

IB DIPLOMA MATHEMATICS AI

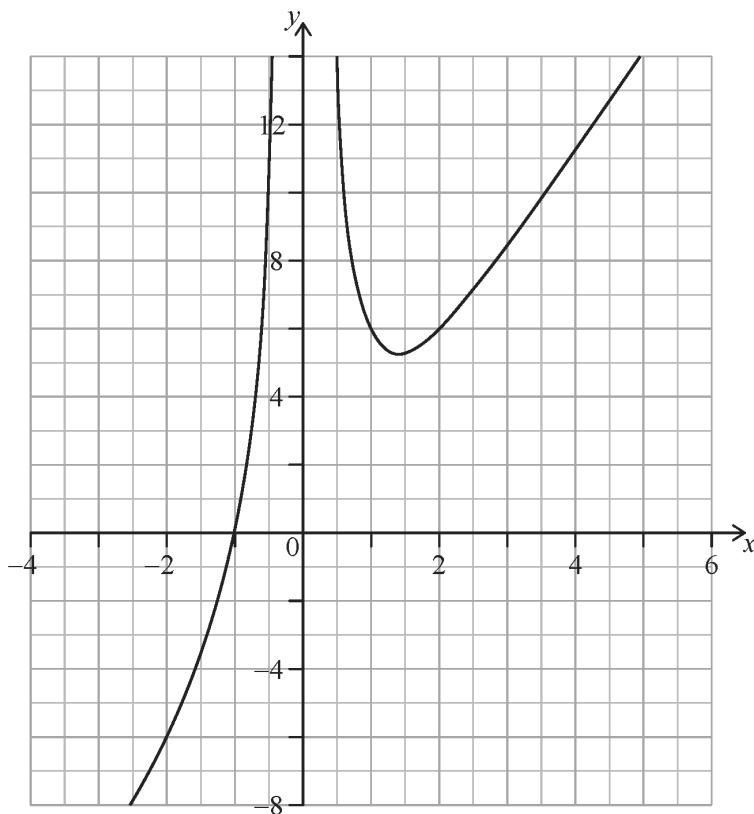
SL
PAPER 2
2021 - 2025

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1 - (MATHAI/21_SL_Summer_2023_Q2) - Algebra-functions - Roots

[Maximum mark: 16]

Consider the function $f(x) = 3x - 1 + 4x^{-2}$. Part of the graph of $y = f(x)$ is shown below.



The function is defined for all values of x except for $x = a$.

(a) Write down the value of a . [1]

(b) Use your graphic display calculator to find the coordinates of the local minimum. [2]

The equation $f(x) = w$, where $w \in \mathbb{R}$, has three solutions.

(c) Identify one possible value for w . [1]

The line $y = mx - \frac{1}{4}$ is tangent to $f(x)$ when $x = -4$.

(d) Write down whether the value of m is positive or negative. Justify your answer. [2]

A second function is given by $g(x) = kp^x - 9$, where $p > 0$. The graph of $y = g(x)$ intersects the y -axis at point $A(0, -5)$ and passes through point $B(3, 4.5)$.

(e) Find the value of

(i) k ;

(ii) p .

[4]

(f) Write down the equation of the horizontal asymptote of $y = g(x)$.

[2]

(g) Find the solution of $f(x) = g(x)$ when $x > 0$.

[2]

Consider a third function, h , where $h(x) = f(x) + g(x)$. The point $C(-1, q)$ lies on the graph of $g(x)$.

(h) State whether C also lies on the graph of $h(x)$. Justify your answer.

[2]

2 - (MATHAI/21_SL_Summer_2024_Q1) - Algebra-functions - Roots, Statistics

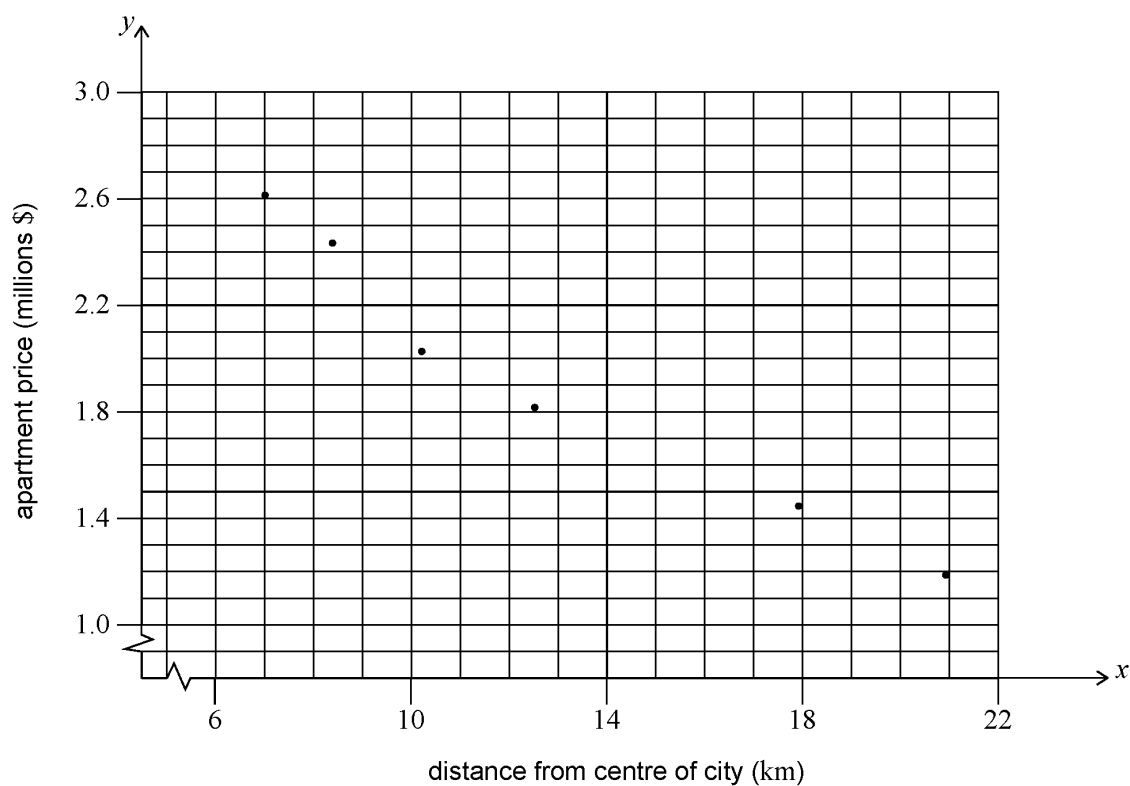
[Maximum mark: 19]

Xavie conducted a study to see if there is a relationship between the price of an apartment, y , and its distance, x , from the city centre of Melbourne.

They took a random sample of six typical apartments along a train line in the city. Xavie obtained the data shown in the following table.

x (kilometres)	7.0	8.4	10.3	12.5	17.8	20.9
y (millions of dollars)	2.61	2.44	2.03	1.81	1.45	1.18

A plot of these data is seen in the following graph.



- (a) Write down the value of the Spearman's rank correlation coefficient, r_s . [1]
- (b) (i) Find the Pearson's product-moment correlation coefficient, r .
- (ii) Use your value of r to state which **two** of the following would best describe the correlation between the variables.

Positive	Negative	Strong	Weak	No correlation	[4]
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The relationship between the variables can be modelled by the regression equation $y = ax + b$.

- (c) (i) Write down the value of a .
- (ii) Write down the value of b .
- (iii) According to this model, state in context what the value of b represents. [3]
- (d) Xavie uses the regression equation to estimate the price of a typical apartment located 19.6 km from the city centre.
- (i) Find this estimated price.
- (ii) State two reasons that Xavie might use to justify the validity of this estimate. [5]

To verify whether this relationship applies in a different direction from the city centre, Xavie considers two locations, A and B, both an equal distance from the city centre. They take a random sample of seven apartments from each location and record the prices (in millions of dollars) in the following tables.

Apartment price in location A						
1.21	1.25	1.31	1.32	1.58	1.95	2.13

Apartment price in location B						
1.51	1.58	1.69	2.61	2.72	2.81	2.95

Xavie conducts a t -test, at the 5 % level of significance, to see if the mean apartment price in location A is different to the mean apartment price in location B. They assume the population variances are the same.

