AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname StemUp Model Solution

Forename(s) _____

Candidate signature _____

I declare this is my own work.

A-level MATHEMATICS

Paper 1

Tuesday 4 June 2024 Afternoon Time allowed: 2 hours

Materials
- You must have the AQA Formulae for A-level Mathematics booklet.
- You should have a graphical or scientific calculator that meets the requirements of the specification.

Instructions
- Use black ink or black ball-point pen. Pencil should only be used for drawing.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer each question in the space provided for that question.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do **not** write outside the box around each page or on blank pages.
- Show all necessary working; otherwise marks for method may be lost.
- Do all rough work in this book. Cross through any work that you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.

Advice
- Unless stated otherwise, you may quote formulae, without proof, from the booklet.
- You do not necessarily need to use all the space provided.

For Examiner's Use	
Question	Mark
1	
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TOTAL	

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

1 Find the coefficient of x in the expansion of

$$(4x^3 - 5x^2 + 3x - 2)(x^5 + 4x + 1)$$

Circle your answer.

[1 mark]

(–5) –2 7 11

Do not write outside the box

2 The function f is defined by $f(x) = e^x + 1$ for $x \in \mathbb{R}$

Find an expression for $f^{-1}(x)$

Tick (✓) **one** box.

[1 mark]

$f^{-1}(x) = \ln(x - 1)$ ✓

$f^{-1}(x) = \ln(x) - 1$

$f^{-1}(x) = \dfrac{1}{e^x + 1}$

$f^{-1}(x) = \dfrac{x - 1}{e}$

Turn over for the next question

Do not write outside the box

3 The expression

$$\frac{12x^2 + 3x + 7}{3x - 5}$$

can be written as

$$Ax + B + \frac{C}{3x - 5}$$

State the value of A

Circle your answer.

[1 mark]

3 (4) 7 9

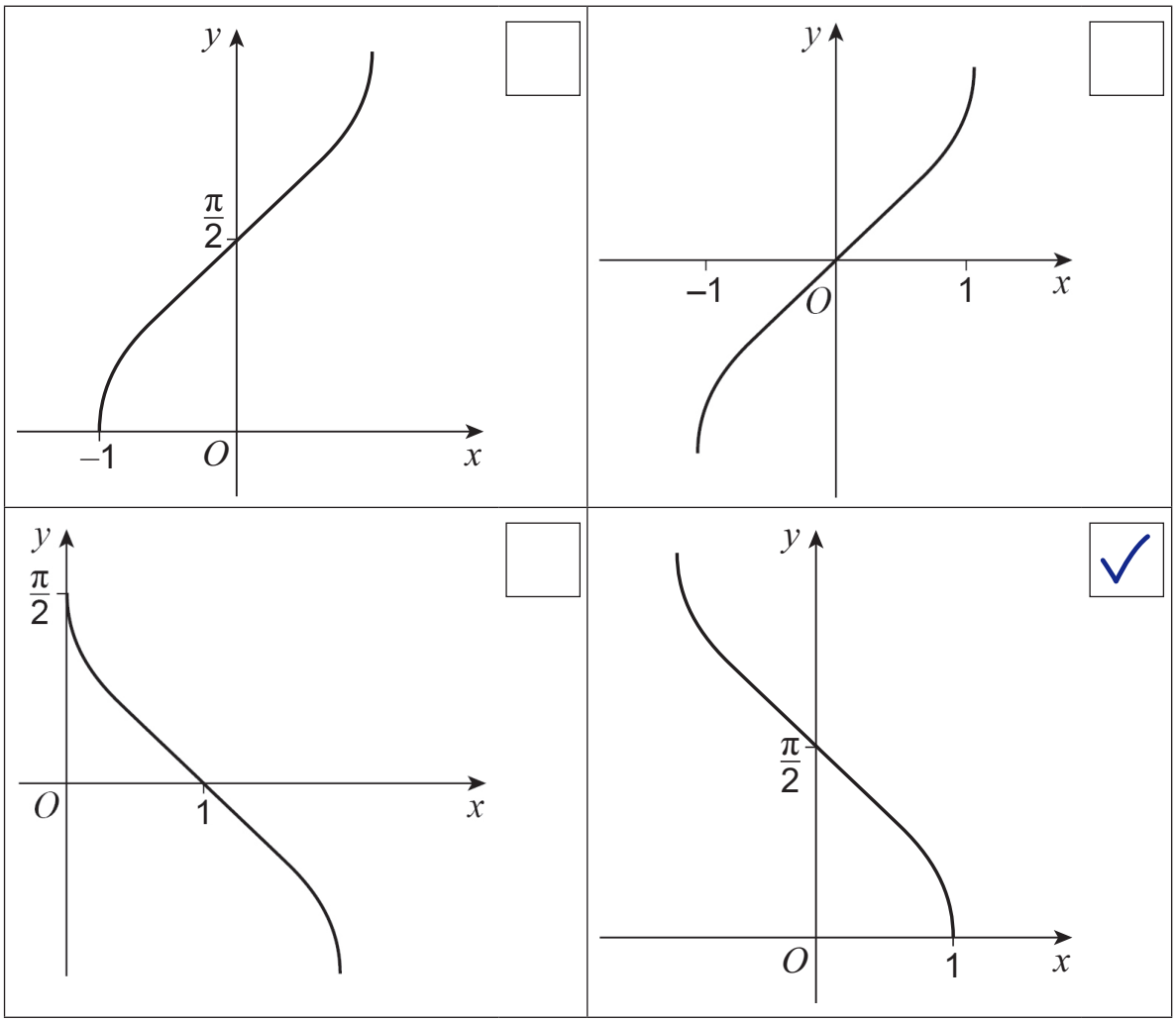
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4 One of the diagrams below shows the graph of $y = \arccos x$

