies the functional equation $-af(|x|) = f\left(\frac{1}{|x|^a}\right)$, where $a \in R$ and $x \in R \setminus \{0\}$.

A possible rule for f is

- A. $f(x) = e^x$
- B. $f(x) = \sqrt{x}$
- C. $f(x) = \sin(x)$
- D. $f(x) = \log_e(x)$
- E. $f(x) = x^2$

Question 11

The equation of the tangent to the graph with equation $y = 2(x-3)^6 + 4$ at its turning point is

- A. $x = 3$
- B. $y = 3$
- C. $x = -3$
- D. $y = 4$
- E. $x = 4$

Question 12

The average rate of change of $f(x) = \sqrt{2-x}$ from $x = -2$ to $x = 1$ is

- A. -1
- B. $-\frac{1}{2}$
- C. $-\frac{1}{3}$
- D. $-\frac{1}{4}$
- E. $\frac{1}{3}$

Question 13

If $f(x) = \log_e |x-1|$, then the derivative of f is

- A. $\frac{1}{x-1}$, for $x > 1$
- B. $\frac{1}{x-1}$, for $x < 1$
- C. $\frac{1}{x-1}$, for $x > 0$
- D. $\frac{1}{x-1}$, for $x \in \mathbb{R} \setminus \{1\}$
- E. $\frac{1}{x-1}$, for $x \in \mathbb{R} \setminus \{-1\}$

Question 14

The area bounded by the curve with equation $y = \log_e(x)$, the x -axis and the line $x = 4$ is approximated using left-end rectangles of width 1 unit. This area, in units², is

- A. $\log_e 6$
- B. $\log_e 24$
- C. $8\log_e(2) - 4$
- D. 1.55
- E. 1.79

Question 15

The area, correct to three decimal places, bounded by the y -axis and the curves with equations $f(x) = \cos(2x) + 2$ and $g(x) = e^x$ is

- A. 3.357
- B. 0.879
- C. 0.878
- D. 0.882
- E. -0.882

Question 16

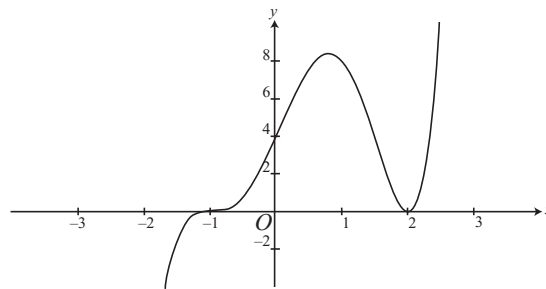
For a particular city, the time from sunrise to sunset, S hours, x days after the winter solstice, is modelled by the function $S(x) = -5 \cos\left(\frac{\pi}{183}x\right) + 12$, for $0 \leq x \leq 183$.

The average value of S , over the interval $[0, n]$, is 8 hours. The value of n is closest to

