

External Assessment 2023

MATHEMATICS METHODS

MTM415117

Section **A**

Pages: 32

Questions: 19

Information Sheet: 1

Preparation time for this exam: 15 minutes

Suggested working time: 80 minutes

Instructions:

Calculators are not allowed to be used in this section.

Section A will be collected after 80 minutes.

- There are **five (5) parts** to this section.
- Answer **all** questions and **all** items within each question.
- Write your answers in the spaces provided in this exam paper.
 - Spare diagrams have been provided at the end of Part 1. Indicate in the box provided if you have used the spare diagrams.
- The exam is **three (3) hours** in length. It is suggested that you spend **approximately 80 minutes** in total answering the questions in this exam booklet.
- During the first 80 minutes you may move onto Section B, but you **cannot** use your calculator until told by your supervisor(s).
- The Mathematics Methods Information Sheet can be used throughout the exam.
- All answers must be written in **English**.
- You **must** make sure your answers address the listed criteria.

Marker use	
C4	/ 16
C5	/ 16
C6	/ 16
C7	/ 16
C8	/ 16

Additional Exam Instructions

For questions worth **one (1)** mark, you are not required to show workings. Markers will look at the presentation of the answer(s) and at the argument(s) leading to the final answer(s).

For questions worth **two (2)** or more marks **you are required** to show relevant workings.

Marks will be allocated:

- according to the degree to which workings convey a logical line of reasoning, and
- for suitable justifications and explanations of methods and processes when requested.

Criteria

You **must** make sure your answers address:

- Criterion 4 understand polynomial, hyperbolic, exponential and logarithmic functions
- Criterion 5 understand circular functions
- Criterion 6 use differential calculus in the study of functions
- Criterion 7 use integral calculus in the study of functions
- Criterion 8 understand binomial and normal probability distributions and statistical inference.

Guide to Exam Structure

		Parts	Questions available	Questions to answer	Suggested working time	Marks available
Section A	Part 1		3	3	16 minutes	16 marks
	Part 2		4	4	16 minutes	16 marks
	Part 3		4	4	16 minutes	16 marks
	Part 4		4	4	16 minutes	16 marks
	Part 5		4	4	16 minutes	16 marks
Totals			19	19	80 minutes	80 marks
Section B	Part 1		5	5	20 minutes	20 marks
	Part 2		3	3	20 minutes	20 marks
	Part 3		4	4	20 minutes	20 marks
	Part 4		4	4	20 minutes	20 marks
	Part 5		4	4	20 minutes	20 marks
Totals			20	20	100 minutes	100 marks
Totals			39	39	180 minutes (3 hours)	180 marks

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Part 1

Marker use

- Answer **all** questions in this part.
- This part assesses **Criterion 4**.

Question 1

Expand $(2x + 3)^3 + (3x + 2)^3$

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Question 2

Marker use

Two (2) functions f and g are defined as the following:

$$f: (-2, \infty) \rightarrow \mathbb{R} \text{ where } f(x) = \ln(x + 2), \text{ and}$$

$$g: \mathbb{R} \rightarrow \mathbb{R} \text{ where } g(x) = -x$$

The graph of f is displayed in Figure 1 below:

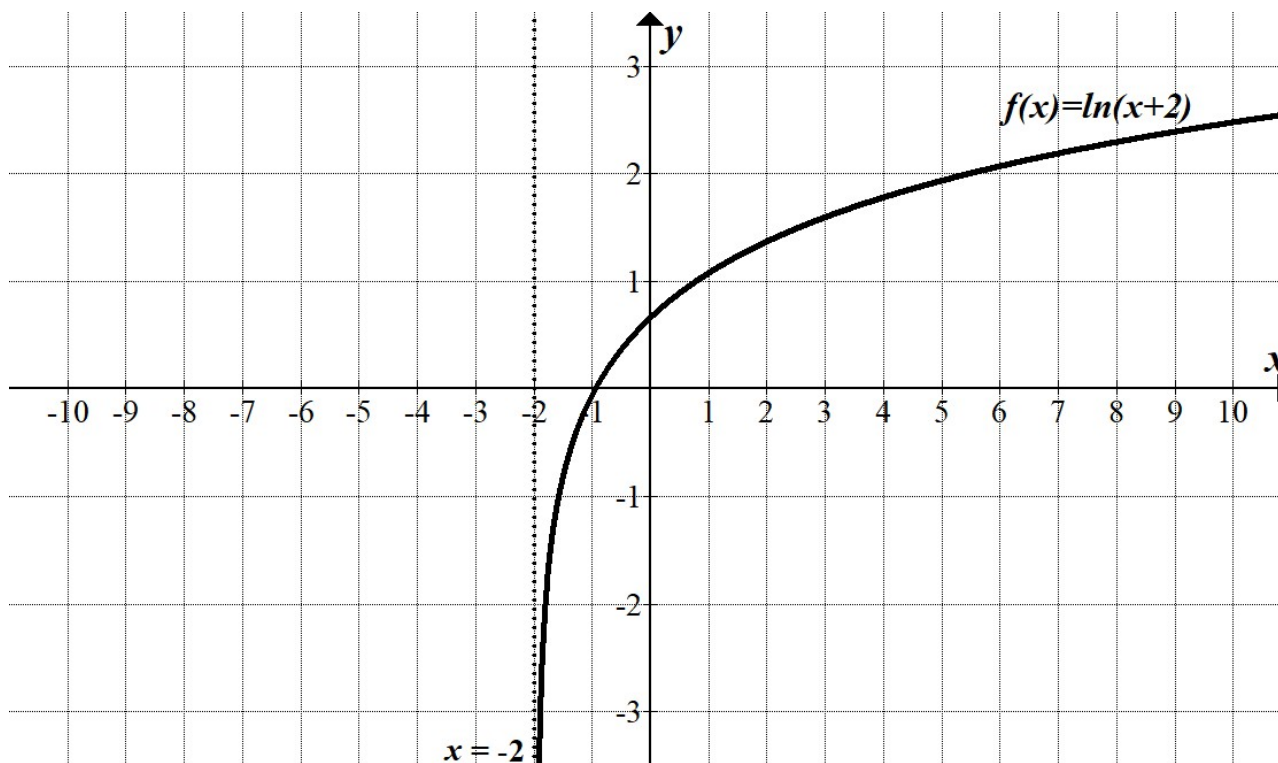


Figure 1: Graph of function to refer to when answering Question 2.

Spare diagram used (X)

a) Determine $f(g(x))$

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b) Will $f(g(1))$ be defined?

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Question 2 continues

Question 2 continued

Marker use

c) Sketch $f(g(x))$ on the same axes as in Figure 1.

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d) What values of x will need to be **excluded** so that $f(g(x))$ is a function?

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Exam continues over the page

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Question 3

a) Determine the graph of the function graphed in Figure 2 in the form

$$f(x) = \frac{a}{x - h} + k, \quad x \neq -2$$

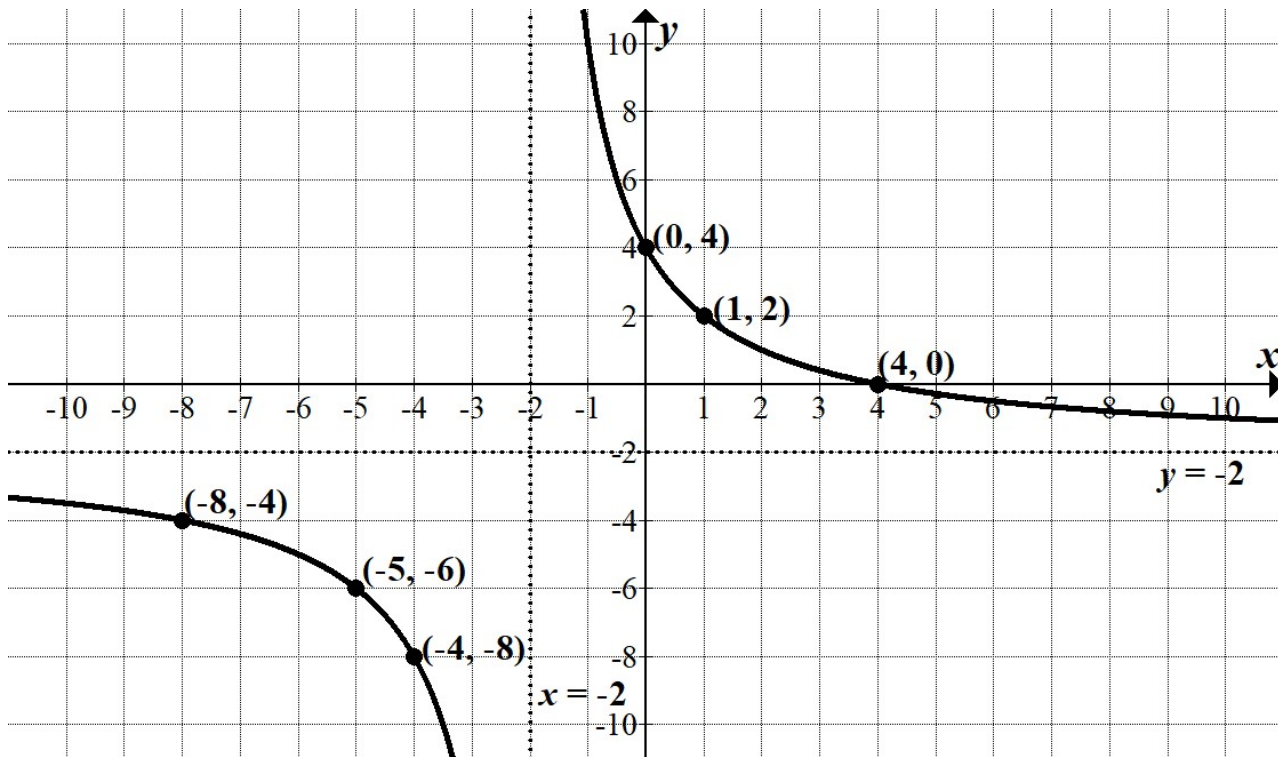


Figure 2: Graph of the function to refer to when answering Question 3 a).

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Question 3 continued

Figure 3 relates to items b), c) and d).

We want to model parts of this hyperbola with square root functions.