Identify the graph of $y = \arccos x$

Tick (✓) **one** box.

[1 mark]



Turn over for the next question

Do not write outside the box

5 Solve the equation

$$\sin^2 x = 1$$

for $0° < x < 360°$

[3 marks]

$\sin^2 x = 1$

$\sin x = \pm 1$

$\sin x = 1 \Rightarrow x = 90°$

$\sin x = -1 \Rightarrow x = 270°$

$\therefore x = 90°, 270°$

Do not write outside the box

6 Use the chain rule to find $\frac{dy}{dx}$ when $y = (x^3 + 5x)^7$

[2 marks]

Let $u = x^3 + 5x$, so $y = u^7$

$\frac{du}{dx} = 3x^2 + 5$, $\frac{dy}{du} = 7u^6$

$\frac{dy}{dx} = \frac{dy}{du} \times \frac{du}{dx} = 7(x^3 + 5x)^6 \times (3x^2 + 5)$

$\frac{dy}{dx} = 7(3x^2 + 5)(x^3 + 5x)^6$

Turn over for the next question

Do not write outside the box

7 Show that

$$\frac{3+\sqrt{8n}}{1+\sqrt{2n}}$$

can be written as

$$\frac{4n-3+\sqrt{2n}}{2n-1}$$

where n is a positive integer.

[4 marks]

$\sqrt{8n} = \sqrt{4} \times \sqrt{2n} = 2\sqrt{2n}$

$\frac{3+\sqrt{8n}}{1+\sqrt{2n}} = \frac{3+2\sqrt{2n}}{1+\sqrt{2n}} \times \frac{1-\sqrt{2n}}{1-\sqrt{2n}}$

$= \frac{3-3\sqrt{2n}+2\sqrt{2n}-2\sqrt{2n}\times\sqrt{2n}}{1-2n}$

$= \frac{3-3\sqrt{2n}+2\sqrt{2n}-4n}{1-2n}$

$= \frac{3-\sqrt{2n}-4n}{1-2n}$ (multiply top and bottom by -1)

$= \frac{4n-3+\sqrt{2n}}{2n-1}$ as required

Do not write outside the box

8 (a) Find the first three terms, in ascending powers of x, in the expansion of

$$(2 + kx)^5$$

where k is a positive constant.