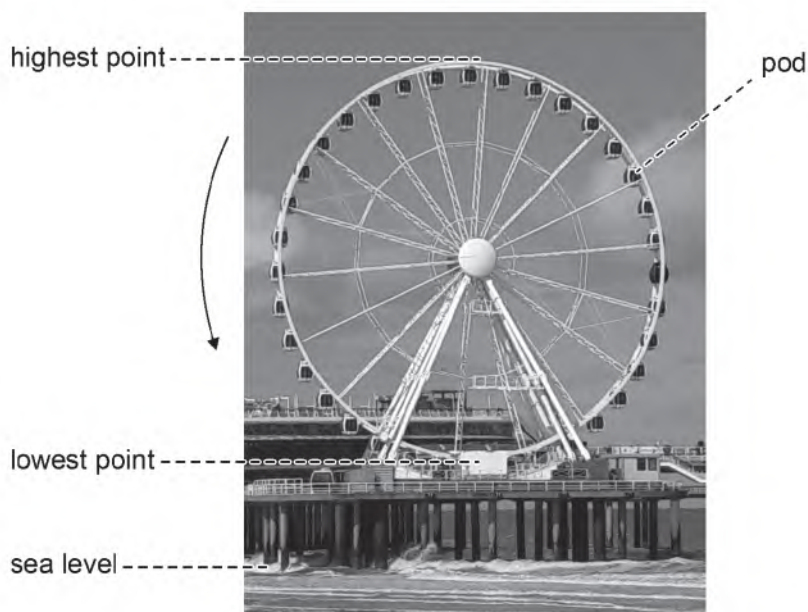
For this test, Xavie takes the null hypothesis to be $\mu_A = \mu_B$.

- (e) Write down the alternative hypothesis. [1]
- (f) Find the p -value for this test. [2]
- (g) State the conclusion of the test. Justify your answer. [2]
- (h) State one additional assumption Xavie has made about the distributions to conduct this test. [1]

3 - (MATHAI/21_SL_Winter_2024_Q2) - Geometry, Trigonometry, Algebra-functions - Roots

[Maximum mark: 16]

The Scheveningen Ferris wheel's lowest point is 8 m above sea level, and its highest point is 45 m above sea level.



- (a) (i) Show that the radius of the Ferris wheel is 18.5 m.
- (ii) Calculate the circumference of the Ferris wheel. [2]

There are pods, equally spaced around the wheel, that carry passengers.

- (b) When the wheel rotates 10° , find the distance that a pod travels along the circumference. [3]

The height in metres, above sea level, of a particular pod is modelled by the function:

$$h(t) = a \sin(bt) + d, \text{ for } a, b > 0,$$

where t is the time, measured in minutes.

The wheel takes 15 minutes to complete 1 revolution.

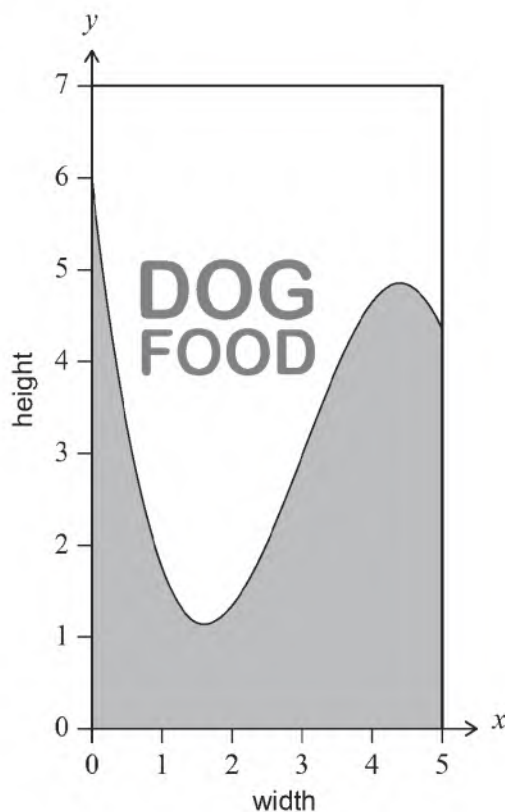
- (c) (i) Find the value of b .
- (ii) Find the value of d .
- (iii) Hence, write down the equation of the sinusoidal model. [5]
- (d) Use the model to find the values of t when the height of this pod is 33 m above sea level for $0 \leq t \leq 15$. [3]
- Since the Ferris wheel opened, it has been operating for 3000 days, and each day it rotates nonstop for 8 hours.
- (e) Calculate the total number of revolutions that the Ferris wheel has made. Give your answer in the form $a \times 10^k$ where $1 \leq a < 10$ and k is an integer. [3]

4 - (MATHAI/21_SL_Winter_2024_Q4) - Geometry, Integration, Algebra-functions - Roots

[Maximum mark: 20]

A type of dog food is sold in cylindrical containers. A new label for the container is being considered. The label will be a rectangle that is 5 cm wide and 7 cm high.

The design on the label is a curve, as shown on the following axes, where one unit represents 1 cm for both axes.



The values in the table approximate points on the curve, correct to one decimal place.

Width, x	0	1	2	3	4	5
Height, y	6	1.7	1.3	3.0	4.7	4.3

- (a) Use the trapezoidal rule with five intervals, and the values given in the table, to estimate the shaded area below the curve.

[3]

The curve used in the label design can be modelled by:

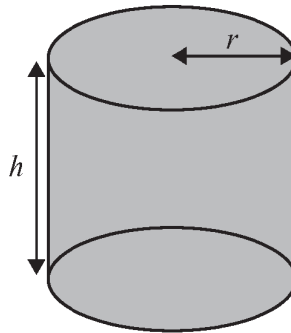
$$y = -\frac{x^3}{3} + 3x^2 - 7x + 6, \text{ for } 0 \leq x \leq 5.$$

- (b) (i) Write down the integral that represents the area of the shaded region.
 (ii) Hence, find the area of the shaded region.

[4]

The dog food is sold in closed cylindrical containers, with radius r and height h .

diagram not to scale



The whole container is made from one type of material, and it is assumed that the thickness of the material is negligible.

Each container has a volume of 400 cm^3 .

- (c) Write down an equation, in terms of r and h , that shows this information. [1]

The amount of material used for each container can be modelled by the external surface area of the container.

The external surface area, A , of the container can be expressed as

$$A = 2\pi r^2 + \frac{k}{r}, \text{ where } r > 0.$$

- (d) Find the value of k . [4]

- (e) (i) Find $\frac{dA}{dr}$.

- (ii) Given that A has a minimum value, find the value of r that will minimize the material used. [5]

The containers are made so that the surface area is minimized. The 5 cm by 7 cm rectangular label is to be glued to the curved surface of the container.

- (f) Show that the label will fit on the container. [3]

5 - (MATHAI/21_SL_Summer_2025_Q2) - Exponentials - Logarithms, Algebra-functions - Roots

[Maximum mark: 15]

Give all answers in this question to the nearest dollar.

Anika invested 10 000 Canadian dollars (CAD) in an account which earns a nominal annual interest rate of 3.4%, compounded monthly.

- (a) Calculate the value of Anika's investment after 6 years. [3]

Anika wants to purchase a house that costs 225 000 CAD. Anika uses the value obtained in part (a) to make an initial payment on the house and takes out a loan to pay the rest.

- (b) Determine the amount of Anika's loan. [1]

Anika amortizes her loan over 15 years. She arranges to make a loan payment at the end of each month. The nominal annual interest rate for the loan is 6.4%, compounded half-yearly.

- (c) Determine Anika's monthly loan payment. [5]

After 2 complete years, Anika decides to increase her monthly loan payment to 2200 CAD. At the time, the remaining amount of the loan is 194 572 CAD.

- (d) (i) Calculate the amount by which the loan will decrease during the next 3 complete years.
(ii) Determine the total interest that Anika will pay over this 3-year period. [6]

6 - (MATHAI/21_SL_Summer_2025_Q3) - Sequences - Series, Algebra-functions - Roots

[Maximum mark: 17]

Felix is training for a competition consisting of running and swimming. He plans to train for 12 weeks to prepare for the competition.