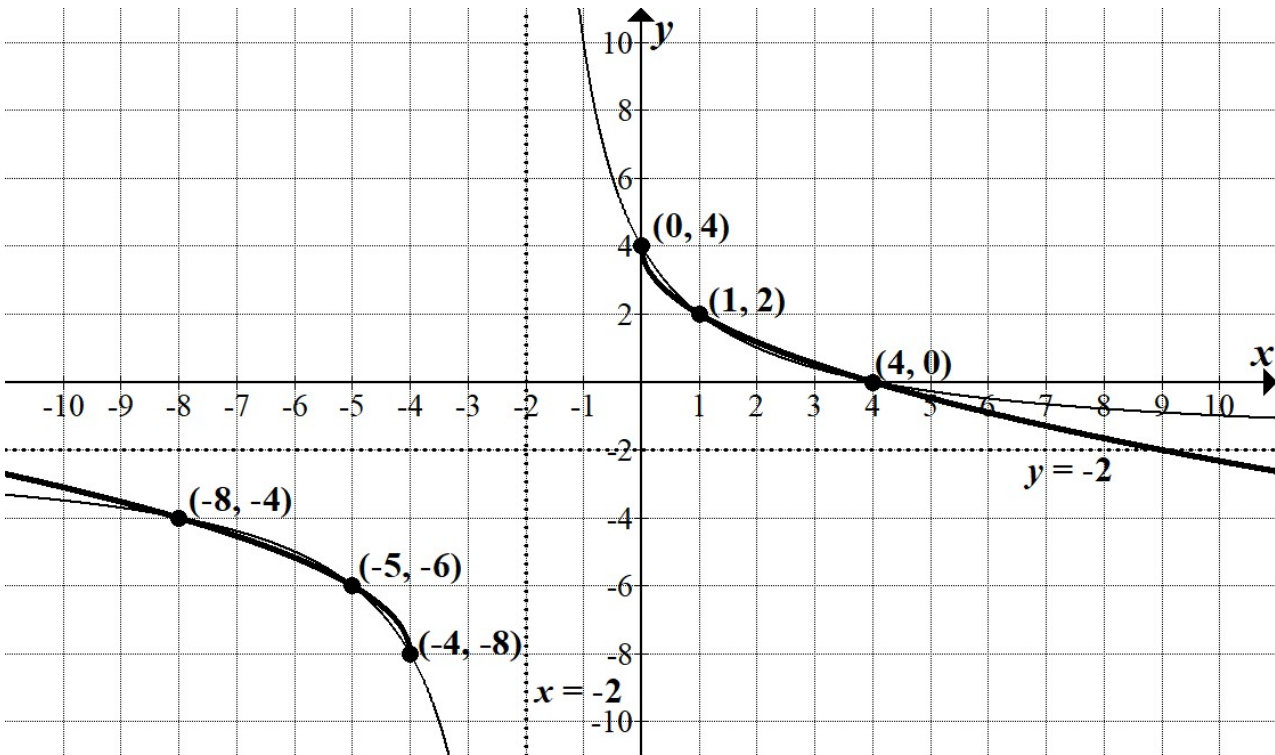


Figure 3: Graph of functions to refer to when answering Question 3 b) – d).

- b) Determine the function in the form $g(x) = a\sqrt{x} + c$ with domain $[0, \infty)$ that also passes through the points $(0, 4)$, $(1, 2)$ and $(4, 0)$.

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- c) Describe the transformations to $g(x)$ to make the function $h(x)$ that has a domain of $(-\infty, -4]$ and passes through $(-4, -8)$, $(-5, -6)$ and $(-8, -4)$.

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Question 3 continues

Question 3 continued

Marker use

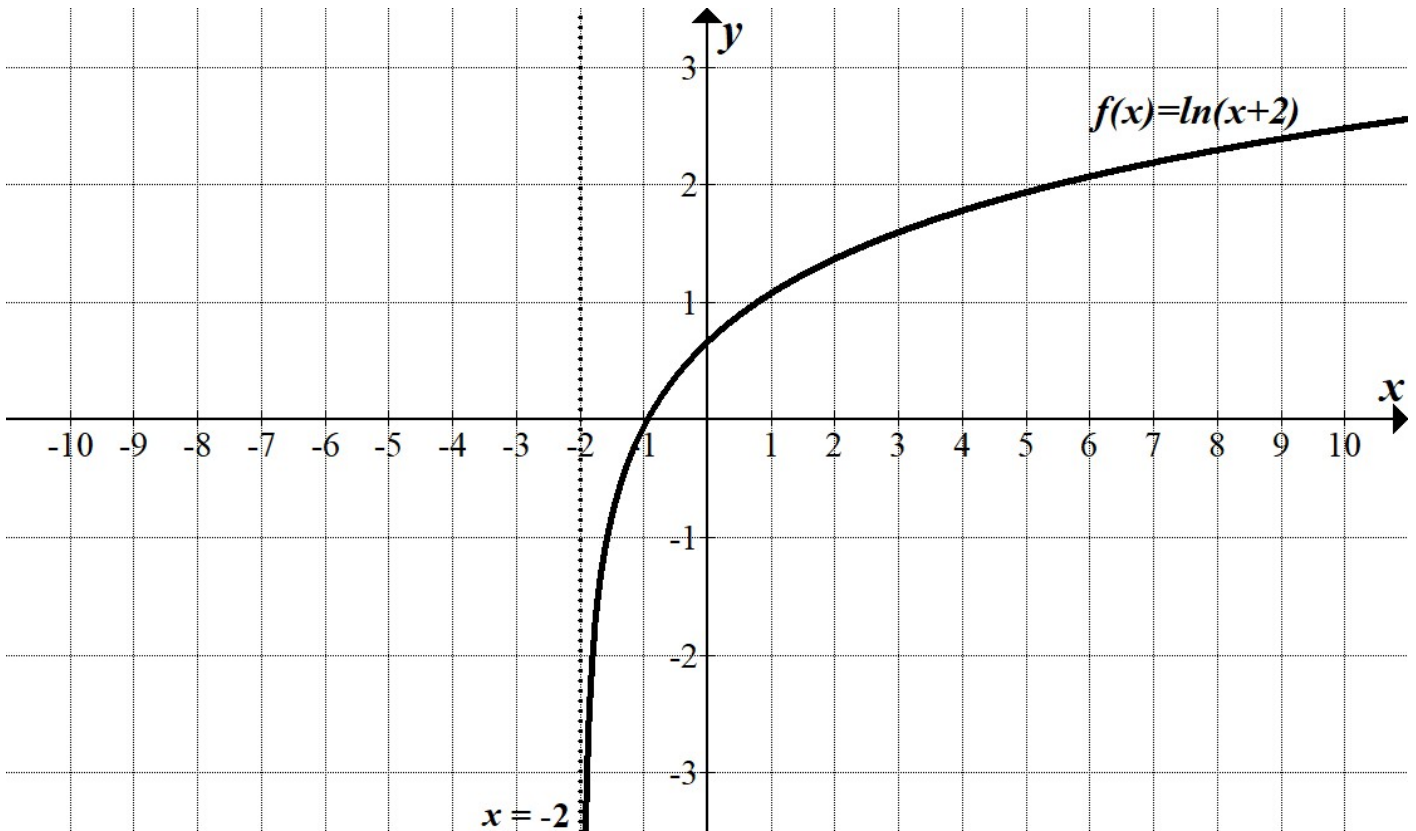
d) Give an expression for $h(x)$

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Total
C4
/16

Spare Diagrams

Question 2 c)



Part 2

- Answer **all** questions in this part.
- This part assesses **Criterion 5**.

Question 4

Convert $\frac{7\pi}{6}$ radians into degrees.

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Question 5

Simplify the following expressions:

a) $\cos\left(\frac{5\pi}{6}\right)$

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b) $\sin\left(\frac{3\pi}{2} + \frac{\pi}{6}\right)$

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Question 6

Marker use

Figure 4 is the graph of a function in the form $y = a \tan(n(x + b)) + c$

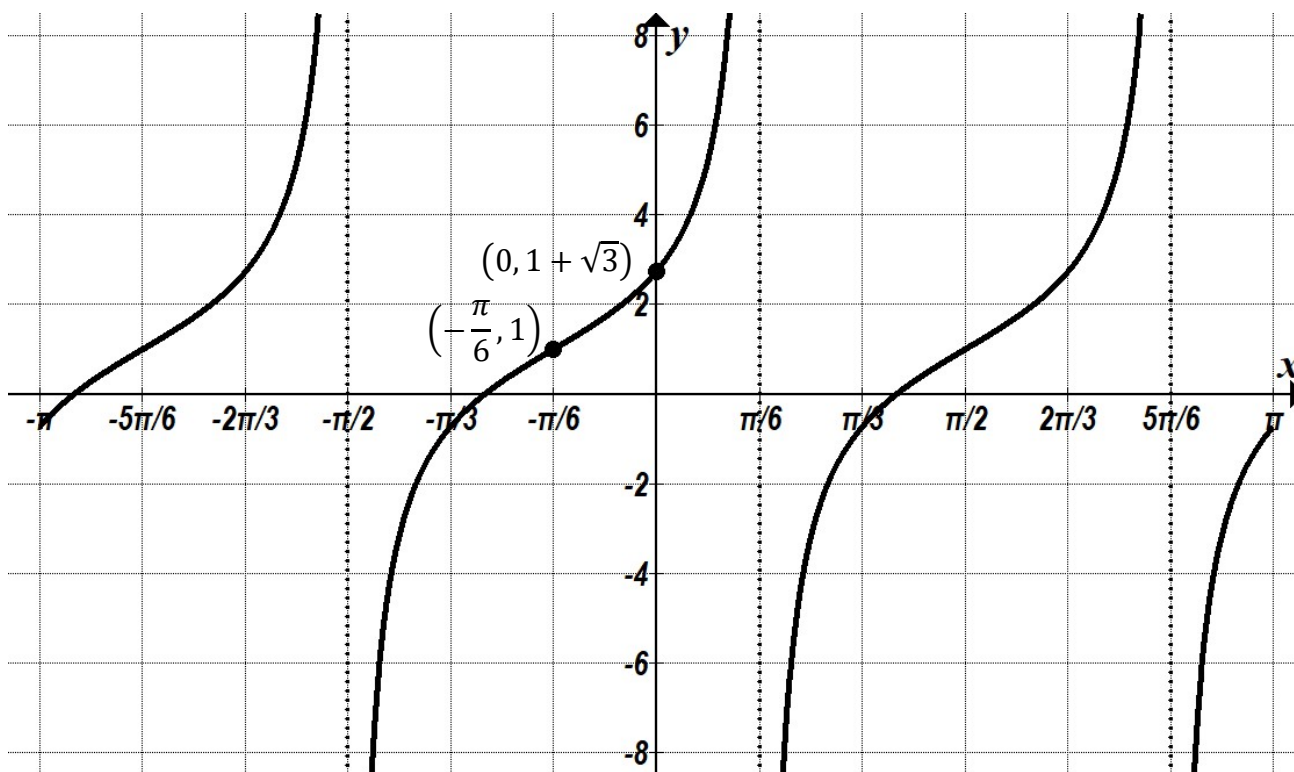


Figure 4: Graph of the function to refer to when answering Question 6.

a) Show that $n = \frac{3}{2}$

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b) Why is one possible value for the phase shift $\frac{\pi}{2}$ radians right?

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c) Hence complete the equation of the graph.

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Question 7

Marker use

Solve $2 \cos\left(x - \frac{\pi}{3}\right) = -\sqrt{3}$ for $x \in [-2\pi, 2\pi]$

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Part 3

- Answer **all** questions in this part.
- This part assesses **Criterion 6**.

Question 8

a) Find the derivative of $f(x) = (3x^2 - 2)(4x + 1)$ by expanding the brackets first.

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b) Show how the same answer can be obtained using the product rule for derivatives.