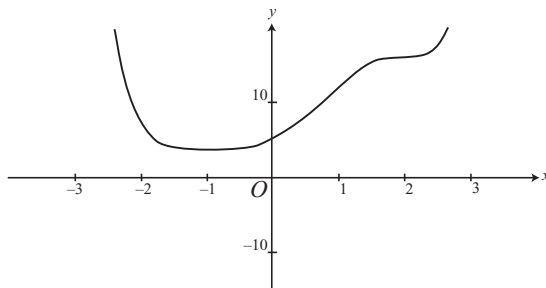
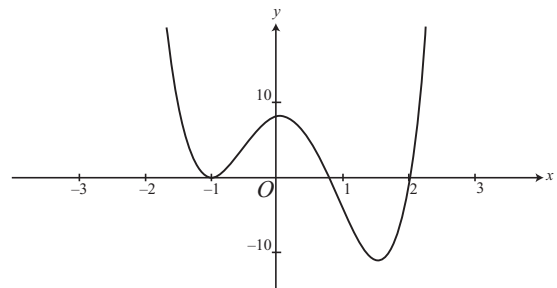
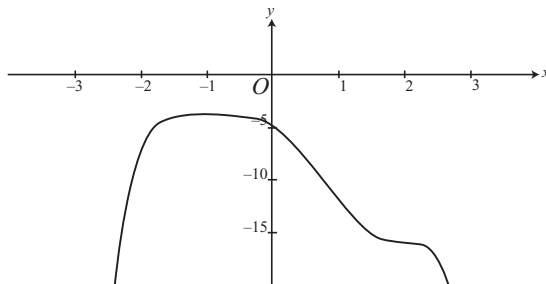
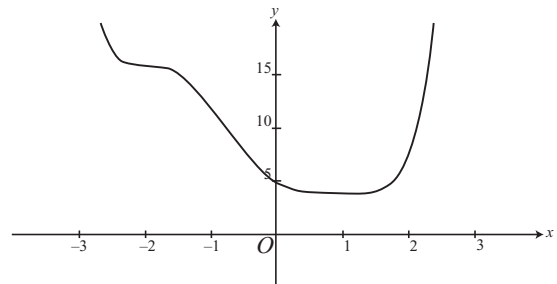
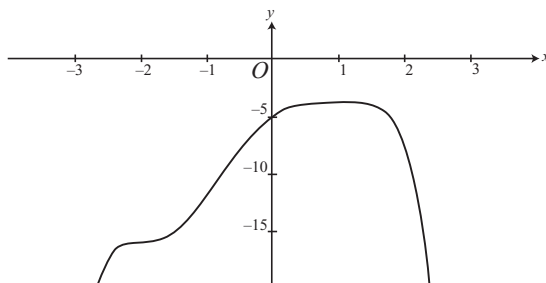
- A. 28 days
- B. 30 days
- C. 60 days
- D. 66 days
- E. 99 days

Question 17

Part of the graph of the derivative of f is shown below.



Part of the graph of f could be

A.**B.****C.****D.****E.**

Question 18

Miriam and her husband have brown eyes, but both carry the recessive gene for blue eyes. It is known that couples in these circumstances will have a child with blue eyes in 1 out of every 4 births. If they have three children altogether, the probability that at least one will have blue eyes is

- A. $\frac{27}{64}$
- B. $\frac{37}{64}$
- C. $\frac{1}{4}$
- D. $\frac{3}{4}$
- E. $\frac{9}{64}$

Question 19

The probability distribution for a discrete random variable, X , is defined by the probability function

$$p(x) = \frac{x^2 + 1}{10}, \text{ for } x \in \{-1, 0, 1, 2\}.$$

The expectation of X , $E(X)$, is

- A. 1.5
- B. 1.4
- C. 1.1
- D. 1
- E. 0.8

Question 20

The probability distribution for a continuous random variable, T , is defined by the probability density function

$$f(t) = \begin{cases} \sin(2t) & 0 \leq t \leq \frac{\pi}{2} \\ 0 & \text{otherwise} \end{cases}$$

The mode of the distribution is

- A. 0
- B. 1
- C. π
- D. $\frac{\pi}{2}$
- E. $\frac{\pi}{4}$

Question 21

The speed of vehicles travelling along a particular section of a rural freeway is modelled as a normally distributed random variable with a mean of 96 km/h and a standard deviation of 12 km/h.

According to this model, the percentage of vehicles that are exceeding the speed limit of 110 km/h is closest to

- A. 5%
- B. 10%
- C. 12%
- D. 14%
- E. 20%

Question 22

Consider a Markov chain where the n th state is given by $S_n = T^n \times S_0$.

Which one of the following could represent the transition matrix, T , and the initial state matrix, S_0 , respectively?