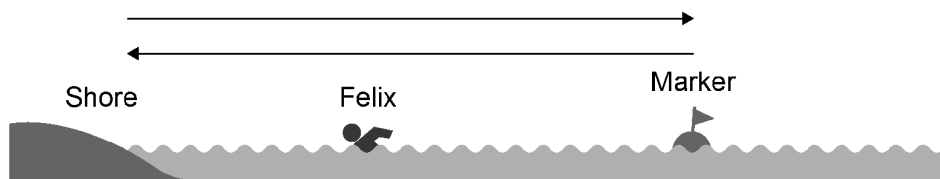
The running part of the competition is a 5 km race. During the 12 weeks, Felix runs on **3 days each week**. On the first day of training, Felix runs 2 km. Each subsequent day that he runs, he increases his distance by 5%.

- (a) Explain why the distances of each of Felix's runs form a geometric sequence and state the common ratio. [2]
- (b) Find the total distance of Felix's first 15 runs. [2]

A published recommendation states that, on the last day of training, an athlete should run a distance that is at least twice as far as the race distance.

- (c) Show that Felix's final run of his 12-week training plan meets this recommendation. [3]

For the swimming part of the competition, competitors must swim 375 m out to a marker in the water and then 375 m back to the shore.



Felix plans to swim **2 times per week** to train for the swimming portion of the competition. On each day he swims in the 1st week, Felix swims out to a marker that is 80 m from the shore, and then swims back to shore.

At the start of each subsequent week, the marker is moved to increase the distance between the marker and the shore by a constant amount. Felix swims a total distance of 704 m in the 4th week.

The distances that Felix swims each week form an arithmetic sequence, where each term, u_n , is the **total distance** he swims in the n th week.

- (d) (i) Find u_1 . [7]
- (ii) Determine the increase in the total distance Felix swims each week.
- (iii) Hence calculate the distance between the marker and the shore in the 2nd week of training.
- (e) Calculate the distance of Felix's final swim in his 12th week of training. [3]

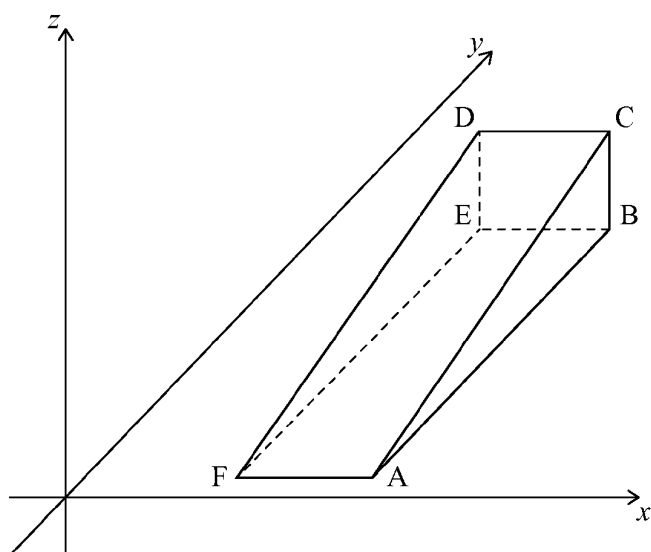
7 - (MATHAI/21_SL_Summer_2025_Q4) - Vectors - Lines - Planes, Geometry, Algebra-functions - Roots

[Maximum mark: 14]

AirFlow Industries is designing a doorstop in the shape of a triangular prism, ABCDEF.

The points $A(13, 1, 0)$, $B(13, 25, 0)$ and $C(13, 25, 7)$ are the coordinates of the vertices of one of the triangular faces of the prism. Point $D(4, 25, 7)$ is another vertex as shown in the following diagram. All the measurements are in centimetres.

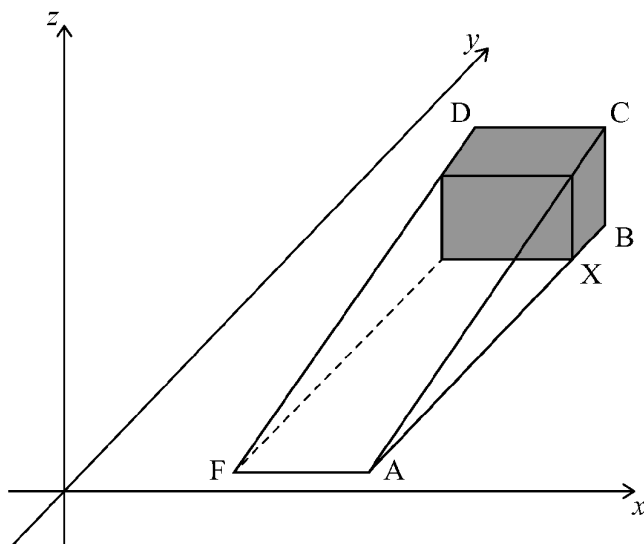
diagram not to scale



- Write down the coordinates of F. [2]
- Find AC . [2]
- Show that triangle ABC is a right-angled triangle. [2]
- Find the volume of material needed to make the doorstop. [3]

To lower the cost of the doorstop, AirFlow decides to reduce its volume to 625 cm^3 by removing the shaded section shown in the following diagram. The remaining triangular faces are still right-angled triangles.

diagram not to scale



The length of the smaller doorstop, AX , can be calculated by

$$AX = AB \times \sqrt{\frac{V_s}{V_o}}$$

where V_s is the volume of the smaller doorstop, and V_o is the volume of the original doorstop, both in cubic centimetres.

- (e) Find AX . [2]

The material needed to make the doorstop costs 0.025 US dollars (USD) per cubic centimetre. The production of each doorstop requires 10% more material than its final volume, due to wastage in the production process.

To make a profit, the company will sell the doorstop for 20% more than the cost of the material.

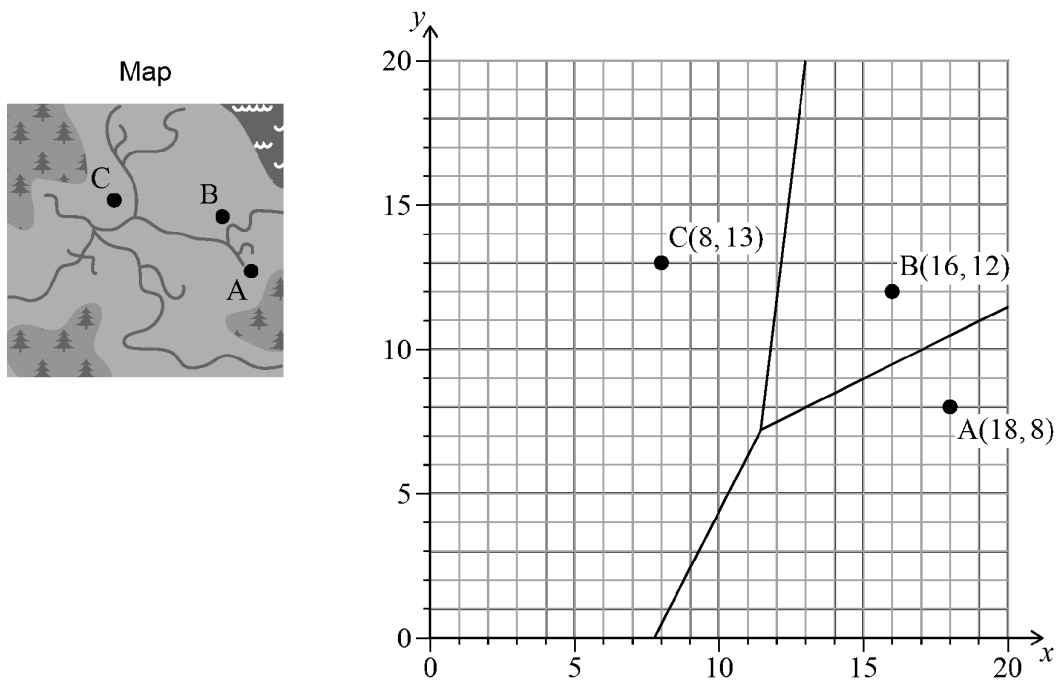
- (f) Determine the price, to two decimal places, the company will charge for the **new** doorstop. [3]

8 - (MATHAI/21_SL_Summer_2025_Q5) - Geometry, Vectors - Lines - Planes, Algebra-functions - Roots

[Maximum mark: 19]

The locations of three fire stations within a 50 by 50 kilometre rural area of Japan are shown on the following map.

A Voronoi diagram can be used to determine the part of the rural area for which each fire station is responsible. The Voronoi diagram for the three fire stations is shown on the coordinate grid beside the map, where 1 unit represents 2.5 km.