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Question 9

Marker use

Differentiate (no simplification required):

a)

$$y = \ln(4x + 1) + \sin(3x^2)$$

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b)

$$f(x) = 5e^{3x^2+x} + \frac{x^2}{x+1}$$

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Question 10

Marker use

The graph of $g(x) = x^3 - 4x^2 + x + 6$ is shown in Figure 5.

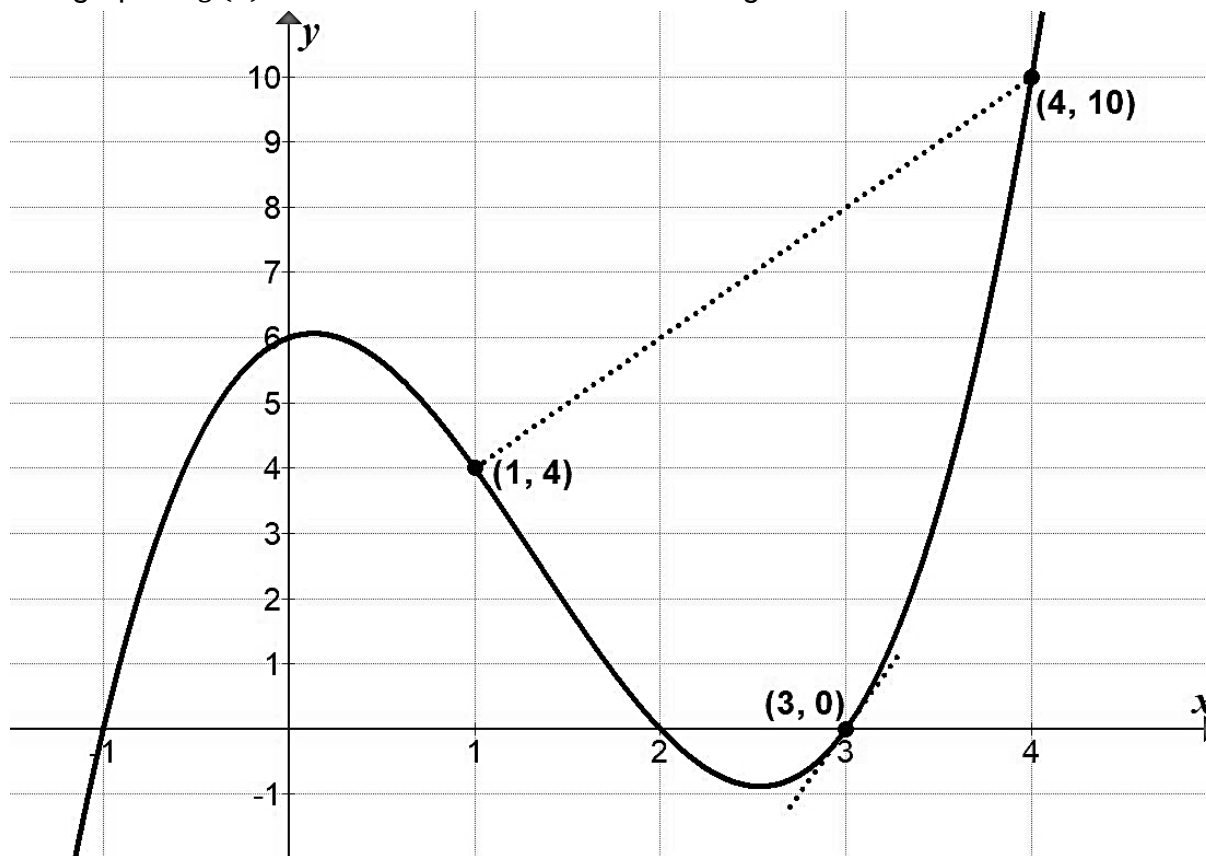


Figure 5: Graph of function to refer to when answering Question 10.

- a) Find the average rate of change of $g(x)$ from the point $(1, 4)$ to the point $(4, 10)$

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- b) Find the instantaneous rate of change for $g(x)$ at the point $x = 3$

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Question 11

Marker use

Find the derivative by first principles of $f(x) = \frac{x^3}{3}$

Recall that $(x + h)^3 = x^3 + 3x^2h + 3xh^2 + h^3$

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Total
C6
/ 16

Part 4

- Answer **all** questions in this part.
- This part assesses **Criterion 7**.

Question 12

Evaluate the following integrals:

a)

$$\int_1^4 \frac{x^2 + 1}{x} dx$$

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b)

$$\int -\cos\left(\frac{\pi}{3}x\right) dx$$

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c)

$$\int_{\frac{1}{2}}^1 e^{2x-1} dx$$

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Question 13

Marker use

Given that $\int_a^b f(x)dx = 5$ and $\int_b^a g(x)dx = 8$, find the value of k that solves the equation:

$$\int_a^b (3f(x) + kg(x))dx = -17$$

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Question 14

The two (2) functions

$$f(x) = -x^3 + x, \quad \text{for } -1 \leq x \leq 1 \text{ and}$$

$$g(x) = -x^2 + 2x, \quad \text{for } 0 \leq x \leq 2$$

are sketched in Figure 6 below:

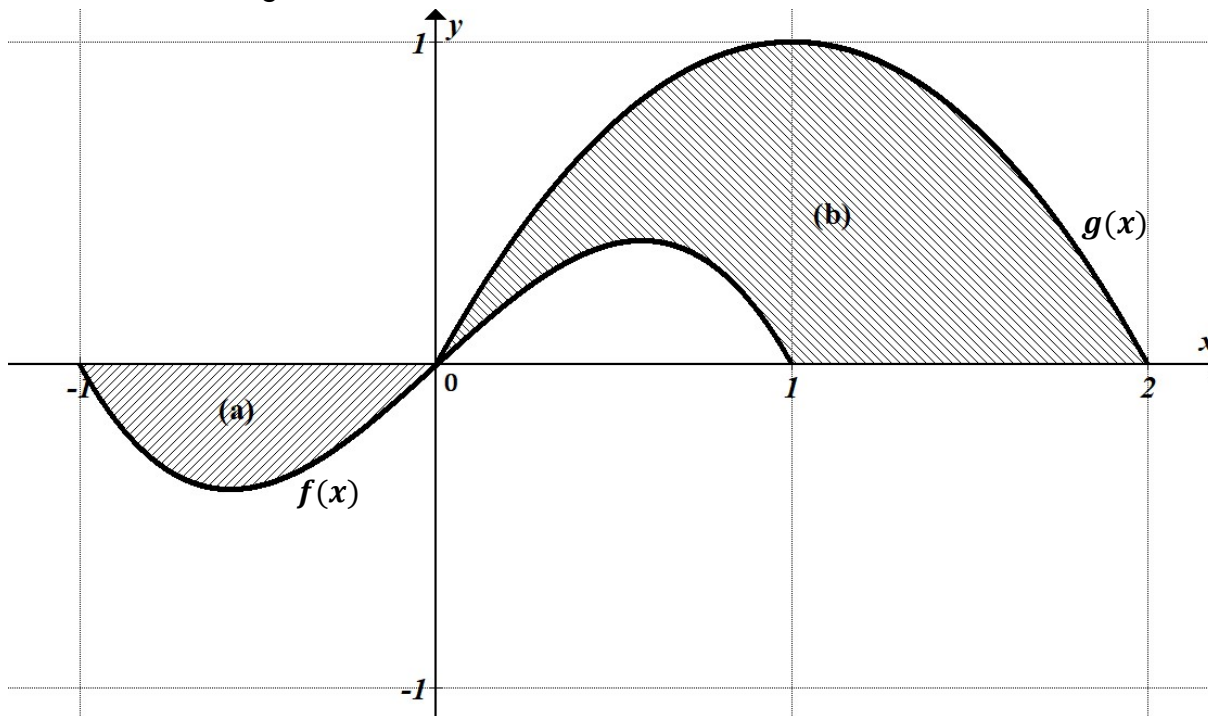


Figure 6: Graph of functions to refer to when answering Question 14.

a) Find the shaded area (a) in Figure 6.

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b) Hence or otherwise, find the shaded area (b) in Figure 6.

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Question 15

Marker use

A student has been learning how to find the area under a curve using integration and wants to test their skills by finding the area of a triangle. They draw the following diagram:

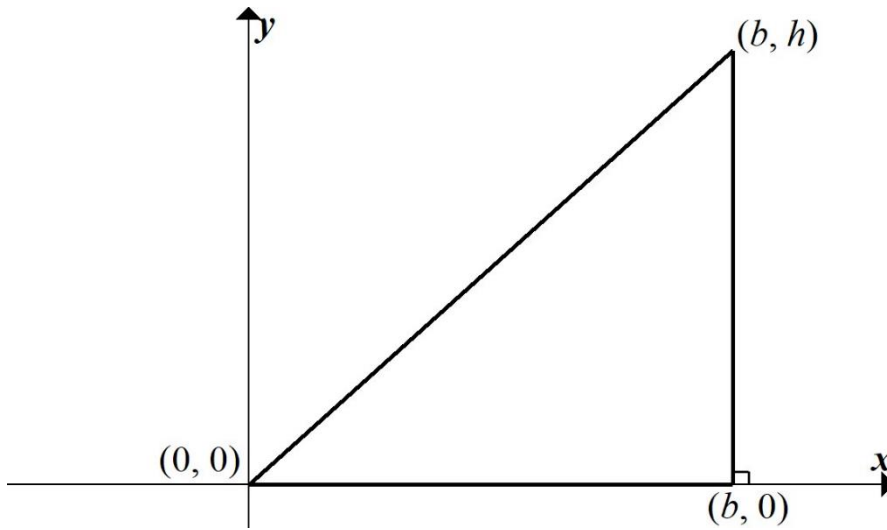


Figure 7: Diagram of a triangle.

- a) Find the equation of the line forming the hypotenuse of the triangle.

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- b) Using integration and the formulae from a), show that the area of the triangle is

$$A = \frac{1}{2}bh$$

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Total
C7
/16

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Part 5

- Answer **all** questions in this part.
- This part assesses **Criterion 8**.

Question 16

Frank has contracted a virus. A home test is found to give a positive result 60% of the time if the person has the virus.

Frank believes that if he takes two (2) tests then the likelihood at least one (1) will give a positive result is 84%.

a) Explain why it is appropriate to use the binomial distribution in this case.

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b) Show that Frank's calculations are correct.

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Question 17

Marker use

A discrete random variable X has the following distribution table:

x	-2	-1	0	1	2
$P(X = x)$	0.1	0.2	0.4	0.2	0.1

Table 1

a) Find $E(X)$, the expected value of X .

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b) Show that $var(X)$, the variance of X , is equal to 1.2.

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c) Given that $sd(X) = 1.095$, what proportion of the distribution is within 2 standard deviations of the mean?

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Question 17 continues

Question 17 continued

Marker use

d) The distribution Y is similar to the distribution of X , where each x value is increased by 100, so we have

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y	98	99	100	101	102
$P(Y = y)$	0.1	0.2	0.4	0.2	0.1

Table 2

What is the mean and variance for this new distribution Y ?

Mean:

Variance:

Question 18

A newspaper reporter surveys ten (10) people on the street and finds that six (6) people prefer product A instead of product B.