[3 marks]

$(2 + kx)^5 = 2^5 + {}^5C_1 \times 2^4(kx) + {}^5C_2 \times 2^3(kx)^2 + \ldots$

$= 32 + 5 \times 16kx + 10 \times 8k^2x^2 + \ldots$

$= 32 + 80kx + 80k^2x^2 + \ldots$

First three terms: $32 + 80kx + 80k^2x^2$

8 (b) Hence, given that the coefficient of x is four times the coefficient of x^2, find the value of k

[2 marks]

Coefficient of x = 4 × coefficient of x^2

$80k = 4 \times 80k^2$

$320k^2 - 80k = 0 \Rightarrow 80k(4k - 1) = 0$

$k = 0$ or $k = \frac{1}{4}$

k is positive, so $k = \frac{1}{4}$

Turn over ▶

Do not write outside the box

9 (a) Show that, for small values of θ measured in radians

$$\cos 4\theta + 2\sin 3\theta - \tan 2\theta \approx A + B\theta + C\theta^2$$

where A, B and C are constants to be found.

[3 marks]

For small θ: $\sin\theta \approx \theta$, $\tan\theta \approx \theta$, $\cos\theta \approx 1 - \frac{\theta^2}{2}$

$\cos 4\theta \approx 1 - \frac{(4\theta)^2}{2} = 1 - 8\theta^2$

$2\sin 3\theta \approx 2(3\theta) = 6\theta$

$\tan 2\theta \approx 2\theta$

$\cos 4\theta + 2\sin 3\theta - \tan 2\theta \approx 1 - 8\theta^2 + 6\theta - 2\theta$

$= 1 + 4\theta - 8\theta^2$

$\therefore A = 1, \quad B = 4, \quad C = -8$

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9 (b) Use your answer to part **(a)** to find an approximation for

$$\cos 0.28 + 2 \sin 0.21 - \tan 0.14$$

Give your answer to three decimal places.

[2 marks]

$4\theta = 0.28, \quad 3\theta = 0.21, \quad 2\theta = 0.14 \quad \Rightarrow \quad \theta = 0.07$

$\cos 0.28 + 2 \sin 0.21 - \tan 0.14 \approx 1 + 4(0.07) - 8(0.07)^2$

$= 1 + 0.28 - 0.0392$

$= 1.2408$

$\approx 1.241 \quad (3 \text{ d.p.})$

Turn over for the next question

Do not write outside the box

10 (a) An arithmetic sequence has 300 terms.

The first term of the sequence is –7 and the last term is 32

Find the sum of the 300 terms.

[2 marks]

$S_n = \frac{n}{2}(a + l)$

$S_{300} = \frac{300}{2}(-7 + 32)$

$= 150 \times 25$

$= 3750$

Do not write outside the box

10 (b) A school holds a raffle at its summer fair.

There are nine prizes.

The total value of the prizes is £1260

The values of the prizes form an arithmetic sequence.

The top prize has the highest value, and the bottom prize has the least value.

The value of the top prize is six times the value of the bottom prize.

Find the value of the top prize.

[4 marks]

Let the bottom prize be a and the common difference be d

Top prize $l = a + 8d$ and $l = 6a$

$S_9 = \frac{9}{2}(a + l) = 1260$

$a + l = 280$

$a + 6a = 280 \Rightarrow 7a = 280$

$a = 40$

$l = 6 \times 40 = 240$ (check: $8d = 200$, $d = 25$, $40 + 8 \times 25 = 240$)