- (a) (i) Find the midpoint of $[BC]$.
- (ii) Find the gradient of the perpendicular bisector of $[BC]$.
- (iii) Hence find the equation of the edge between sites B and C. [6]
- (b) (i) Identify the fire station that is expected to respond, based on the Voronoi diagram, if a fire is reported at a location with coordinates $(14, 10)$. Justify your response.
- (ii) Suggest a reason why a different fire station might respond to this fire. [2]

A fire is reported at a location D with coordinates $\left(11\frac{1}{3}, 7\frac{1}{6}\right)$. The distance of D from A on the Voronoi diagram, to six significant figures, is 6.71855 units (16.7964 km on the map).

- (c) (i) Show that the distance of D from B, to six significant figures, is also 6.71855 units.
- (ii) Show that any of the three fire stations would be expected to respond to the fire reported at D. [4]

The equation of the edge between fire stations A and B is $y = 0.5x + 1.5$. The edge between fire stations A and C has an x -intercept of 7.75.

- (d) (i) Determine the area, to the nearest square unit, of the region within the given Voronoi diagram for which fire station A is responsible.
- (ii) Hence, calculate the actual area, in square kilometres, of this region. [7]

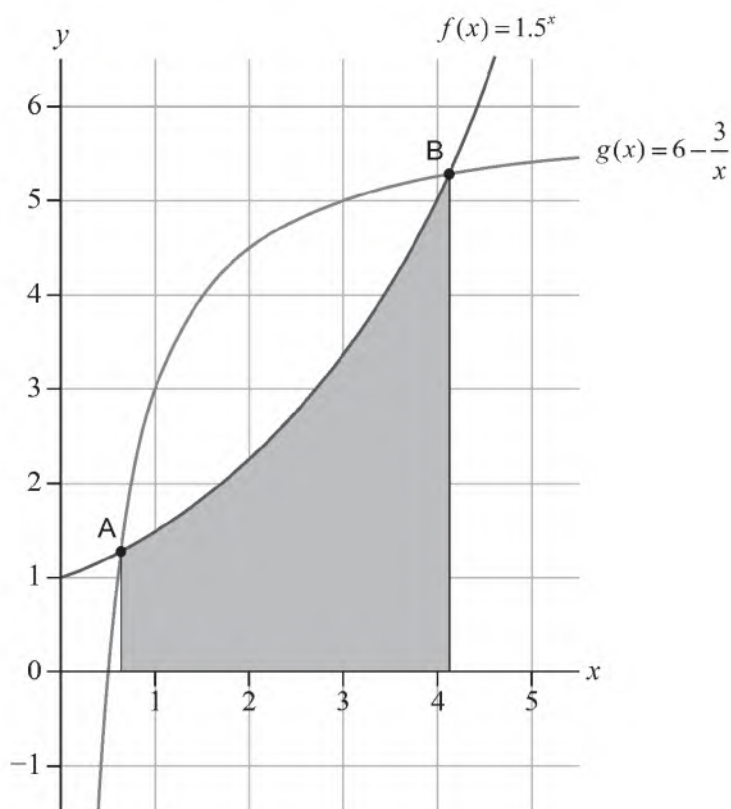
9 - (MATHAI/22_SL_Summer_2025_Q2) - Algebra-functions - Roots, Integration, Differentiation

[Maximum mark: 12]

The diagram shows part of the graphs of the functions

$$f(x) = 1.5^x \quad x \geq 0$$

$$g(x) = 6 - \frac{3}{x} \quad x > 0.$$



- (a) Solve $f(x) = g(x)$. [3]
- (b) (i) Write down the integral that represents the area of the shaded region.
- (ii) Calculate the area of this shaded region.
- (iii) Hence, or otherwise, calculate the area of the region enclosed between the curves $y = f(x)$ and $y = g(x)$. [6]

The tangent to the graph of $y = f(x)$ is parallel to the tangent to the graph of $y = g(x)$ at $x = k$.

- (c) Find the value of k . [3]

10 - (MATHAI/22_SL_Summer_2025_Q5) - Geometry, Algebra-functions - Roots, Differentiation

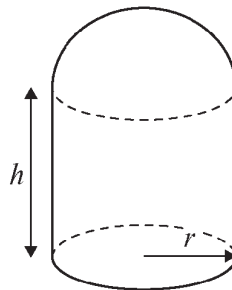
[Maximum mark: 16]

Ju Shen designs a plastic cover, in the shape of a cylinder combined with a hemisphere on top, as shown in the diagram.

The plastic used to make the cover forms the curved surface of both the hemisphere and the cylinder; there is no bottom to the cover, however it stands on a flat horizontal surface.

Let the height of the cylinder be h cm and the internal radius of its base be r cm.

diagram not to scale



- (a) Find an expression for the total internal surface area, $A \text{ cm}^2$, of the cover in terms of r and h . [2]
- (b) Show that the total volume, $V \text{ cm}^3$, enclosed by the cover and the horizontal surface is given by the expression

$$V = \frac{2\pi r^3 + 3\pi r^2 h}{3}. \quad [2]$$

The total volume enclosed by the cover is $10\,000 \text{ cm}^3$.

- (c) Hence show that $h = \frac{30\,000 - 2\pi r^3}{3\pi r^2}$. [2]

Ju Shen uses the total internal surface area to model the amount of plastic used to construct the cover.

- (d) Show that A is given by the expression

$$A = \frac{2\pi r^2}{3} + \frac{20\,000}{r}. \quad [2]$$

Ju Shen wants to use the minimum amount of plastic in the construction of the cover.

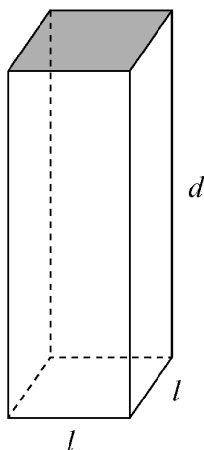
- (e) Find an expression for $\frac{dA}{dr}$. [3]
- (f) Find the value of r and the value of h that minimizes the use of plastic. [4]
- (g) By interpreting your answer to part (f), suggest the best shape for Ju Shen's plastic cover. [1]

11 - (MATHAI/23_SL_Summer_2025_Q3) - Geometry, Algebra-functions - Roots, Differentiation

[Maximum mark: 20]

Kailash manufactures drink containers in the shape of a cuboid. The container has a square top and a square base of length, l cm. Its height, d cm, is three times the length of the base.

diagram not to scale



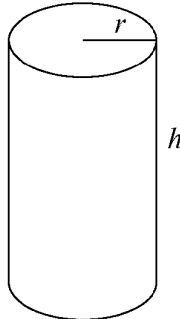
- (a) Write down an expression for d in terms of l . [1]

The container can hold 375 cm^3 of drink.

- (b) Find the value of l and d . [3]
- (c) Calculate the total external surface area of the container. [3]

To reduce environmental impact, Kailash is trying to minimize the amount of material needed for the production of the 375 cm^3 container.

He is willing to change the shape to a cylinder with radius $r \text{ cm}$, and height $h \text{ cm}$, as shown below.



The cylindrical container of drink must also hold 375 cm^3 .

- (d) Find an expression for the height, h , of the container in terms of r . [2]

Let the total external surface area be $A \text{ cm}^2$.

- (e) Show that $A = 2\pi r^2 + \frac{750}{r}$. [2]

- (f) Find $\frac{dA}{dr}$. [3]

- (g) Hence or otherwise

- (i) find the value of r that will minimize A .
(ii) find the minimum value of A needed for the cylinder. [3]

To produce the containers, additional material is required:

- 10% additional surface area for the cuboid
- 25% additional surface area for the cylinder.

Kailash will choose the container that requires the least total amount of material.

- (h) Determine which container Kailash should choose. Justify your answer. [3]

ANSWERS

1 - (MATHAI/21_SL_Summer_2023_Q2) - Algebra-functions - Roots

(a) $(a =) 0$

A1

[1 mark]

(b) $(1.39, 5.24)$ $((1.38672\dots, 5.24025\dots))$

A1A1

Note: Award **A1** for each correct coordinate; do not accept 2 sf values. Award at most **A0A1** if parentheses are missing. Accept $x = 1.39$, $y = 5.24$.

[2 marks]

(c) any value greater than 5.24025...

A1

Note: Accept a specific value **OR** a description of the correct interval for all values.