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The newspaper editor says this not large enough of a sample, as this gives a 95% confidence interval of

$$(0.6 - 0.304, 0.6 + 0.304) = (29.6\%, 90.4\%).$$

She tells the reporter to survey 1000 people instead, a 100-times increase.

Assuming the larger survey still finds that 60% of people prefer product A, what will the 95% confidence interval be now?

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Question 19

Marker use

Below is a graph of the normal distribution for X , $\mu = 0, \sigma = 1$ with the top 30% shaded.

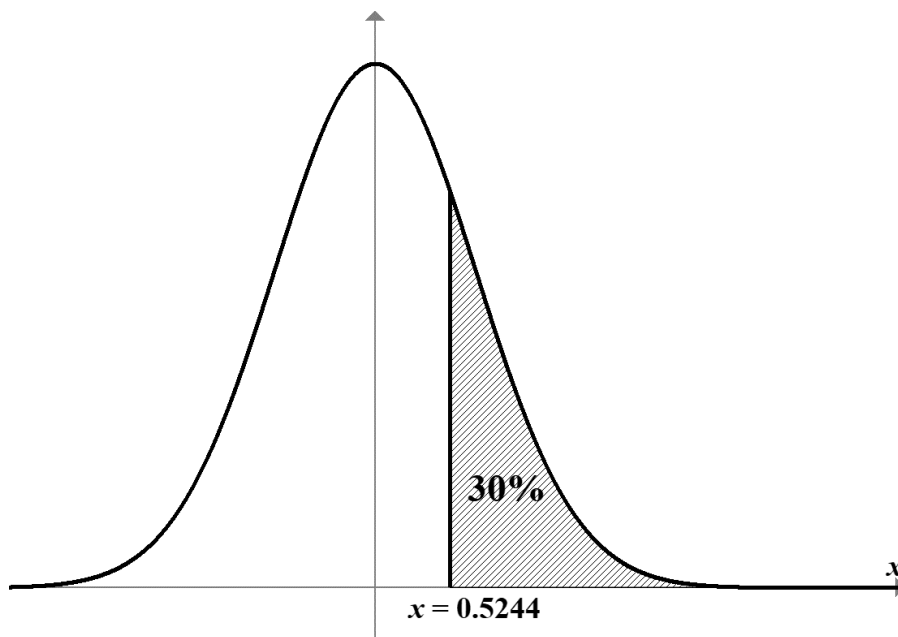


Figure 8: Graph of normal distribution for X , $\mu = 0, \sigma = 1$.

Thus we have $P(X \geq 0.5244) = 30\%$.

a) Write a probability expression that is equal to 20%

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b) Write a probability expression that is equal to 40%

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C8
/16

End of Section A
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& CERTIFICATION

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External Assessment 2023

MATHEMATICS METHODS

MTM415117

Section **B**

Pages: 36

Questions: 20

Information Sheet: 1

Suggested working time: 100 minutes

Instructions:

Calculators are allowed to be used in this section.

- There are **five (5) parts** to this section.
- Answer **all** questions and **all** items within each question.
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 - Spare diagrams have been provided at the end of Parts 3, 4 and 5. Indicate in the box provided if you have used the spare diagrams.
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Marker use	
C4	/20
C5	/20
C6	/20
C7	/20
C8	/20

Additional Exam Instructions

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Totals			19	19	80 minutes	80 marks
Section B	Part 1		5	5	20 minutes	20 marks
	Part 2		3	3	20 minutes	20 marks
	Part 3		4	4	20 minutes	20 marks
	Part 4		4	4	20 minutes	20 marks
	Part 5		4	4	20 minutes	20 marks
Totals			20	20	100 minutes	100 marks
Totals			39	39	180 minutes (3 hours)	180 marks

Part 1

- Answer **all** questions in this part.
- This part assesses **Criterion 4**.

Question 20

Sketch the graph of the following function, including all intercepts and asymptotes.

$$f(x) = \frac{1}{(x-2)^2} - 3$$

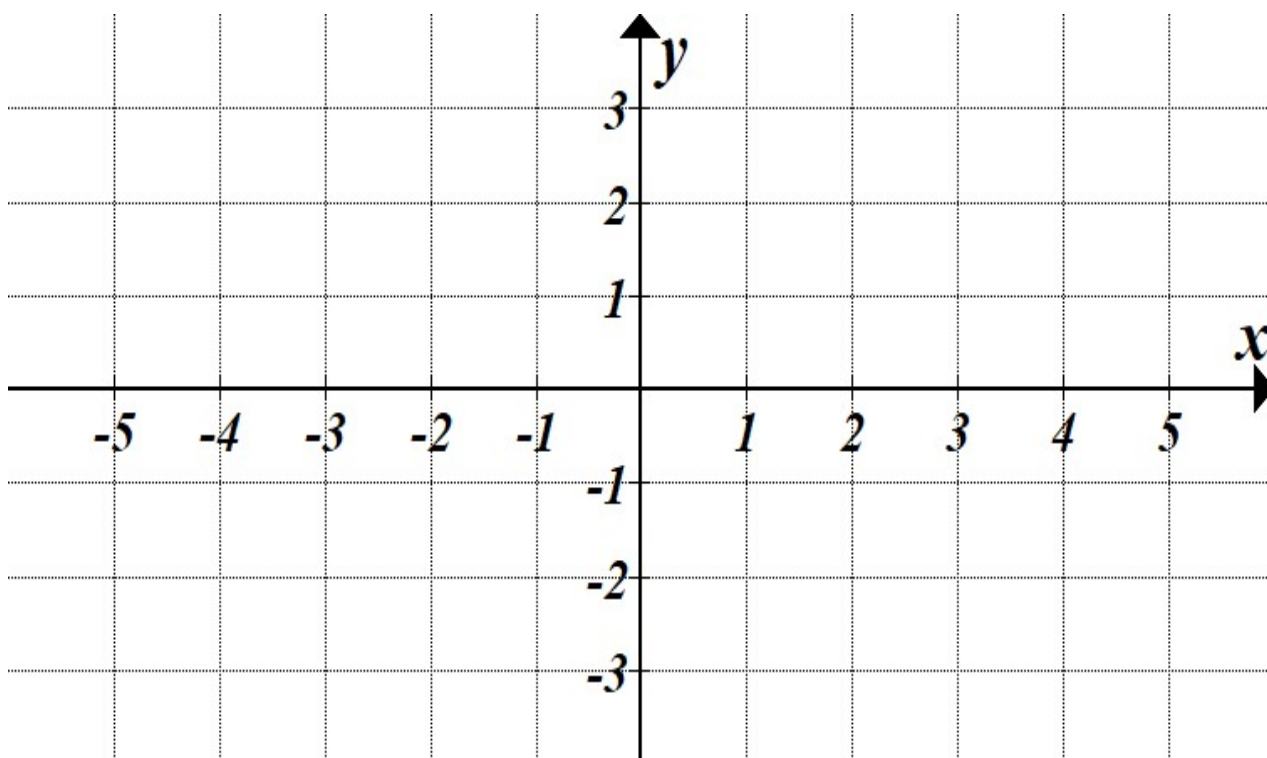


Figure 9: Graph for sketching answer to Question 20.

Spare diagram used (X)

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Question 21

Marker use

Find the equation of the following logarithmic function in the form $y = a \times \log_2(x - h) + k$

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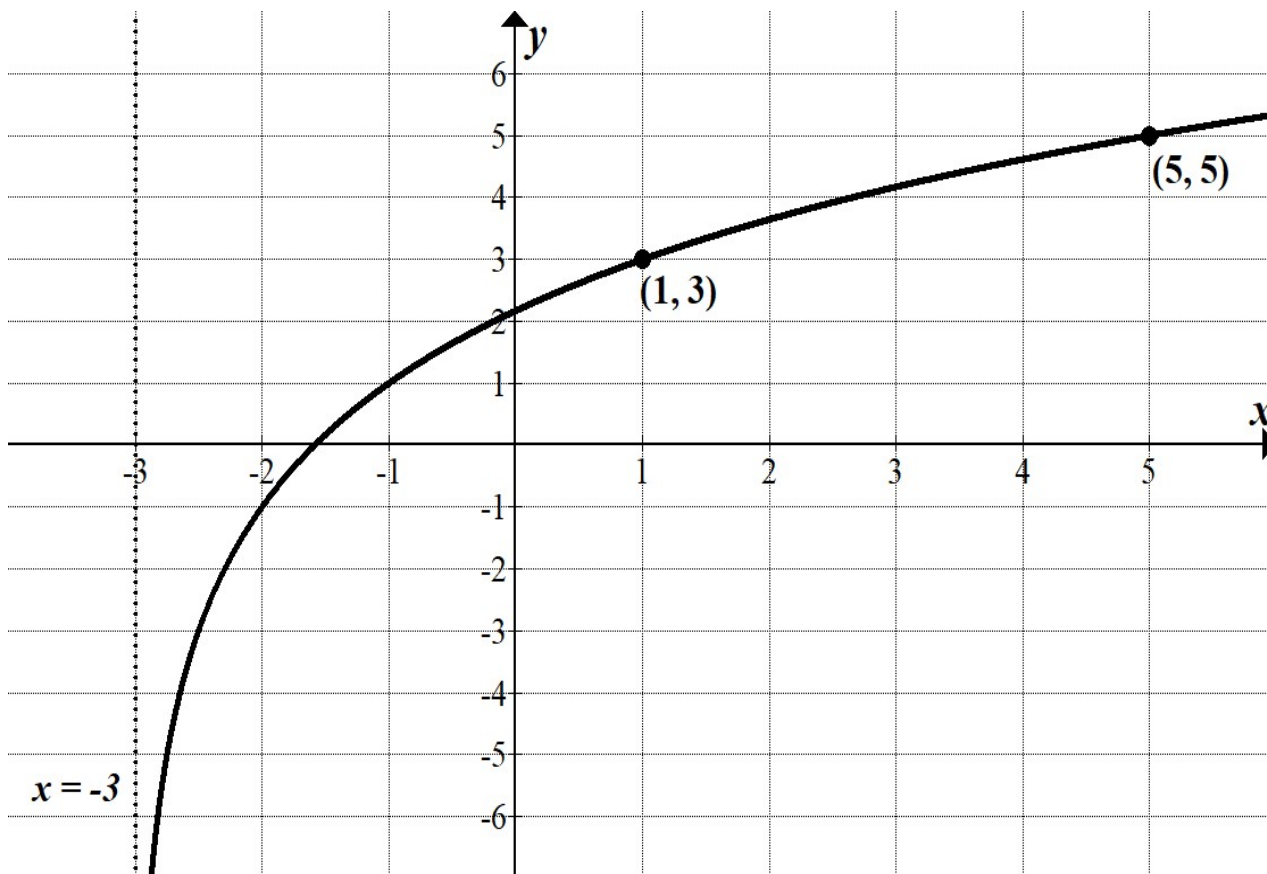


Figure 10: Graph for Question 21.

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Question 22

Marker use

For the equation

$$\log_2(x + 3) + \log_2(x + 4) = \log_2(6x + 18)$$

a student uses their calculator and finds the solution $x = 2$

a) Verify algebraically that $x = 2$ is a solution.