- A. $\begin{bmatrix} 0.35 & 0.65 \\ 0.55 & 0.45 \end{bmatrix}$ and $\begin{bmatrix} 0.8 \\ 0.2 \end{bmatrix}$
- B. $\begin{bmatrix} 0.25 & 0.55 \\ 0.85 & 0.45 \end{bmatrix}$ and $\begin{bmatrix} 0 \\ 1 \end{bmatrix}$
- C. $\begin{bmatrix} 0.35 & 0.55 \\ 0.65 & 0.45 \end{bmatrix}$ and $\begin{bmatrix} 27 \\ 33 \end{bmatrix}$
- D. $\begin{bmatrix} 0.8 \\ 0.2 \end{bmatrix}$ and $\begin{bmatrix} 0.35 & 0.65 \\ 0.55 & 0.45 \end{bmatrix}$
- E. $\begin{bmatrix} 27 \\ 33 \end{bmatrix}$ and $\begin{bmatrix} 0.35 & 0.55 \\ 0.65 & 0.45 \end{bmatrix}$

SECTION 2

Instructions for Section 2

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

A decimal approximation will not be accepted if an **exact** answer is required to a question.

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

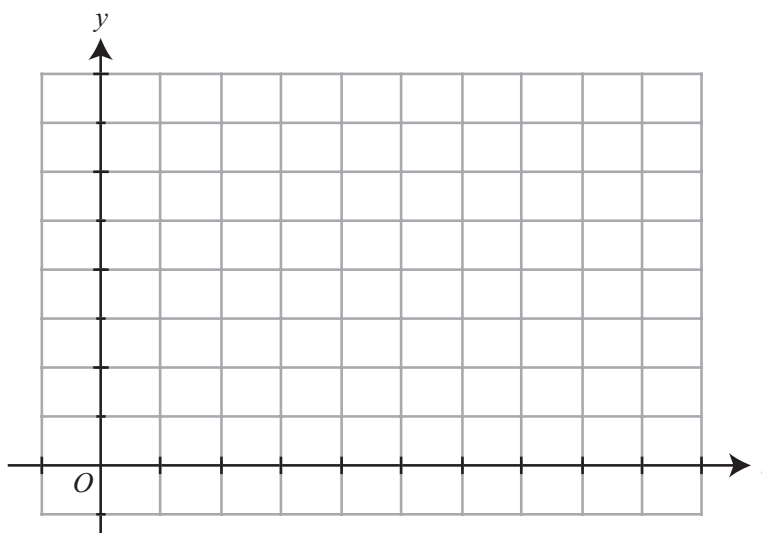
The incubation period, T days, for a new strain of influenza virus, commonly known as blue flu, is modelled by the probability density function

$$v(t) = \begin{cases} -\frac{1}{108}(t^3 - 15t^2 + 63t - 81) & 3 \leq t \leq k \\ 0 & \text{otherwise} \end{cases}$$

- a. Show that $k = 9$.

1 mark

- b. Sketch the graph of $y = v(t)$ on the axes below. Label axes intercepts and any stationary points with their **exact** coordinates.



3 marks

- c. Find the **median** incubation period for this virus, in days, correct to two decimal places.

2 marks

A new drug, Fluaway, has been developed to treat the symptoms of blue flu. The time taken for a standard dose of Fluaway to take effect is modelled by a normally distributed random variable with a mean of 5 hours.

For 90% of patients, a standard dose of Fluaway takes effect within 6 hours and 15 minutes of being administered.

- d. Find the standard deviation, in hours, correct to two decimal places.

2 marks

Vivienne is a medical practitioner at an infectious disease clinic.

- e. Vivienne randomly selects ten patients with blue flu and administers a standard dose of Fluaway to each of them. Find the probability that, in at least two of the patients, the drug will take more than 6 hours and 15 minutes (that is, 6.25 hours) to take effect. Give the answer correct to three decimal places.

2 marks

- f. Vivienne randomly selects k patients with blue flu and administers a standard dose of Fluaway to each of them. What is the minimum value of k required to ensure that there is at least a 95% chance that at least one patient will take more than 6 hours and 15 minutes to respond to the drug?