[1 mark]

(d) **METHOD 1**attempt to relate gradient of function to graph of f **R1**e.g. the function is increasing at $x = -4$

$$m > 0$$

A1**METHOD 2**attempt to find value of $f'(-4)$ **R1**

$$\left(= \frac{25}{8} = 3.125 \right)$$

$$m > 0$$

A1**Note:** The **A1** can only be awarded if the correct value of $f'(-4)$ or m is found**METHOD 3**attempt to substitute $(-4, -12.75)$ into equation of tangent

$$-12.75 = m(-4) - \frac{1}{4} \text{ so } m = 3.125$$

R1

$$m > 0$$

A1**Note:** Do not award **R0A1**.**[2 marks]**

(e) (i) attempt to substitute $(0, -5)$ or $(3, 4.5)$ into $g(x)$ **(M1)**

$$-5 = k \times p^0 - 9$$

$$(k =) 4$$

A1

(ii) attempt to substitute $(3, 4.5)$ and their part (e)(i) into $g(x)$ **(M1)**

$$4.5 = 4 \times p^3 - 9$$

$$p^3 = 3.375$$

$$(p =) 1.5$$

A1**[4 marks]**

(f) $y = -9$

A2

Note: Award **A1** for -9 seen, **A2** for a completely correct equation.

Condone $g(x) = -9$

[2 marks]

(g) $(x =) 4$ **(M1)A1**

Note: Award **M1** for equating $f(x)$ to their $g(x)$

Award **(M1)A0** for the y -coordinate (11.25) as the answer or part of the answer (e.g. coordinates).

Award **(M1)A0** for an answer of $(x =) -2.39421\dots$

[2 marks]

(h) **METHOD 1:**

$$f(-1) = 0 \Rightarrow h(-1) = g(-1) \quad (\text{This justification could be graphical.})$$

R1

yes

A1

Note: Award **R1** for any reasoning based on the fact that -1 is the x -intercept of f .
Accept equivalent arguments in words. Do not award **R0A1**.

METHOD 2:

$$g(-1) = -\frac{19}{3} \quad (-6.33333\dots)$$

$$h(x) = 3x - 1 + 4x^{-2} + 4 \times 1.5^x - 9$$

$$h(-1) = 3(-1) - 1 + 4(-1)^{-2} + 4 \times 1.5^{-1} - 9$$

$$h(-1) = -\frac{19}{3} \quad (-6.33333\dots)$$

R1

yes

A1

Note: Award **R1** for showing that $g(-1) = -\frac{19}{3}$ and $h(-1) = -\frac{19}{3}$. Do not award **R0A1**.

[2 marks]

2 - (MATHAI/21_SL_Summer_2024_Q1) - Algebra-functions - Roots, Statistics

(a) $r_s = -1$ **A1**
[1 mark]

(b) (i) $r = -0.979$ ($-0.979191\dots$) **A2**

(ii) strong **AND** negative **A1A1**

Note: Award at most **A1A0** if additional answers are seen.
Due to the demand of the question, do not accept “negative (from the graph)” if their r value is positive.

[4 marks]

(c) (i) $a = -0.0992$ ($a = -0.0992075\dots$) **A1**

(ii) $b = 3.19$ ($b = 3.19150\dots$) **A1**

(iii) b represents the (typical) price of an apartment in the centre (of the city) **A1**

Note: To award the **A1**, some reference to “centre” or “zero distance from the city” needs to be seen.

[3 marks]

(d) (i) attempt to substitute 19.6 for x **(M1)**

$$y = -0.0992075\dots \times 19.6 + 3.19150\dots$$

$$= 1.25 \quad (1.24704\dots)$$

A1

price = 1.25 million (AUD) (1.24704...million)

A1

(ii) interpolation **R1**

strong correlation. **R1**

[5 marks]

(e) $\mu_A \neq \mu_B$ **A1**

[1 mark]

(f) $p = 0.0224$ ($0.0223977\dots$) **A2**

Note: Award **A1** for 0.022 (2sf)

Award **A1** for an answer of $p = 0.0265$ ($0.0265017\dots$), from use of unpooled GDC settings.

[2 marks]

(g) $0.0223977\dots < 0.05$ **R1**

(there is sufficient evidence to) reject the null hypothesis **A1**

Note: Do not award **R0A1**.

[2 marks]

(h) (the two populations are) normally distributed **A1**

Note: Do not accept “independent” as that applies to the samples, not the populations.

[1 mark]

[Total 19 marks]

3 - (MATHAI/21_SL_Winter_2024_Q2) - Geometry, Trigonometry, Algebra-functions - Roots

(a) (i) $\frac{45-8}{2}$ A1
 18.5 (m) AG

Note: Use of 18.5 in the calculation is reverse engineering, and falls short of the demand of the command term "Show that". In such cases, award **A0**.

(ii) $(2\pi \times 18.5 =) 116 \text{ (} 116.2389\dots, 37\pi \text{) (m).}$ A1
[2 marks]

(b) recognition the distance is the arc length (M1)
 $\frac{10^\circ}{360^\circ} \times 2\pi \times 18.5$ OR $\frac{116.2389\dots}{36}$ (A1)
 $= 3.23 \left(3.228859\dots, \frac{37\pi}{36} \right) \text{ (m)}$ A1
[3 marks]

(c) (i) $\left(b = \frac{360}{15} = \right) 24$ A1

(ii) $\frac{\text{max} + \text{min}}{2}$ (A1)
 $(d =) \frac{45+8}{2}$ OR $45 - 18.5$ OR $8 + 18.5$
 $= 26.5$ A1

(iii) $h(t) = 18.5 \sin(24t) + 26.5$ A1A1

Note: Award **A1** for 18.5 seen as parameter a , **A1** for a completely correct equation (including LHS).

[5 marks]

(d) attempt to equate 33 with $h(t)$ OR sketch graph of curve and line (M1)

$$h(t) = 18.5 \sin(24t) + 26.5 = 33$$

$t = 0.857 \text{ (} 0.857083\dots \text{) and } t = 6.64 \text{ (} 6.64291\dots \text{) (minutes)}$ A1A1
[3 marks]

(e) 4 (revolutions per hour) seen OR 32 (revolutions per day) seen (A1)
 $(4 \times 8 \times 3000 =) 96000$ (A1)

9.6×10^4 A1
[3 marks]
[Total 16 marks]

4 - (MATHAI/21_SL_Winter_2024_Q4) - Geometry, Integration, Algebra-functions - Roots

$$(a) \quad \frac{1}{2} \times 1 \times ((6 + 4.3) + 2(1.7 + 1.3 + 3 + 4.7))$$

A1A1

$$= 15.9 \text{ (15.85) (cm}^2\text{)}$$

A1
[3 marks]

$$(b) \quad (i) \quad \int_0^5 \left(-\frac{x^3}{3} + 3x^2 - 7x + 6 \right) dx$$

A2

Note: Award **A2** for an integral with correct integrand and correct limits.

$$(ii) \quad 15.4 \text{ (15.4166..., } \frac{185}{12} \text{) (cm}^2\text{)}$$

A2

Note: If their limits are outside the domain, award at most **A1A0FT**.

[4 marks]

$$(c) \quad 400 = \pi r^2 h$$

A1

$$(d) \quad \text{METHOD 1} \quad \left(\text{Substitution of } h = \frac{400}{\pi r^2} \text{ in } A = 2\pi r^2 + 2\pi r h \right)$$

$$A = 2\pi r^2 + 2\pi r h$$

(A1)

attempt to isolate h

(M1)

$$h = \frac{400}{\pi r^2}$$

correct substitution of their h into correct expression

(M1)

$$A = 2\pi r^2 + 2\pi r \left(\frac{400}{\pi r^2} \right) \left(A = 2\pi r^2 + \frac{800}{r} \right)$$

$$k = 800$$

A1

$$\text{METHOD 2} \quad \left(\text{Equating } 2\pi r h \text{ and } \frac{k}{r} \right)$$

$$A = 2\pi r^2 + 2\pi r h \quad \text{OR} \quad 2\pi r h = \frac{k}{r}$$

(A1)

attempt to isolate h

(M1)

$$h = \frac{400}{\pi r^2}$$

correct substitution of their h into $2\pi r^2 + 2\pi r h = 2\pi r^2 + \frac{k}{r}$

(M1)

$$2\pi r \left(\frac{400}{\pi r^2} \right) = \frac{k}{r}$$

$$k = 800$$

A1
[4 marks]

(e) (i) $\frac{dA}{dr} = 4\pi r - 800r^{-2}$

A1(M1)A1

Note: Award **A1** for $4\pi r$ seen, and **(M1)** for expressing $\frac{800}{r}$ as $800r^{-1}$ (can be implied through $\mp \frac{800}{r^2}$ seen), **A1** for $-800r^{-2}$. Award at most **A1(M1)A0** if any additional terms are seen.