Value of the top prize = £240

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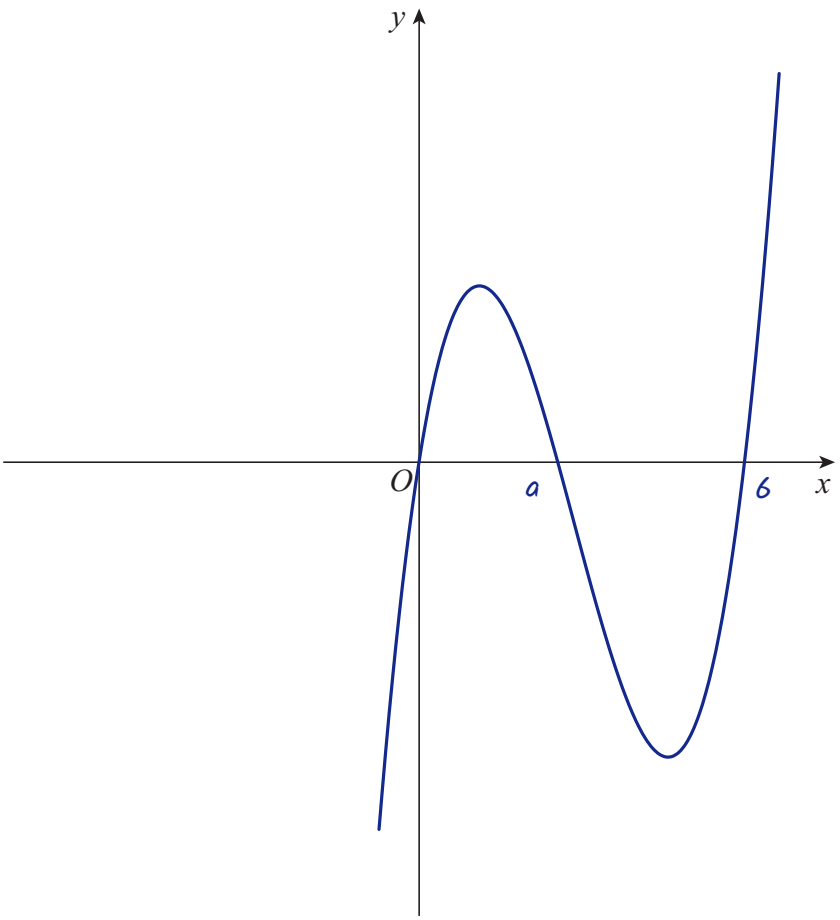
11 It is given that

$$f(x) = x(x - a)(x - 6)$$

where $0 < a < 6$

11 (a) Sketch the graph of $y = f(x)$ on the axes below.

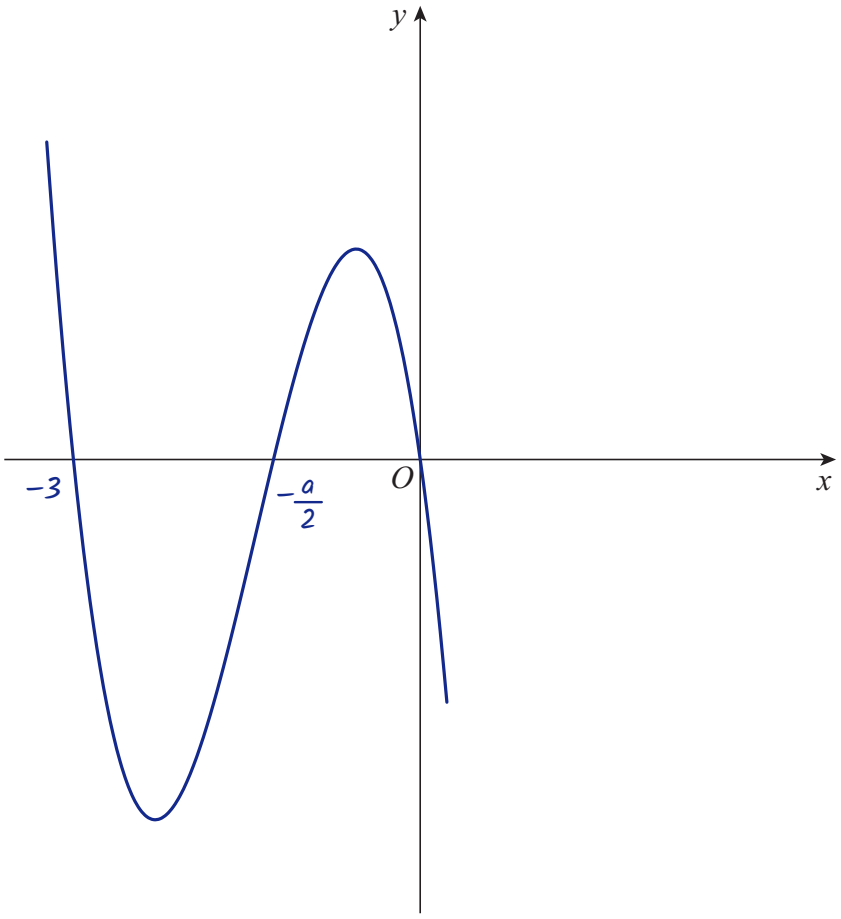
[3 marks]