2 marks

- g. An alternative drug, Blugone, has been released. At the clinic, Vivienne's decision as to which of the two drugs to prescribe to patients on a particular day depends only on which drug was prescribed the previous day. If Fluaway was prescribed yesterday, there is a probability of 0.2 that Blugone will be prescribed today.

The transition matrix for the probabilities of Vivienne prescribing Fluaway or Blugone is $\begin{bmatrix} 0.8 & 0.3 \\ 0.2 & 0.7 \end{bmatrix}$.

- i. What is the probability that Blugone will be prescribed tomorrow, given that it was prescribed today?

- ii. On Monday of this week she prescribed Fluaway to her blue flu patients. What is the probability that she will prescribe Blugone on Friday of the same week?

- iii. In the long term, what proportion of days does she prescribe Blugone?

1 + 2 + 1 = 4 marks

Total 16 marks

Question 2

The shape of the vertical cross-section of an irrigation channel can be modelled by the following function:

$$f : [-5, 5] \rightarrow \mathbb{R}, \text{ where } f(x) = A(x^{\frac{4}{3}} - 5) \text{ and } A \text{ is a real constant.}$$

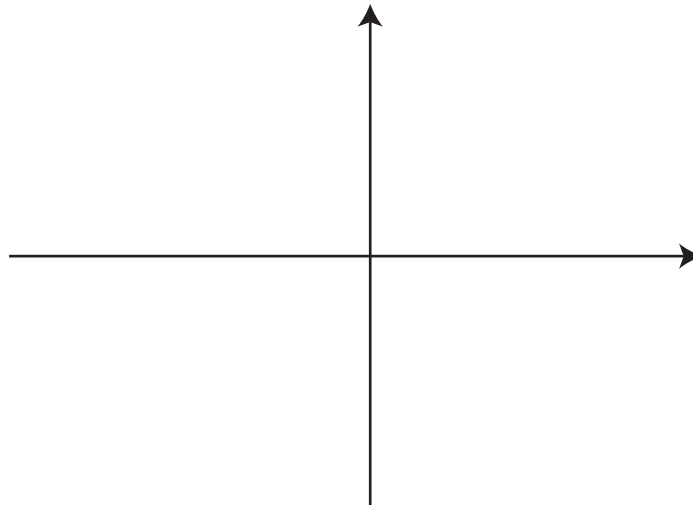
The x -axis represents normal ground level. f is the vertical distance, in metres, of the edge of the channel above ground level. x is the horizontal distance, in metres, of the edge of the channel from the centre of the channel. Give exact answers unless otherwise stated.

- a.** The lowest point of the channel is represented by the turning point of the graph of f which has coordinates $(0, -2)$.

Show that the value of A is $\frac{2}{5}$.

1 mark

- b.** Sketch the graph of f on the axes below, clearly labelling the endpoints and axial intercepts with their coordinates.



5 marks

- c.** What is the maximum possible depth, in metres, of the water in the channel?

1 mark

On a particular day, the maximum depth of the water in the channel is 2 m.

- d. i.** Find the area, in m^2 , bounded by the x -axis and the graph of f .

- ii. Hence**, if the length of the channel is 1 km, find the volume, in m^3 , of water in the channel.

2 + 1 = 3 marks

Due to weeds at the bottom of the channel, a more accurate estimate of the vertical cross-sectional area of water in the channel, on the day given in **part d**, can be found by using a triangle with vertices $(0, -2)$, $(-5^{\frac{3}{4}}, 0)$ and $(5^{\frac{3}{4}}, 0)$. Assume the length of the channel is 1 km.

- e. i.** What is the estimated volume, in m^3 correct to two decimal places, of water in the channel using this method?

- ii.** The depth of water in the channel starts to decrease by 2 cm/h because of evaporation.