(ii) $0 = 4\pi r - 800r^{-2}$

(M1)

$$r = 3.99 \left(3.99294\dots, \sqrt[3]{\frac{200}{\pi}} \right) \text{ (cm)}$$

A1

Note: Award at most **M1A0** if k is not found.

[5 marks]

(f) $(h =) 7.99 \text{ (7.98589...)} \text{ (cm)}$

A1

$(C =) 2\pi (3.99294\dots) \approx 25.1 \text{ (25.0884...)} \text{ (cm)}$

A1**EITHER**

the longest dimension of the label (7 cm) is less than both values and hence the label will fit (in any rotation)

R1**OR**

$7 < 7.99 \text{ and } 5 < 25.1$

R1

Note: Do not accept an argument based on the comparison of areas.

[3 marks]**[Total 20 marks]**

5 - (MATHAI/21_SL_Summer_2025_Q2) - Exponentials - Logarithms, Algebra-functions - Roots

(a) **EITHER**

$$N = 72$$

(M1)(A1)

$$I\% = 3.4$$

$$PV = \pm 10\,000$$

$$P/Y = 12$$

$$C/Y = 12$$

Note: Award **M1** for an attempt to use a financial app in their technology (i.e., at least three entries seen, but not necessarily correct), **A1** for all entries correct.

OR

$$N = 72$$

(M1)(A1)

$$I\% = 3.4 / 12$$

$$PV = \pm 10\,000$$

$$P/Y = 1$$

$$C/Y = 1$$

Note: Award **M1** for an attempt to use a financial app in their technology (i.e., at least three entries seen, but not necessarily correct), **A1** for all entries correct.

OR

attempt to substitute into the compound interest formula

(M1)

$$FV = 10\,000 \times \left(1 + \frac{3.4}{100 \times 12}\right)^{6 \times 12}$$

(A1)**THEN**

$$(FV =) 12\,259 \text{ (CAD)}$$

A1
[3 marks]

(b) 212 741 (CAD)

A1
[1 mark]

- (c) $N = 180$ (M1)(A1)(A1)(A1)
 $FV = 0$
 $I\% = 6.4$
 $PV = \pm 212\,741$
 $P/Y = 12$
 $C/Y = 2$

Note: Award **M1** for attempt to use a financial app with at least three entries seen, but not necessarily correct, **A1** for N and I , **A1** for P/Y and C/Y , **A1** for their PV from (b) and $FV = 0$. Approaches that use the compound interest formula receive no marks.

$(PMT =) 1832$ (CAD) **A1**

Note: Accept -1832 (CAD).

[5 marks]

- (d) (i) $N = 36$ (M1)(A1)
 $PV = \pm 194\,572$
 $PMT = 2200$

Note: Award **M1** for adjusting at least one of N , PV , or PMT ; **A1** for correct entries (PV and PMT must have opposite signs). Allow **FT** from incorrect entries for P/Y and/or C/Y from part (c).

$(FV =) 148\,099$ (CAD) (A1)
 $(194\,572 - 148\,099)$

$46\,473$ (CAD) **A1**

- (ii) $2200 \times 12 \times 3 (= 79\,200)$ (A1)
 $(79\,200 - 46\,473 =)$

$32\,727$ (CAD) **A1**
[6 marks]
Total [15 marks]

6 - (MATHAI/21_SL_Summer_2025_Q3) - Sequences - Series, Algebra-functions - Roots

(a) **EITHER**

The ratio of consecutive terms is constant.

R1**OR**

Each term of the sequence is found by multiplying the previous term by a constant.

R1

Note: Do not accept "it has a common ratio" unless it is stated or illustrated that the ratio is between consecutive terms. Do not accept "because $r = 1.05$ " or "because each subsequent day that he runs he increases his distance by 5%" for the explanation. The explanation must refer to a constant ratio or repeated multiplication by a constant.

THEN $r = 1.05$ **A1**

Note: Award **R0A1** for $r = 1.05$ seen with incorrect or no explanation.

[2 marks](b) attempt to substitute into the sum formula for geometric sequence **OR**attempt to write the sum in sigma notation using the term formula **OR** a sum of geometric sequence terms**(M1)**

$$(S_{15} =) \frac{2(1.05^{15} - 1)}{1.05 - 1} \quad \text{OR} \quad \sum_{i=1}^{15} (2 \times 1.05^{i-1}) \quad \text{OR} \quad 2 + 2 \times 1.05 + 2 \times 1.05^2 + \dots$$

43.2 (km) (43.1571... (km))

A1**[2 marks]**(c) choosing $n = 36$ **(A1)**

attempt to substitute into term formula for geometric sequence

(M1)

$$(u_{36} =) 2 \times 1.05^{36-1}$$

11.0 (11.0320...) $> 5 \times 2$ **OR** 11.0 verbally compared to 5×2 **A1**

Note: Award at most **A1M1A0** if a final distance (11.0 or 11) is not given or if the comparison to 10 (5×2) is not shown. Accept 11 for u_{36} (correct 2sf answer).

[3 marks]

- (d) (i) recognition of swimming out and back **AND/OR** swimming two times per week (M1)
 $(u_1 =) 80 \times 2 \times 2$

$(u_1 =) 320 \text{ (m)}$ A1

- (ii) attempt to substitute into term formula of arithmetic sequence (M1)

$704 = 320 + (4 - 1) d$ OR $\frac{704 - 320}{3}$ (A1)

Note: Equating to 704 must be seen to award the (A1).

$(d =) 128 \text{ (m)}$ A1

- (iii) **METHOD 1: Using increased swimming distance**
 $(128 \div 2 \div 2 =) 32 \text{ (m)}$ (further each week) (A1)

$(80 + 32 =) 112 \text{ (m)}$ (from the shore in week 2) A1

METHOD 2: Using total swimming distance for week 2
 $(320 + 128 =) 448 \text{ (m)}$ (swam in week 2) (A1)

$(448 \div 2 \div 2 =) 112 \text{ (m)}$ (from the shore in week 2) A1

[7 marks]

- (e) **METHOD 1: Using sequence for distance swam per week (i.e. 320, 448, 576...)**
 attempt to substitute *their* answers from (d)(i) and (d)(ii) into term formula (M1)

$(u_{12} =) 320 + (12 - 1) \times 128$
 1728 (m) (for the week) (A1)

864 (m) (on a day in week 12) A1

METHOD 2: Using a sequence (t_n) for distance swam per day each week
(i.e. 160, 224, 288...)

recognizing $t_1 = 160$ and $d = 64$ (A1)

attempt to substitute 160 and 64 into term formula (M1)

$(t_{12} =) 160 + (12 - 1) \times 64$
 864 (m) (on a day in week 12) A1

METHOD 3: Using a sequence (v_n) for distance of marker from shore each week
(i.e. 80, 112, 144...)

attempt to substitute 80 and 32 into term formula (M1)

$(v_{12} =) 80 + (12 - 1) \times 32$
 (marker is) 432 (m) (from shore) (A1)

$(432 \times 2 =) 864 \text{ (m)}$ (on a day in week 12) A1

[3 marks]

[Total: 17 marks]

7 - (MATHAI/21_SL_Summer_2025_Q4) - Vectors - Lines - Planes, Geometry, Algebra-functions - Roots

(a) (4,1,0)

A1A1

Note: Award **A1** for 4 seen as the x -coordinate or 1 seen as the y -coordinate, **A1** for all coordinates correct and in the correct order. Accept $x = 4, y = 1, z = 0$.

[2 marks]
(A1)

(b) correct substitution into distance formula

$$\sqrt{(13-13)^2 + (25-1)^2 + (7-0)^2} \text{ OR } \sqrt{0^2 + 24^2 + 7^2}$$

Note: Accept omission of $(13-13)^2$ or 0^2 .