Do not write outside the box

11 (b) Sketch the graph of $y = f(-2x)$ on the axes below.

[2 marks]



Turn over for the next question

Do not write outside the box

12 The terms, u_n, of a periodic sequence are defined by

$$u_1 = 3 \quad \text{and} \quad u_{n+1} = \frac{-6}{u_n}$$

12 (a) Find u_2, u_3 and u_4

[2 marks]

$u_2 = \frac{-6}{u_1} = \frac{-6}{3} = -2$

$u_3 = \frac{-6}{u_2} = \frac{-6}{-2} = 3$

$u_4 = \frac{-6}{u_3} = \frac{-6}{3} = -2$

12 (b) State the period of the sequence.

[1 mark]

Sequence: 3, −2, 3, −2, ...

Period = 2

Do not write outside the box

12 (c) Find the value of $\sum_{n=1}^{101} u_n$

[2 marks]

$\Sigma u_n = 3 - 2 + 3 - 2 + \ldots + 3 - 2 + 3 \quad (n = 1 \text{ to } 101)$

Each pair $(3 - 2) = 1$, and there are 50 pairs, plus $u_{101} = 3$

$\Sigma u_n = 50 \times 1 + 3$

$= 53$

Turn over for the next question

Do not write outside the box

13 (a) It is given that

$$P(x) = 4x^3 + 8x^2 + 11x + 4$$

Use the factor theorem to show that $(2x + 1)$ is a factor of $P(x)$

[2 marks]

$P(-\frac{1}{2}) = 4(-\frac{1}{2})^3 + 8(-\frac{1}{2})^2 + 11(-\frac{1}{2}) + 4$

$= -\frac{1}{2} + 2 - \frac{11}{2} + 4$

$= 0$

$P(-\frac{1}{2}) = 0$, so by the factor theorem $(2x + 1)$ is a factor of $P(x)$

13 (b) Express $P(x)$ in the form

$$P(x) = (2x + 1)(ax^2 + bx + c)$$

where a, b and c are constants to be found.

[2 marks]

$4x^3 + 8x^2 + 11x + 4 = (2x + 1)(ax^2 + bx + c)$

x^3: $2a = 4 \Rightarrow a = 2$ constant: $c = 4$

x^2: $2b + a = 8 \Rightarrow b = 3$ (check x: $2c + b = 8 + 3 = 11$ ✓)

$P(x) = (2x + 1)(2x^2 + 3x + 4)$

Do not write outside the box

13 (c) Given that n is a positive integer, use your answer to part **(b)** to explain why $4n^3 + 8n^2 + 11n + 4$ is **never** prime.

[2 marks]

$4n^3 + 8n^2 + 11n + 4 = (2n + 1)(2n^2 + 3n + 4)$

n is a positive integer, so $2n + 1 \geq 3$ and $2n^2 + 3n + 4 \geq 9$

Both factors are integers, neither equals 1, and neither equals the cubic,

so the number has a factor other than 1 and itself.

$\therefore$ $4n^3 + 8n^2 + 11n + 4$ is never prime.