Show that the rate at which the volume of water is decreasing in the channel is $20 \times 5^{\frac{3}{4}}h \text{ m}^3/\text{h}$, where h m is the maximum depth of water in the channel. Assume no water is entering the channel.

2 + 4 = 6 marks

Total 16 marks

Question 3

Let $g : R \rightarrow R$, where $g(x) = A \times B^x$, and A and $B \in Z^+$.

- a. Find values for A and B if the graph of g passes through the points $(2, 12)$ and $(4, 48)$.

2 marks

The graph of g_2 is the graph of g dilated by a factor of $\frac{1}{3}$ from the y -axis, followed by a translation of $\frac{4}{3}$ units parallel to the x -axis and 1 unit parallel to the y -axis.

- b. Write down the rule for g_2 and state the range.

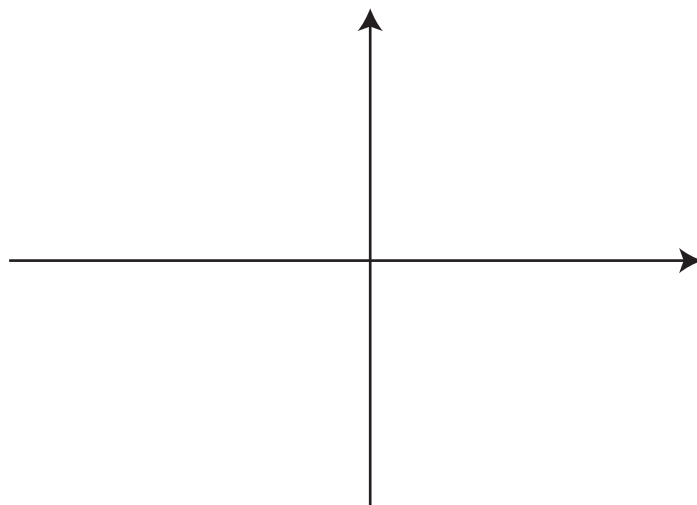
3 marks

Let $g_3 : R \rightarrow R$, where $g_3(x) = 3 \times 2^{(2x+1)} - 1$.

- c. i. Show that $g_3^{-1}(x) = \frac{1}{2} \log_2\left(\frac{x+1}{6}\right)$.

- ii. State the transformations that have occurred to the graph of $y = \log_2(x)$ to get the graph of g_3^{-1} .

- iii. Sketch the graph of g_3^{-1} on the set of axes below, labelling any asymptotes with their equations and intercepts with their coordinates.



- iv. Find the area, in units² correct to one decimal place, bounded by the x -axis and the graphs of $|g_3^{-1}|$ and g_3 .

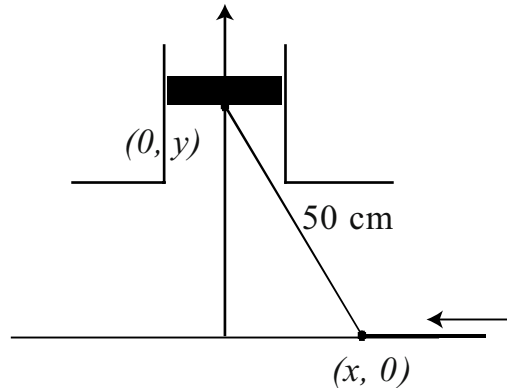
$2 + 2 + 2 + 2 = 8$ marks

Total 13 marks

Question 4

A machine uses a 50 cm long moveable rod to move a piston on a vertical shaft. The coordinates of the ends of the rod are $(x, 0)$ and $(0, y)$, as shown in the diagram.

The position, x cm, of the end of the rod on the x -axis, at time t seconds, is given by $x(t) = 30 \cos\left(\frac{\pi}{8}t\right)$, $t \geq 0$.



- a. Show that the distance y cm in terms of x is given by $y = \sqrt{2500 - x^2}$.