(AC =) 25 (cm)

A1
[2 marks](c) **Method 1**
24 and 7 seen

A1

$$24^2 + 7^2 = 25^2 \text{ OR } 625 = 625 \text{ OR (angle B =) } \cos^{-1} \left(\frac{7^2 + 24^2 - 25^2}{2(7)(24)} \right) = 90^\circ$$

R1

Note: Accept $AB^2 + BC^2 = 625$ as long as the length of AB and of BC are defined.

therefore $\triangle ABC$ must be a right-angled triangle

AG

Method 2A relevant statement describing $\vec{AB}$ and $\vec{BC}$, such as:AB $\parallel$ y -axis **AND** BC $\parallel$ z -axis**OR** x -coordinates are the same for A and B **AND** y -coordinates are the same for B and C **A1**AB perpendicular to BC since x -axis is perpendicular to z -axis **R1**therefore $\triangle ABC$ must be a right-angled triangle **AG**

[2 marks]

(d) width of 9 or correct cross-section area(84) seen

(A1)

correct substitution into volume formula

(A1)

$$V = \frac{1}{2}(24)(7)(9)$$

(Volume =) 756 cm^3

A1

Note: Do not award final **A1** if correct units are not included.

[3 marks]

- (e) correct substitution using *their* AB from part (c) or (d) and *their* original volume from part (d)

(A1)

$$(AX =) 24 \times \sqrt{\frac{625}{756}}$$

$$21.8 \text{ (cm)} \quad (21.8217... \text{ (cm)})$$

A1
[2 marks]

- (f) multiplying 625 by 1.1 or 1.2 or 0.025

(M1)

$$625 \times 1.1 \times 0.025 \times 1.2$$

(A1)

$$(\text{price} =) 20.63 \text{ (20.625) (USD)}$$

A1
[3 marks]
[Total 14 marks]

8 - (MATHAI/21_SL_Summer_2025_Q5) - Geometry, Vectors - Lines - Planes, Algebra-functions - Roots

- (a) (i) attempt to substitute any given coordinates into midpoint formula (M1)

$$(12, 12.5) \text{ or } (12, \frac{25}{2}) \quad \text{A1}$$

Note: Award **A0** if parentheses are omitted.

- (ii) attempt to find gradient of BC using coordinates of B and C (M1)

$$(\text{gradient of BC} =) \frac{12-13}{16-8} \left(= -\frac{1}{8} = -0.125 \right) \quad \text{(A1)}$$

$$(\text{gradient of } \perp =) 8 \quad \text{A1}$$

Note: Follow through within question part for final **A1** from their gradient of BC only if the gradient is seen.

- (iii) **EITHER**

$$8(x-12) = y-12.5 \quad \left(8(x-12) = y-12\frac{1}{2} \right) \quad \text{A1}$$

OR

$$y = 8x - 83.5 \quad \left(y = 8x - 83\frac{1}{2} \right) \quad \text{A1}$$

[6 marks]

- (b) (i) **EITHER**

B is expected to respond since (14, 10) lies in the same cell (of the Voronoi diagram) as fire station B **R1**

OR

B is expected to respond since (14, 10) is closer to B than to any other fire station **R1**

OR

B is expected to respond since it's the closest (nearest responder) to (14, 10) **R1**

OR

Fire station B will respond as the fire is within B's boundaries/area/region. **R1**

Note: Do not award **R1** unless the statement refers to both the distance (closer) to B (or located in the B cell) **and** the responder (point B or fire station B) For example, award **R0** for "Point B is closer to (14, 10)" as there is no reference to a responder.

- (ii) Award **R1** for any viable reason such as:

- fire station B might have already responded to a different fire
- a different fire station might have more manpower or equipment available to fight the fire
- a different fire station might respond to assist fire station B if the fire is large
- the Voronoi diagram only considers straight-line distances, so a different fire station might have a shorter driving route to the fire

R1
[2 marks]

(c) (i) attempt to calculate the length DB **(M1)**

a correct expression for DB **A1**

$$(DB =) \sqrt{\left(11\frac{1}{3} - 16\right)^2 + \left(7\frac{1}{6} - 12\right)^2}$$

DB = 6.71855 **AG**

(ii) **METHOD 1**

$$(DC =) \sqrt{\left(11\frac{1}{3} - 8\right)^2 + \left(7\frac{1}{6} - 13\right)^2}$$
A1

DC = 6.71855 therefore, the fire is equidistant from all 3 fire stations **R1**

so, any of the fire stations would be expected to respond **AG**

Note: Do not award **A0R1**. Do not award **R1** if **AG** statement is not seen.

METHOD 2

The intersection of bisector AB and bisector BC :

$y = 8x - 83.5$ and $y = 0.5x + 1.5$ have an intersection at $D\left(11\frac{1}{3}, 7\frac{1}{6}\right)$ **A1**

Note: Calculator solve is acceptable but D must be clearly identified from a calculation of intersecting lines.

Since D is the intersection of the bisector lines, the fire at D is equidistant from all 3 fire stations **R1**

so, any of the fire stations would be expected to respond **AG**

Note: Do not award **A0R1**. Do not award **R1** if **AG** statement is not seen.

[4 marks]

- (d) (i) **METHOD 1: Dividing into two triangles**
- $(0.5 \times 20 + 1.5 =) 11.5$ seen in an area calculation (A1)
- $(20 - 7.75 =) 12.25$ or $(20 - 11.3333... =) 8.66666...$ seen (A1)
- substitution into triangle area formula for either triangle (M1)
- $(A =) 0.5 \times (20 - 7.75) \times 7.16666... + 0.5 \times 11.5 \times (20 - 11.3333...)$ (A1)
- 93.7291... (sq. units)
- 94 (sq. units) A1

Note: Answer must be given as a whole number to award final **A1**.
Award (A1)(A1)(M1)(A1)A0 for an answer of 93.7 without working.

- METHOD 2: Dividing vertically into triangle and trapezoid**
- $(0.5 \times 20 + 1.5 =) 11.5$ seen in an area calculation (A1)
- attempt to substitute into area of trapezoid formula (M1)
- $(A =) 0.5 \times (7.16666... + 11.5) \times (20 - 11.3333...)$

Note: Lengths of parallel sides must be seen to award the **M1**.

- correct calculation of right triangle area (A1)
- $(A =) 0.5 \times (11.3333... - 7.75) \times 7.16666...$
- $(A =) 0.5 \times (11.3333... - 7.75) \times 7.16666... + 0.5 \times (7.16666... + 11.5) \times (20 - 11.3333...)$ (A1)
- 93.7291... (sq. units)
- 94 (sq. units) A1

Note: Answer must be given as a whole number to award final **A1**.
Award (A1)(M1)(A1)(A1)A0 for an answer of 93.7 without working.

METHOD 3: Dividing horizontally into triangle and trapezoid $(0.5 \times 20 + 1.5 =) 11.5$ seen in an area calculation**(A1)**

attempt to substitute into area of trapezoid formula

(M1)

$$(A =) 0.5 \times [(20 - 7.75) + (20 - 11.3333...)] \times 7.16666...$$

Note: Lengths of parallel sides must be seen to award the **M1**.

correct calculation of right triangle area

(A1)

$$(A =) 0.5 \times (20 - 11.3333...) \times (11.5 - 7.16666...)$$

$$(A =) 0.5 \times (20 - 11.3333...) \times (11.5 - 7.16666...) + 0.5 \times [(20 - 7.75) + (20 - 11.3333...)] \times 7.16666...$$

(A1)

93.7291... (sq. units)

94 (sq. units)

A1

Note: Answer must be given as a whole number to award final **A1**.
Award **(A1)(M1)(A1)(A1)A0** for an answer of 93.7 without working.

METHOD 4: Dividing into two triangles and rectangle $(0.5 \times 20 + 1.5 =) 11.5$ seen in an area calculation**(A1)** $(20 - 11.3333...)$ **OR** $(11.3333... - 7.75)$ **OR** $(11.5 - 7.16666...)$ seen**(A1)**

substitution into triangle area formula.

(M1)

$$0.5 \times (11.3333... - 7.75) \times 7.16666... + (20 - 11.3333...) \times 7.16666... + 0.5 \times (11.5 - 7.16666...) \times (20 - 11.3333...)$$

(A1)

93.7291... (sq. units))

94 (sq. units)

A1

Note: Answer must be given as a whole number to award final **A1**.
Award **(A1)(A1)(M1)(A1)A0** for an answer of 93.7 without working.