Turn over for the next question

Do not write outside the box

14 (a) The equation

$$x^3 = e^{6-2x}$$

has a single solution, $x = \alpha$

By considering a suitable change of sign, show that α lies between 0 and 4

[2 marks]

$x^3 = e^{6-2x} \Rightarrow x^3 - e^{6-2x} = 0$

Let $f(x) = x^3 - e^{6-2x}$

$f(0) = 0 - e^6 = -403.4... < 0$

$f(4) = 64 - e^{-2} = 63.86... > 0$

There is a change of sign and f is continuous on [0, 4],

$\therefore$ α lies between 0 and 4

14 (b) Show that the equation $x^3 = e^{6-2x}$ can be rearranged to give

$$x = 3 - \frac{3}{2}\ln x$$

[3 marks]

$x^3 = e^{6-2x}$

$\ln x^3 = 6 - 2x$

$3 \ln x = 6 - 2x$

$2x = 6 - 3 \ln x$

$x = 3 - \frac{3}{2} \ln x$ as required

Do not write outside the box

14 (c) (i) Use the iterative formula

$$x_{n+1} = 3 - \frac{3}{2}\ln x_n$$

with $x_1 = 4$, to find x_2, x_3 and x_4

Give your answers to three decimal places.

[2 marks]

$x_2 = 3 - \frac{3}{2}\ln 4 = 0.92055\ldots = 0.921$

$x_3 = 3 - \frac{3}{2}\ln(0.92055\ldots) = 3.12416\ldots = 3.124$

$x_4 = 3 - \frac{3}{2}\ln(3.12416\ldots) = 1.29125\ldots = 1.291$

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14 (c) (ii) **Figure 1** below shows a sketch of parts of the graphs of

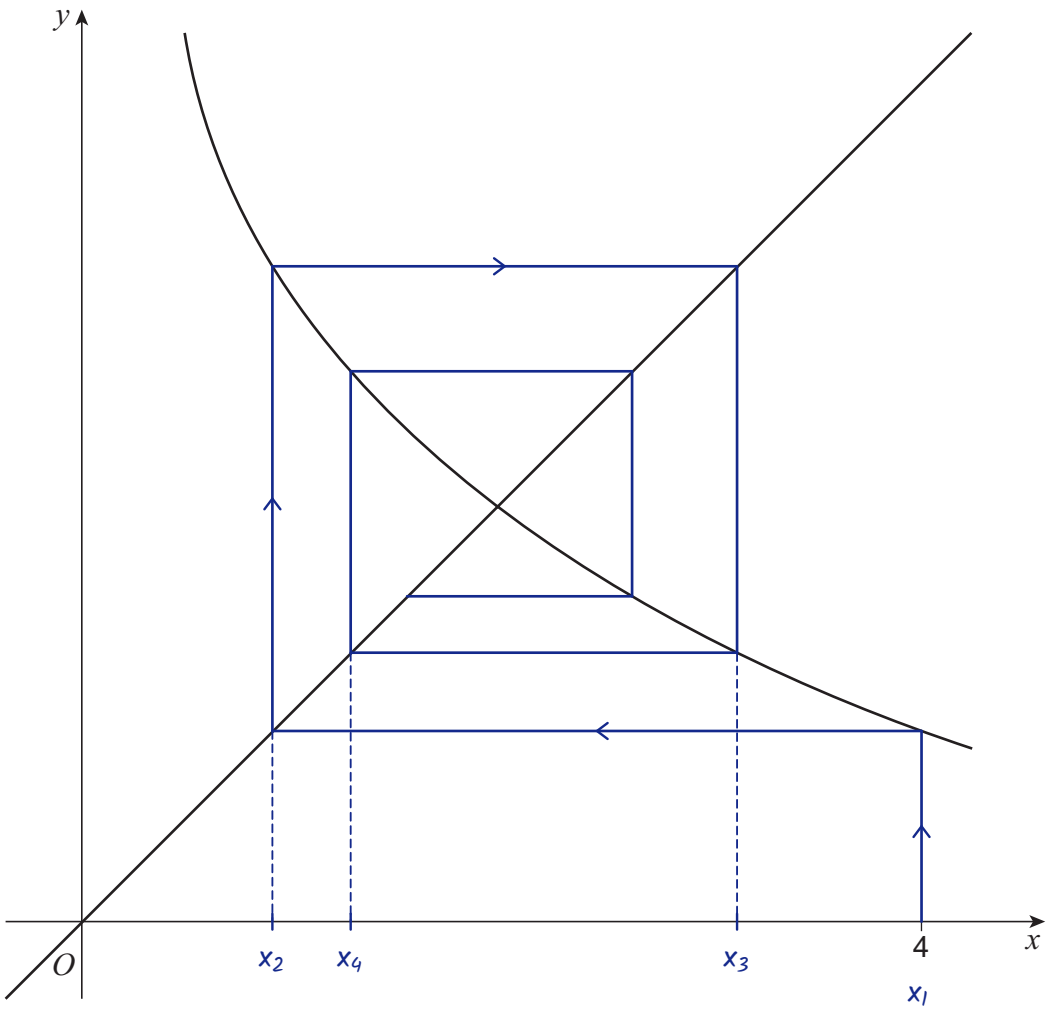
$$y = 3 - \frac{3}{2}\ln x \text{ and } y = x$$