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b) Solve the equation algebraically. Explain why $x = 2$ is the only real solution.

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Question 23

Marker use

a) Determine the inverse of the function $f(x) = \sqrt{3x - 2} + 6$

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b) What will the domain and range of $f^{-1}(x)$ be?

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Question 24

Marker use

A skipping rope is being held by two (2) children 4 m apart at a height of 1 m. The rope just touches the ground in the centre. See Figure 11 below.

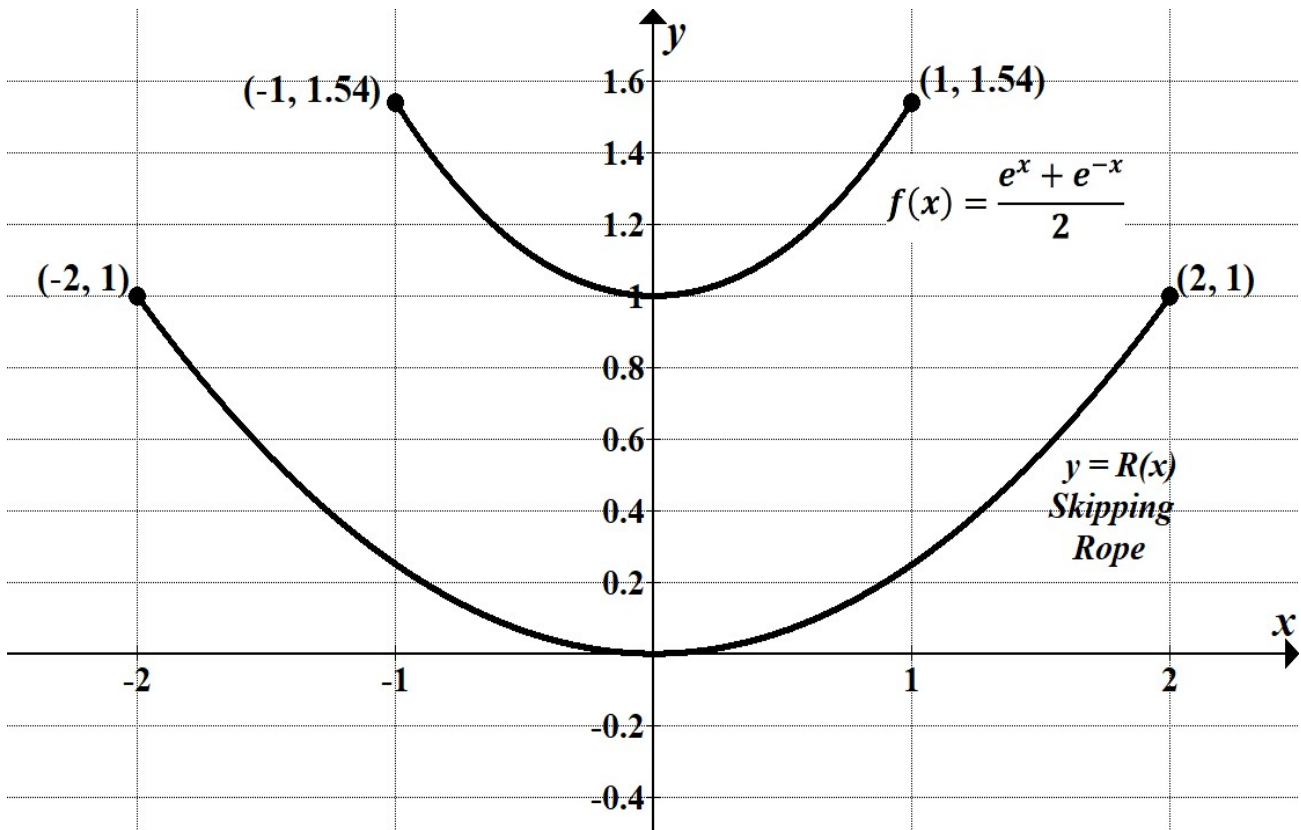


Figure 11: Graph of skipping rope scenario to refer to when answering Question 24.

a) This situation is best modelled by a curve in the form

$$f(x) = \frac{e^x + e^{-x}}{2}$$

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Show algebraically that $f(0) = 1$

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Question 24 continues

Question 24 continued

Marker use

- b) Using the fact that $f(1) = 1.54$ to 2 d.p. find an equation for $R(x)$
in terms of $y = f(x)$

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You do not need to simplify your answer.

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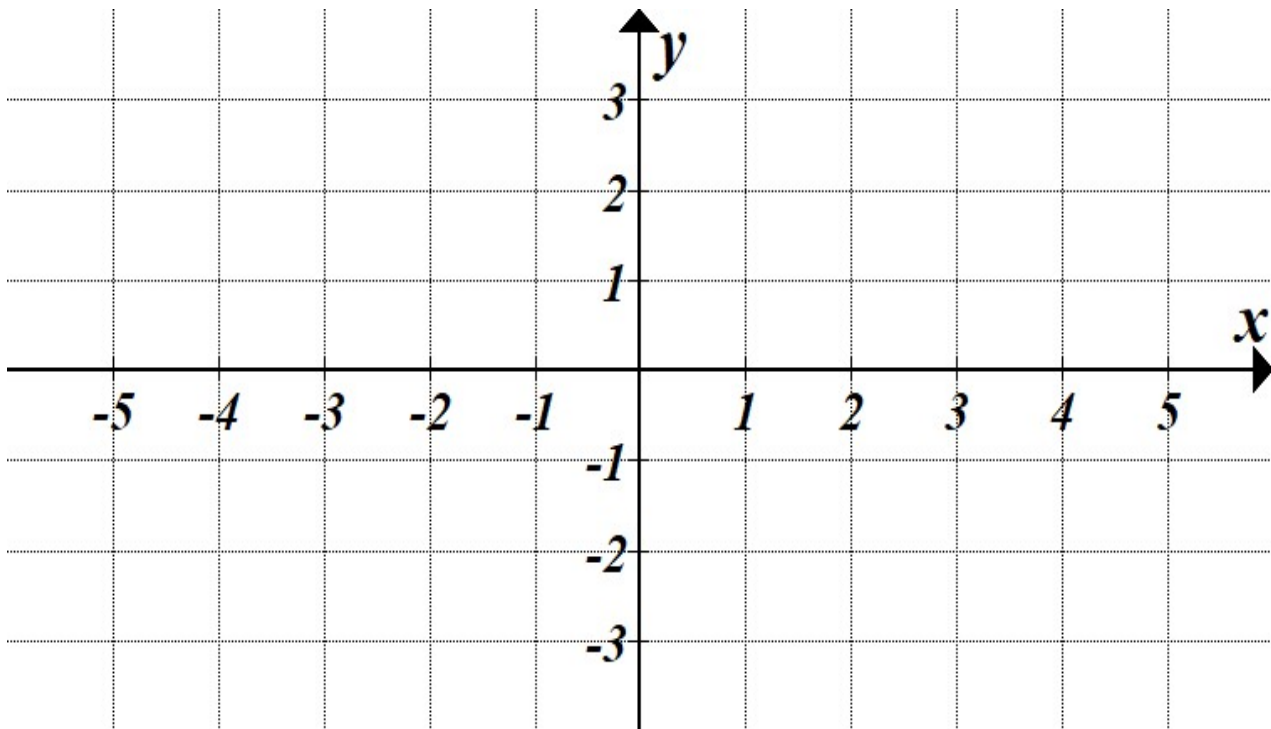
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Total
C4
/20

Spare Diagrams

Question 20



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Part 2

- Answer **all** questions in this part.
- This part assesses **Criterion 5**.

Question 25

Figure 12 shows two (2) points on a sine curve that extends along the domain $[0, 2\pi]$

- a) The two (2) points, $(\pi, 0)$ and $(\frac{3\pi}{2}, 8)$ are a minima and maxima next to each other on the curve.

Plot the remainder of the minima and maxima in Figure 12 for $x \in [0, 2\pi]$

- b) Complete the rest of the curve on Figure 12.

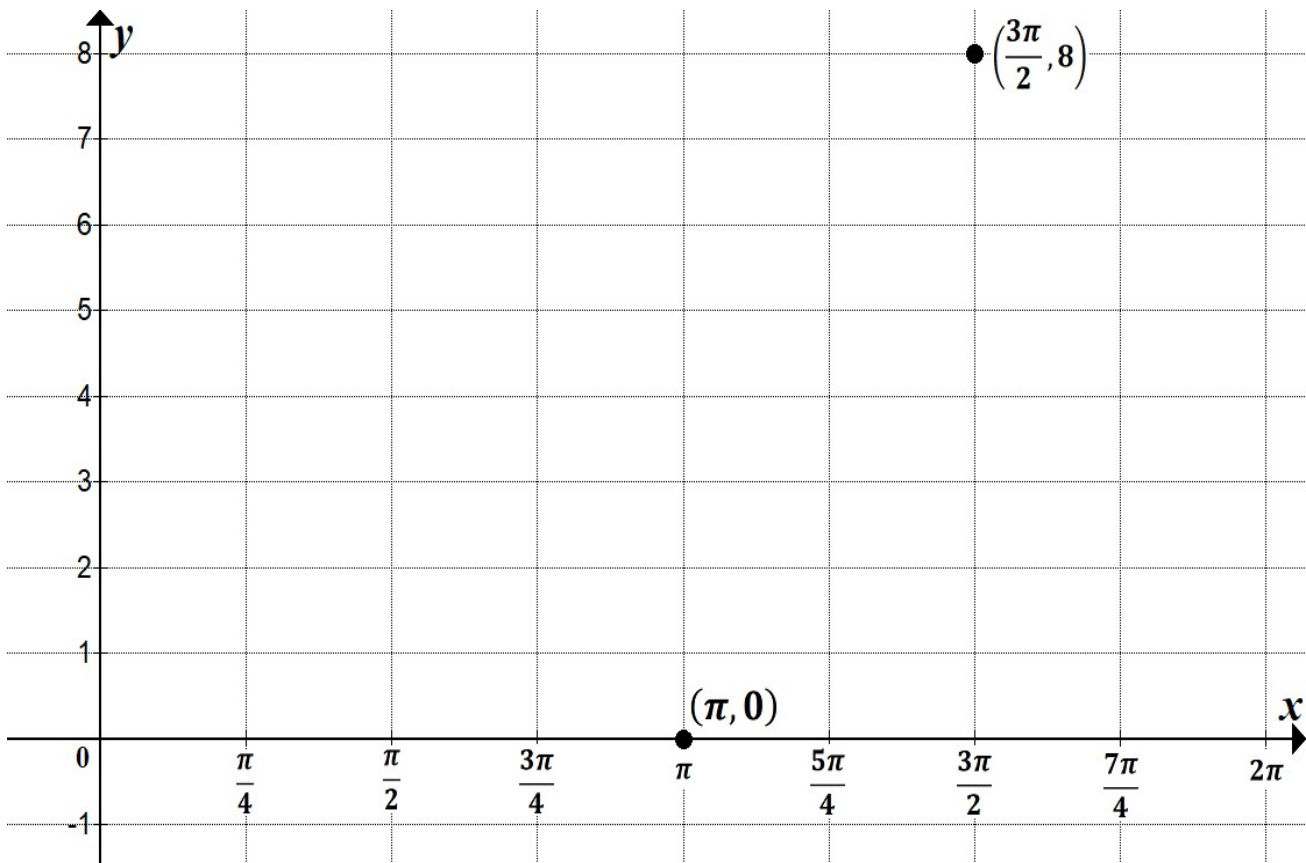


Figure 12: Graph for annotation to answer Question 25.