METHOD 5: Calculus

A and C mid point (13, 10.5)

$$(\text{gradient of AC} =) \frac{13-8}{8-18} = -\frac{5}{10}$$

(gradient of $\perp$ =) 2

$$\text{AC bisector } 2(x-13) = y-10.5 \quad \text{OR} \quad y = 2x - 15.5$$

A1

attempt to integrate their equation and given equation

(M1)

$$\text{area} = \int_{7.75}^{11.3} 2x - 15.5 \, dx + \int_{11.3}^{20} 0.5x + 1.5 \, dx$$

(A1)(A1)

Note: Award **A1** for each correct expression with correct limits.

93.7291... (sq. units))

94 (sq. units)

A1

Note: Answer must be given as a whole number to award final **A1**.

Award **A1(M1)(A1)(A1)A0** for an answer of 93.7 without working.

$$(ii) \quad (1 \text{ sq unit} = 2.5 \text{ km} \times 2.5 \text{ km} =) 6.25 \text{ (km}^2\text{)}$$

(A1)

Note: Award **A1** for 6.25 seen.

$$(94 \times 6.25 \text{ km}^2)$$

$$588 \text{ (587.5) (km}^2\text{)}$$

A1

Note: Accept: 586 (585.807...) (km²) from (93.7291... × 6.25 km²).

[7 marks]
[Total: 19 marks]

9 - (MATHAI/22_SL_Summer_2025_Q2) - Algebra-functions - Roots, Integration, Differentiation

(a) 0.638 (0.637623...) and 4.10 (4.09811...) A2A1**Note:** Award **A2** for one correct answer, accept 4.1. Award **A2A0** if coordinate pair is given.**[3 marks]**(b) (i) $\int_{0.638}^{4.1} 1.5^x dx$ OR $\int_{0.638}^{4.1} f(x) dx$ A1A1**Note:** **A1** for function and dx , **A1** for limits. Award **A1** for $\int_{0.638}^{4.1} y dx$.

Condone the use of modulus within the integrand.

(ii) 9.81 (9.80788...) (from 3sf)

9.80 (9.79844...) (from full)

A2**Note:** Accept 9.8 for **A2**.

(iii) correct expression for area

(A1)

$$\int_{0.638}^{4.1} g(x) - f(x) dx \text{ OR } \int_{0.638}^{4.1} 6 - \frac{3}{x} - 1.5^x dx$$

5.38 (5.38290...)

A1**Note:** Accept 5.39**[6 marks]**(c) $f'(x) = g'(x)$ **(M1)**correct graphs of $f'(x)$ and $g'(x)$ **(M1)****Note:** Award **M1** if $\frac{3}{x^2}$ seen.

(k =) 1.86 (1.86406...)

A1**[3 marks]****Total [12 marks]**

10 - (MATHAI/22_SL_Summer_2025_Q5) - Geometry, Algebra-functions - Roots, Differentiation

(a) $(A =) 2\pi r^2 + 2\pi r h$

A1A1

Note: Award **A1** for either term correct (even if unsimplified) and **A1** for all correct (including simplification and no extra term).

[2 marks]

(b) $V = \frac{2\pi r^3}{3} + \pi r^2 h$

A1A1

$$V = \frac{2\pi r^3 + 3\pi r^2 h}{3}$$

AG

Note: Award **A1** for one correct term, **A1** for both and completion to required form.

[2 marks]

- (c) 10000 substituted into (b)
correct rearrangement with at least one line of intermediate working leading to the given value.

M1

M1

$$h = \frac{30000 - 2\pi r^3}{3\pi r^2}$$

AG

[2 marks]

- (d)
- h
- substituted into their
- A

M1

$$(A =) 2\pi r^2 + 2\pi r \left(\frac{30000 - 2\pi r^3}{3\pi r^2} \right)$$

further consistent rearrangement that leads to **given** A

A1

[2 marks]

(e) $\frac{4\pi r}{3} - \frac{20000}{r^2}$

A1A1A1

Note: Award **A1** for $\frac{4\pi r}{3}$, **A1** for -20000 seen, and **A1** for a correct index for r in second term.

[3 marks]

(f) $\frac{dA}{dr} = 0$

(M1)

EITHER

rearrangement leading to $r^3 = \frac{15000}{\pi}$

(M1)

OR

graph of $\frac{dA}{dr}$

(M1)

THEN

$$r = 16.8 \text{ (16.8389...)} \text{ OR } \sqrt[3]{\frac{15000}{\pi}}$$

A1

Note: Accept correct graph of Area function leading to correct minimum value for r for **M1M1A1**.

$$h = 0$$

A1

[4 marks]

- (g) ... hemisphere

A1

Note: Do not **FT** from incorrect answers to part (f).

[1 mark]

Total [16 marks]

11 - (MATHAI/23_SL_Summer_2025_Q3) - Geometry, Algebra-functions - Roots, Differentiation

(a) $(d=)3l$ A1

[1 mark]

(b) substitution into volume of cuboid formula $V = l^2 \times 3l (= 375)$ (M1)

attempting to solve their $3l^3 = 375$ (M1)

$$l^3 = 125 \text{ OR } l = \sqrt[3]{125} \text{ OR } l^3 = \frac{375}{3}$$

$l = 5, d = 15$ A1

[3 marks]

(c) finding the area of a square and the area of a (non-square) rectangle 5×5 and 5×15 (M1)

$(5 \times 5 + 5 \times 15 + 5 \times 15) \times 2$ (A1)

$= 350 \text{cm}^2$ A1

Note: The final answer is 350cm^2 . Units are required.

[3 marks]

(d) $\pi r^2 h = 375$ (A1)

$h = \frac{375}{\pi r^2}$ A1

Note: Award at most **A0A1** for a final answer $h = \frac{V}{\pi r^2}$.

[2 marks]

(e) attempt to substitute their h into the curved surface area $2\pi r h$ M1

$A = 2\pi r^2 + 2\pi r \left(\frac{375}{\pi r^2} \right)$ A1

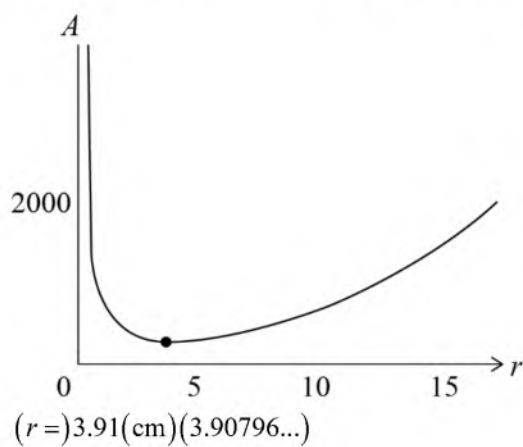
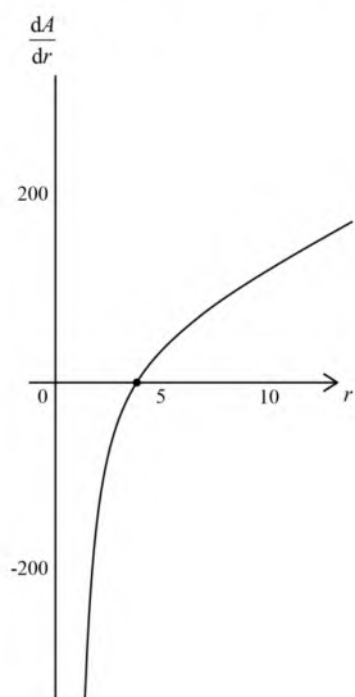
$A = 2\pi r^2 + \frac{750}{r}$ AG

[2 marks]

(f) $\left(\frac{dA}{dr} = \right) 4\pi r - 750r^{-2}$ A1A1A1

Note: Award **A1** for $4\pi r$, **A1** for -750 , **A1** for r^{-2} or equivalent. Award at most **A1A1A0** for additional terms seen.

[3 marks]

(g) (i) **METHOD 1**correct sketch with some indication of min point (need not be labelled) **(M1)****A1****METHOD 2**attempt to solve $4\pi r - \frac{750}{r^2} = 0$, graphically or otherwise **(M1)**

$$(r =) 3.91 \text{ (cm)} (3.90796\dots)$$

A1(ii) $288 \text{ (cm}^2\text{)} (287.873\dots)$ **A1****[3 marks]**

(h) cuboid: 1.10×350 and cylinder: $1.25 \times 287.873\dots$

(M1)

cuboid: 385 and cylinder: 359.842...

R1

he should choose the cylinder

A1

Note: Do not award **R0A1**.

[3 marks]

Total [20 marks]

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