On **Figure 1**, draw a staircase or cobweb diagram to show how convergence takes place.

Label, on the x-axis, the positions of x_2, x_3 and x_4

[2 marks]

Figure 1



Do not write outside the box

14 (c) (iii) Explain why the iterative formula

$$x_{n+1} = 3 - \frac{3}{2}\ln x_n$$

fails to converge to α when the starting value is $x_1 = 0$

[1 mark]

With $x_1 = 0$: $x_2 = 3 - \frac{3}{2}\ln 0$

but $\ln 0$ is undefined ($\ln x$ only exists for $x > 0$), so x_2 cannot be evaluated and the iteration fails.

Turn over for the next question

Do not write outside the box

15 (a) Show that the expression

$$\sin 2\theta \operatorname{cosec} \theta + \cos 2\theta \sec \theta$$

can be written as

$$4 \cos \theta - \sec \theta$$

where $\sin \theta \neq 0$ and $\cos \theta \neq 0$

[4 marks]

$\sin 2\theta \operatorname{cosec} \theta + \cos 2\theta \sec \theta$

$= 2 \sin \theta \cos \theta \times \frac{1}{\sin \theta} + (2\cos^2 \theta - 1) \times \frac{1}{\cos \theta}$

$= 2 \cos \theta + \frac{2\cos^2 \theta}{\cos \theta} - \frac{1}{\cos \theta}$

$= 2 \cos \theta + 2 \cos \theta - \sec \theta$

$= 4 \cos \theta - \sec \theta$ as required

Do not write outside the box

15 (b) A student is attempting to solve the equation

$$\sin 2\theta \operatorname{cosec} \theta + \cos 2\theta \sec \theta = 3 \text{ for } 0° \leq \theta \leq 360°$$

They use the result from part **(a)**, and write the following **incorrect** solution:

$$\sin 2\theta \operatorname{cosec} \theta + \cos 2\theta \sec \theta = 3$$

Step 1 $4 \cos \theta - \sec \theta = 3$

Step 2 $4 \cos \theta - \dfrac{1}{\cos \theta} - 3 = 0$

Step 3 $4 \cos^2 \theta - 3 \cos \theta - 1 = 0$

Step 4 $\cos \theta = 1$ or $\cos \theta = -0.25$

Step 5 $\theta = 0°, 104.5°, 255.5°, 360°$

15 (b) (i) Explain why the student should reject one of their values for $\cos \theta$ in Step 4.

[1 mark]

$\cos \theta = 1 \Rightarrow \sin \theta = 0$, so $\operatorname{cosec} \theta = \dfrac{1}{\sin \theta}$ is undefined

(we need $\sin \theta \neq 0$), so $\cos \theta = 1$ must be rejected.