Spare diagram used (X)

Question 25 continues

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Question 25 continued

Marker use

c) What is the period of the graph?

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d) State an equation for the curve in the form $y = a(\sin(n(x + b))) + c$

Question 26

A flywheel of radius 1 m is spinning at the rate of one (1) revolution per minute anti-clockwise.

The coordinates (x, y) of point A on the wheel after t seconds are given by:

$$x = \cos\left(\frac{\pi t}{30}\right),$$

$$y = \sin\left(\frac{\pi t}{30}\right) \quad \text{for } t > 0.$$

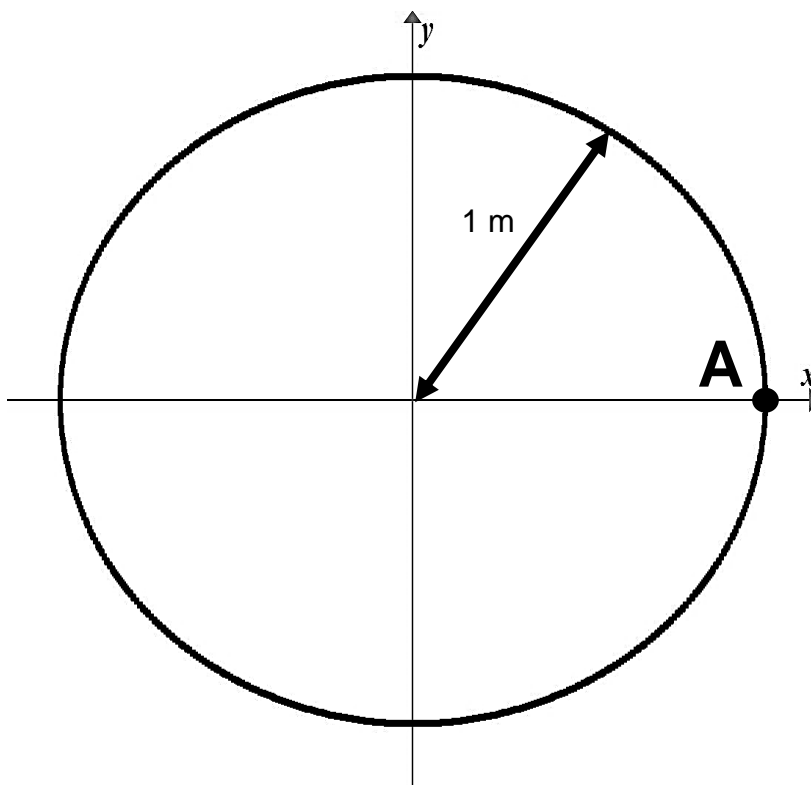


Figure 13: Diagram of a spinning flywheel, highlighting A.

a) In the first revolution when will point A be at the top of the wheel?

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b) Find the coordinates of point A after 5 seconds.

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Question 26 continues

Question 26 continued

Marker use

- c) The wheel is sped up so that it revolves twice (2 times) as fast.

Assuming A starts from the same position, what will be the new equations for the coordinates of the point A.

$x =$

$y =$

- d) Find the coordinates of point A after 100 seconds at the faster speed.

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Question 27

The cross-section of the hull of a boat can be modelled by the equation

$$y = -10 \sin\left(\frac{\pi}{10}(x + 5)\right) + k$$

where k can be varied by altering the amount of weight in the boat.

Pictured in Figure 14 is the case when $k = 3$

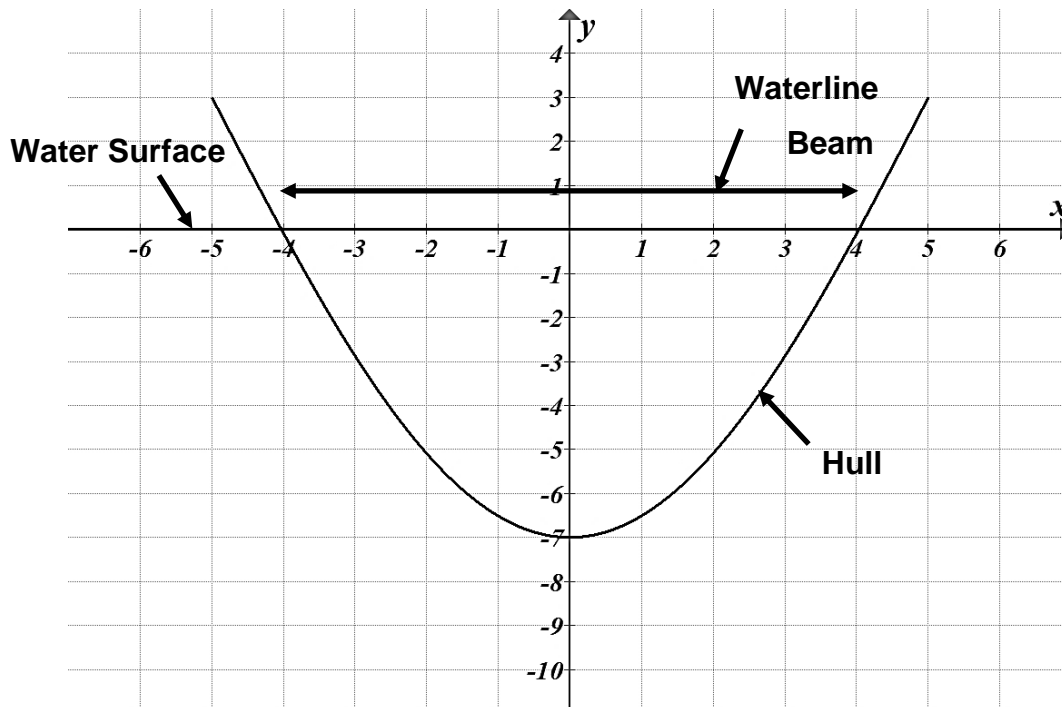


Figure 14: Graph of a boat's hull, highlighting the water surface and waterline beam.

The waterline beam is the distance between the two points where the hull touches the water surface.

When $k = 3$, the waterline beam is 8.06 m (2 d.p.).

- a) Show **algebraically** that when $k = 5$, the x -intercepts are $-\frac{10}{3}$ and $\frac{10}{3}$ m

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Question 27 continues

Question 27 continued

Marker use

b) Hence, what is the length of the waterline beam when $k = 5$?

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c) The boat would like to fit through a canal that is 6 m wide.

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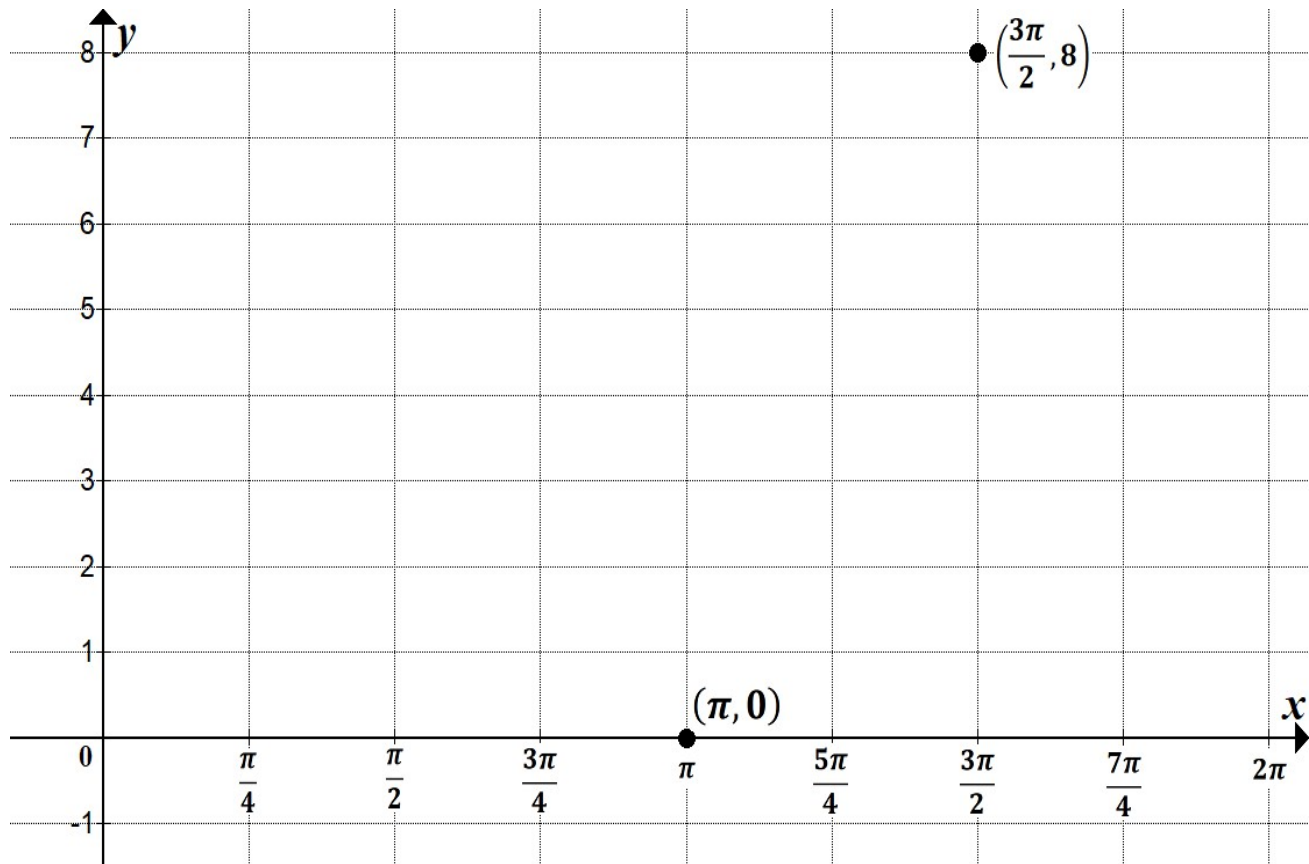
What is the least value of k that is required for the waterline beam to be at most 6 m?

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Total
C5
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Spare Diagrams

Question 25 a) and b)



Part 3

- Answer **all** questions in this part.
- This part assesses **Criterion 6**.

Question 28

Two (2) **positive** numbers, x and y are such that $xy = 16$

Find the minimum value of $x + y$

You are not required to justify the minimum value here.

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Question 29

Sketch **on the same set of axes** the derivative of the function $y = f(x)$ sketched in Figure 15 below, where the two pieces of the function are given by

$$y = -2x - 4, \quad \text{for } x \in (-4, -2),$$

$$y = -x^2 + 4, \quad \text{for } x \in [-2, 2].$$

Your derivative values should be exact.