1 mark

- b. Consider y in terms of t .

- i. Show that a rule for $y(t)$, the distance y cm at time t s, is $y(t) = \sqrt{2500 - 900 \cos^2\left(\frac{\pi}{8}t\right)}$

- ii. Hence find the average value of y in the first 8 seconds of the motion of the rod. (Answer correct to three decimal places.)

1 + 2 = 3 marks

- c. The piston is at its highest position on the y -axis when $x = 0$. The piston is at its lowest position on the y -axis when $x = 30$ or $x = -30$. Find the distance y cm, from the origin to the highest and lowest positions of the end of the rod on the y -axis.

2 marks

- d. For $t \in [0, 16]$, solve the equations $x(t) = 15$ and $x(t) = -15$. Hence find, in the first 16 seconds of the motion of the rod, the total length of time for which $-15 \leq x \leq 15$.

2 marks

- e. Show that the speed of the end of the rod on the **x -axis**, when the x -axis endpoint is $(15, 0)$, is

$$\frac{15\sqrt{3}\pi}{8} \text{ cm/s.}$$

2 marks

- f. Find the **exact** maximum speed of the end of the rod on the **x -axis**.

3 marks

Total 13 marks

MATHEMATICAL METHODS AND MATHEMATICAL METHODS (CAS)

Written examinations 1 and 2

FORMULA SHEET

Directions to students

Detach this formula sheet during reading time.

This formula sheet is provided for your reference.

Mathematical Methods and Mathematical Methods CAS

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

$$\frac{d}{dx}(x^n) = nx^{n-1} \qquad \int x^n dx = \frac{1}{n+1} x^{n+1} + c, n \neq -1$$

$$\frac{d}{dx}(e^{ax}) = ae^{ax} \qquad \int e^{ax} dx = \frac{1}{a} e^{ax} + c$$

$$\frac{d}{dx}(\log_e(x)) = \frac{1}{x} \qquad \int \frac{1}{x} dx = \log_e |x| + c$$

$$\frac{d}{dx}(\sin(ax)) = a \cos(ax) \qquad \int \sin(ax) dx = -\frac{1}{a} \cos(ax) + c$$

$$\frac{d}{dx}(\cos(ax)) = -a \sin(ax) \qquad \int \cos(ax) dx = \frac{1}{a} \sin(ax) + c$$

$$\frac{d}{dx}(\tan(ax)) = \frac{a}{\cos^2(ax)} = a \sec^2(ax)$$

$$\text{product rule: } \frac{d}{dx}(uv) = u \frac{dv}{dx} + v \frac{du}{dx} \qquad \text{quotient rule: } \frac{d}{dx}\left(\frac{u}{v}\right) = \frac{v \frac{du}{dx} - u \frac{dv}{dx}}{v^2}$$

$$\text{chain rule: } \frac{dy}{dx} = \frac{dy}{du} \frac{du}{dx} \qquad \text{approximation: } f(x+h) \approx f(x) + hf'(x)$$

Probability

$$\Pr(A) = 1 - \Pr(A')$$

$$\Pr(A \cup B) = \Pr(A) + \Pr(B) - \Pr(A \cap B)$$

$$\Pr(A|B) = \frac{\Pr(A \cap B)}{\Pr(B)}$$

$$\text{mean: } \mu = E(X)$$

$$\text{variance: } \text{var}(X) = \sigma^2 = E((X - \mu)^2) = E(X^2) - \mu^2$$

probability distribution		mean	variance
discrete	$\Pr(X = x) = p(x)$	$\mu = \sum x p(x)$	$\sigma^2 = \sum (x - \mu)^2 p(x)$
continuous	$\Pr(a < X < b) = \int_a^b f(x) dx$	$\mu = \int_{-\infty}^{\infty} x f(x) dx$	$\sigma^2 = \int_{-\infty}^{\infty} (x - \mu)^2 f(x) dx$

END OF FORMULA SHEET

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