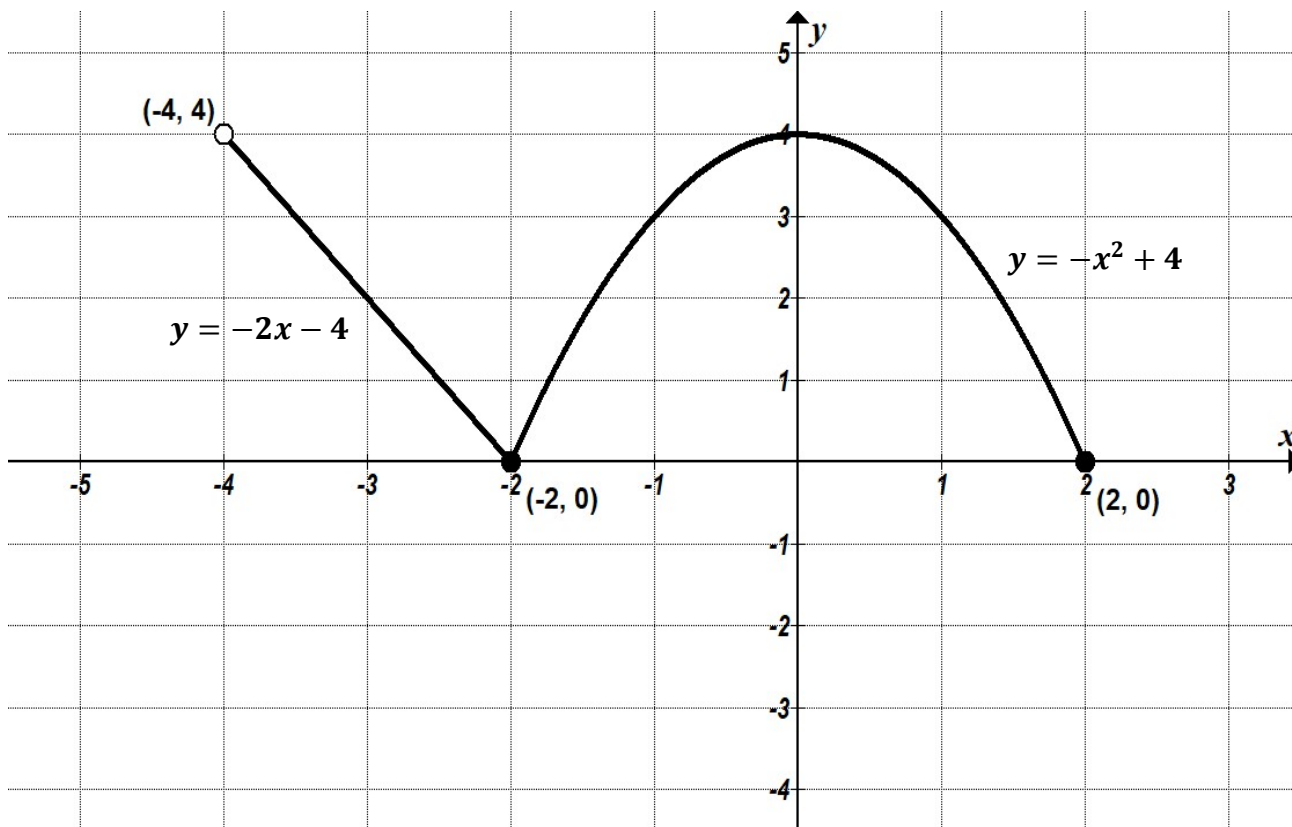


Figure 15: Graph for sketching answer to Question 29.

Spare diagram used (X)

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Question 30

Marker use

Given

$$f(x) = \ln(2x - 4) + 3 \text{ and}$$

$$g(x) = e^{2x-5} + 2$$

- a) Show that $f(x)$ and $g(x)$ have a point of intersection at $x = \frac{5}{2}$

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- b) Show that $f(x)$ and $g(x)$ have the same gradient at $x = \frac{5}{2}$

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- c) Give a reason why $f(x)$ and $g(x)$ have the same tangent at $x = \frac{5}{2}$

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Question 31 continued

Marker use

- c) Sketch a graph of the **derivative** function, $\frac{dT}{dh}$, for $h \in [-1, 11]$

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You only need to label the zeros here.

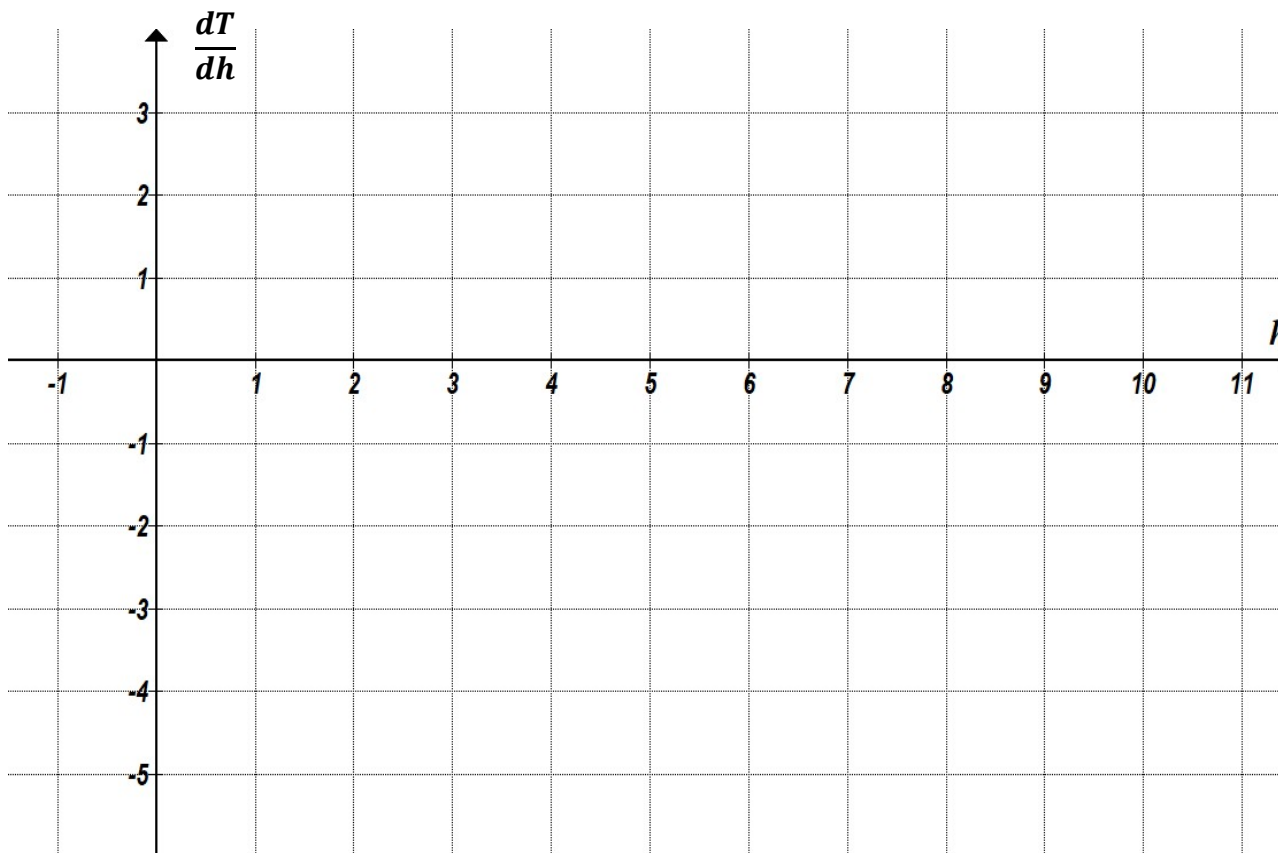


Figure 16: Graph for sketching answer to Question 31 c).

Spare diagram used (X)

- d) For which hours of the day is the air temperature increasing?

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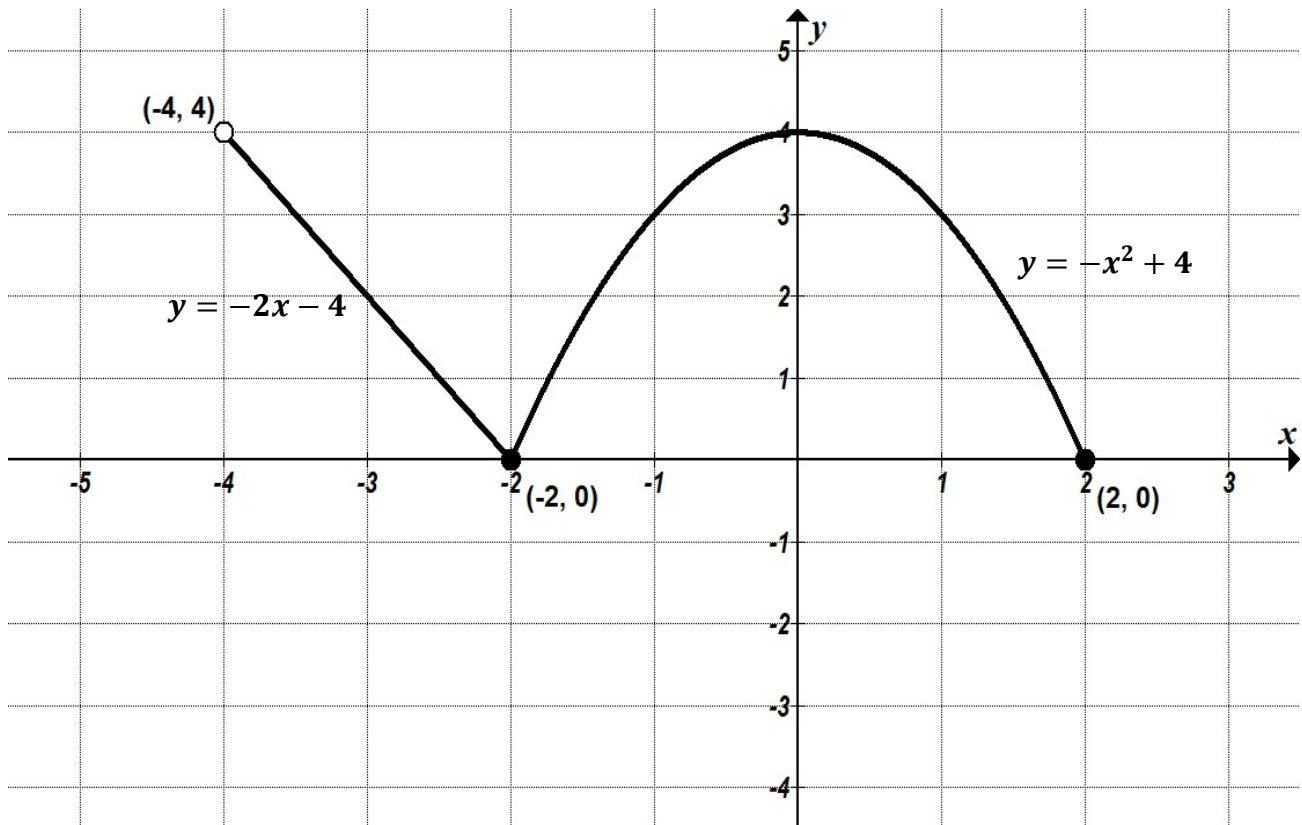
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Total
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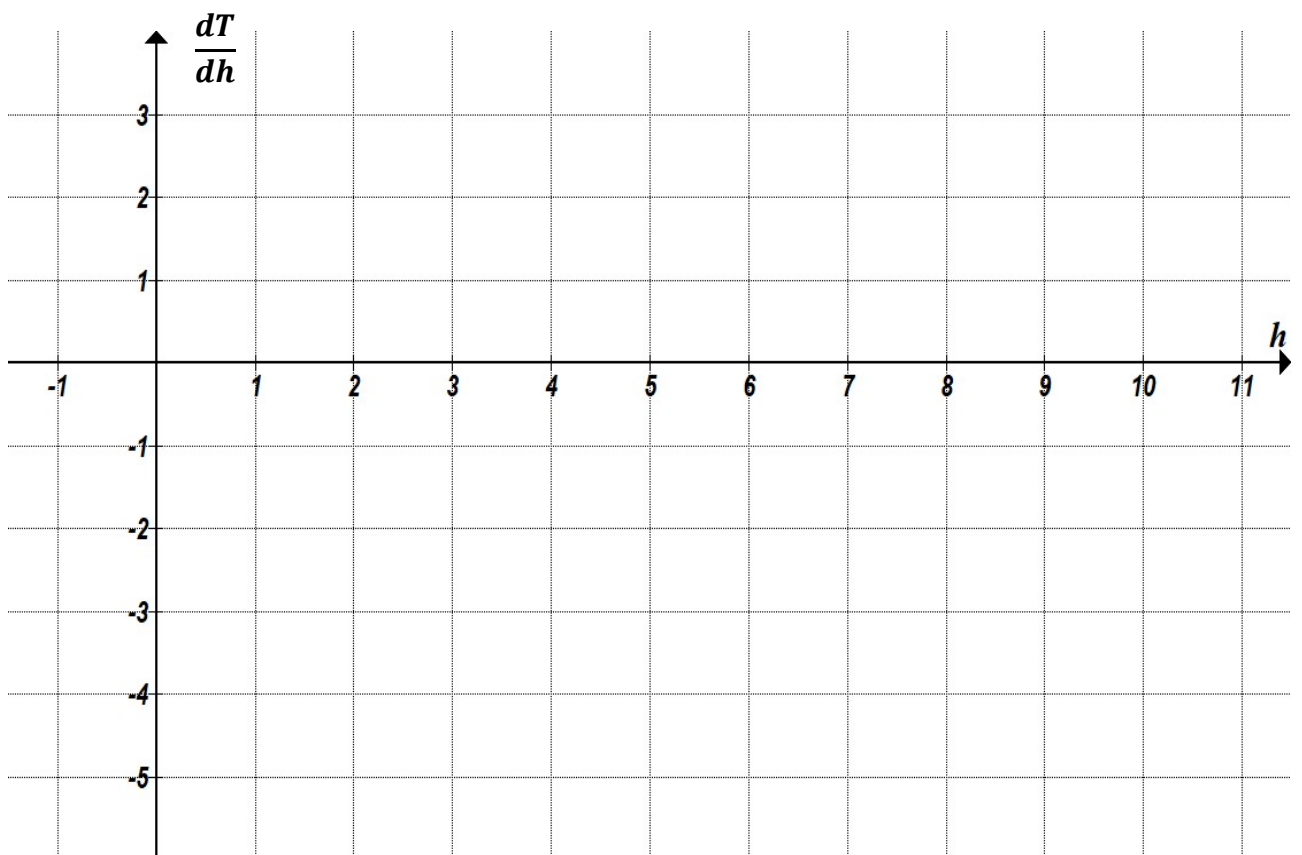
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Spare Diagrams

Question 29



Question 31 c)



Exam continues over the page

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Part 4

- Answer **all** questions in this part.
- This part assesses **Criterion 7**.

Question 32

Two (2) students are asked to evaluate

$$\int \frac{1}{3x} dx$$

The first says

$$\int \frac{1}{3x} dx = \frac{\ln|3x|}{3} + C$$

a) The second uses

$$\int \frac{1}{3x} dx = \frac{1}{3} \int \frac{1}{x} dx$$

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Evaluate

$$\frac{1}{3} \int \frac{1}{x} dx$$

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b) Explain why the two (2) answers are different.

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Question 33

Marker use

a)

Evaluate

$$\int_1^2 \frac{1}{x^2} dx$$

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b)

Solve for k ,

$$\int_1^k \frac{1}{x^2} dx = 0.99$$

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c)

What do you expect would happen to

$$\int_1^k \frac{1}{x^2} dx$$

as $k \rightarrow \infty$?

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Question 34

Two (2) giant identical silver tunnels are to be constructed at the entrance to a fast-food restaurant. All dimensions are in metres (m).

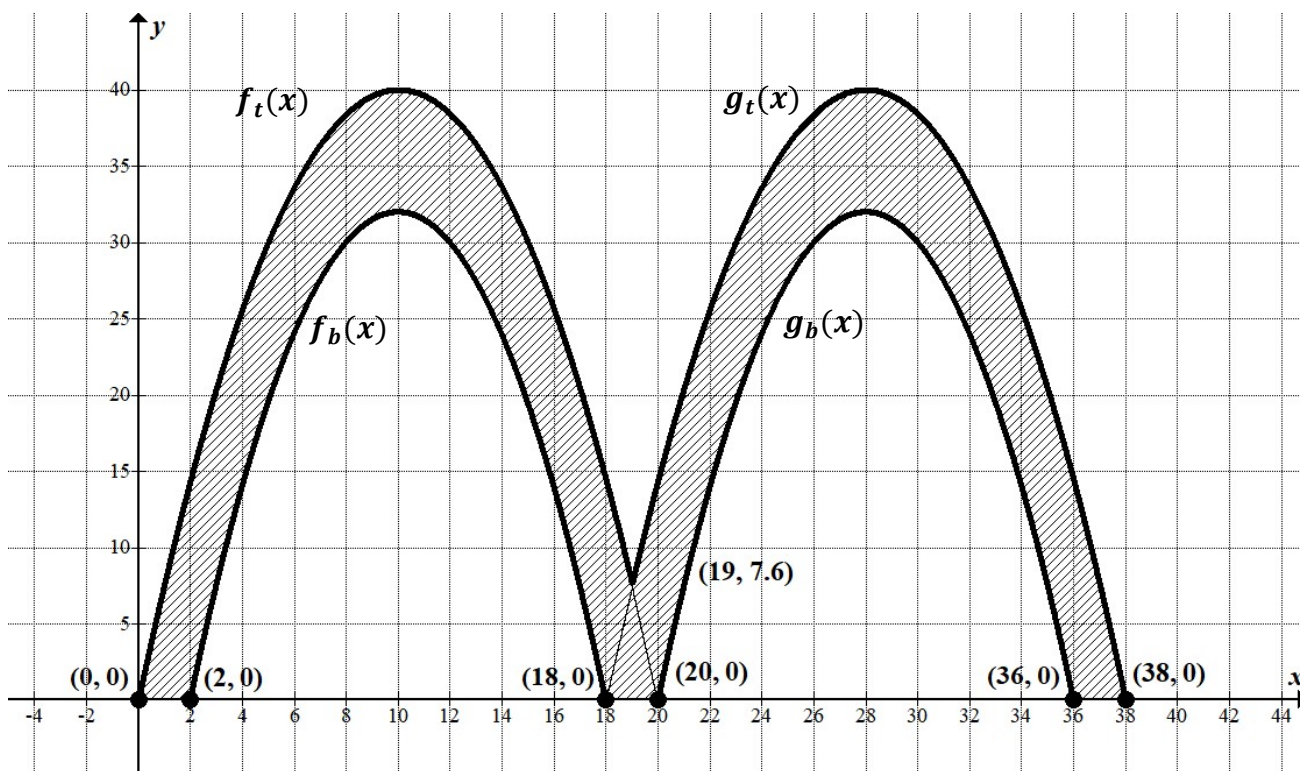


Figure 17: Graph of two (2) silver tunnels (dimensions in metres).

The four (4) functions making up the tunnel are given by:

$$f_t(x) = -\frac{2}{5}x^2 + 8x$$

$$f_b(x) = -\frac{1}{2}x^2 + 10x - 18$$

and the same functions translated 18 m to the right, given by:

$$g_t(x) = -\frac{2}{5}(x - 18)^2 + 8(x - 18)$$

$$g_b(x) = -\frac{1}{2}(x - 18)^2 + 10(x - 18) - 18$$

Question 34 continues

Question 34 continued

Marker use

Write an expression involving the integrals of the four (4) functions for the cross-sectional area of the tunnels.

Calculate the area of the cross-section showing working for integration. You may perform substitution using the calculator.

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Question 35

Marker use

a) Show that $\frac{d}{dx}(x \sin(x)) = x \cos(x) + \sin(x)$

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b) Using the fact that $x \cos(x) = x \cos(x) + \sin(x) - \sin(x)$, find

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$$\int_0^{\frac{\pi}{2}} x \cos x \, dx$$

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Total
C7
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Part 5

- Answer **all** questions in this part.
- This part is worth 20 marks and it is suggested that you spend **approximately 20 minutes** on this part.
- This part assesses **Criterion 8**.

Question 36

In a fantasy board game, multiple rolls of a six (6) on a fair six-sided die are required to defeat an Orc.

- a) If the player has already rolled three (3) sixes in a row, what is the probability the next roll will be a six?

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- b) What is the probability of the next four (4) rolls all being sixes?

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- c) What is the probability of **none** of the next four (4) rolls being sixes?

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- d) For the next five (5) rolls, what is the probability of rolling at least three (3) sixes?

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Question 37

People's forearm length is normally distributed with a mean of 40 cm and a standard deviation of 10 cm.

- a) What is the probability that a person randomly selected will have a forearm length of greater than 45 cm?

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- b) What forearm length would put a person in the longest 20% of forearm lengths in the population?

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- c) If ten (10) people are selected at random, what is the probability that at least two (2) of them will have a forearm length of greater than 45 cm?

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Question 38

Marker use

A distribution X has a mean of 135 and

$$P(X \geq 150) = 0.1$$

Find the standard deviation, $sd(X)$

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Question 39

Marker use

A marketing company is supporting Party A in the next election.

They wish to produce results that look favourable for Party A.

In their latest pre-poll, they sample 500 people, with 53% in favour of Party A.

- a) They wish to publish 53% support for Party A with a 95% confidence interval.

Calculate the 95% confidence interval for the true support for Party A.

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- b) Because the confidence interval in (a) is partly below 50%, they are concerned this is negative publicity for Party A.

What is the highest possible confidence interval they can publish, so that the lowest value it includes is 50%?

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Total
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