15 (b) (ii) State the correct solutions to the equation

$$\sin 2\theta \operatorname{cosec} \theta + \cos 2\theta \sec \theta = 3 \text{ for } 0° \leq \theta \leq 360°$$

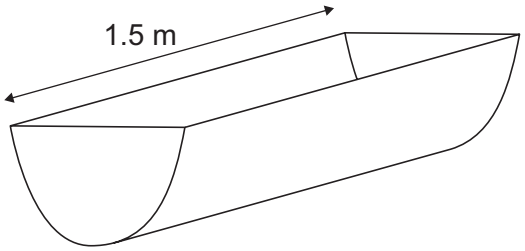
[1 mark]

$\theta = 104.5°, \ 255.5°$

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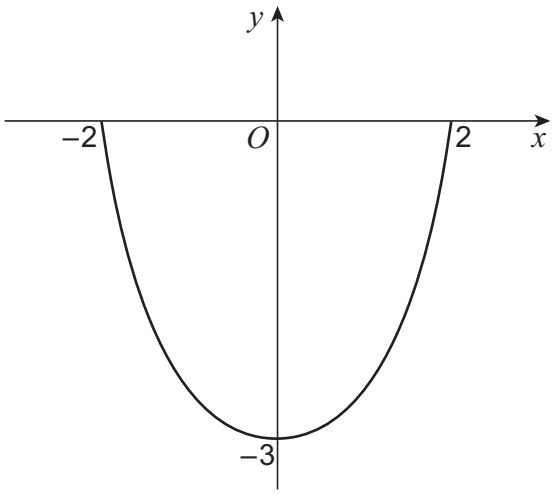
16 **Figure 2** below shows a 1.5 metre length of pipe.

Figure 2



The symmetrical cross-section of the pipe is shown below, in **Figure 3**, where x and y are measured in centimetres.

Figure 3



Do not write outside the box

Use the trapezium rule, with the values shown in the table below, to find the best estimate for the **volume** of the pipe.

x	0	0.4	0.8	1.2	1.6	2
y	–3	–2.943	–2.752	–2.353	–1.572	0

[5 marks]

The cross-section is symmetrical, so area = 2 × area from $x = 0$ to $x = 2$

$h = 0.4$

Area (0 to 2) $\approx \frac{0.4}{2}[3 + 0 + 2(2.943 + 2.752 + 2.353 + 1.572)]$

$= 0.2[3 + 2(9.62)] = 0.2 \times 22.24$

$= 4.448 \text{ cm}^2$

Area of cross-section $\approx 2 \times 4.448 = 8.896 \text{ cm}^2$

Length = 1.5 m = 150 cm

Volume $\approx 8.896 \times 150 = 1334.4 \text{ cm}^3$

Volume $\approx 1330 \text{ cm}^3$ (3 s.f.)

Turn over for the next question

Do not write outside the box

17 The function f is defined by

$$f(x) = |x| + 1 \text{ for } x \in \mathbb{R}$$

The function g is defined by

$$g(x) = \ln x$$

where g has its greatest possible domain.

17 (a) Using set notation, state the range of f

[2 marks]

$|x| \geq 0$ for all x, so $f(x) = |x| + 1 \geq 1$

Range of f: $\{y : y \geq 1\}$

17 (b) State the domain of g

[1 mark]

Domain of g: $\{x : x > 0\}$

17 (c) The composite function h is given by

$$h(x) = gf(x) \text{ for } x \in \mathbb{R}$$

17 (c) (i) Write down an expression for $h(x)$ in terms of x

[1 mark]

$h(x) = g(f(x)) = \ln(|x| + 1)$

Do not write outside the box

17 (c) (ii) Determine if h has an inverse.

Fully justify your answer.

[2 marks]

$h(1) = \ln(1 + 1) = \ln 2$ and $h(-1) = \ln(|-1| + 1) = \ln 2$

Two different values of x give the same value of h(x), so h is many-to-one (not one-to-one).

$\therefore$ h does not have an inverse.

Turn over for the next question

Do not write outside the box

18 (a) Use a suitable substitution to show that

$$\int_0^4 (4x+1)(2x+1)^{\frac{1}{2}}\,\mathrm{d}x$$

can be written as

$$\frac{1}{2}\int_a^9 \left(2u^{\frac{3}{2}} - u^{\frac{1}{2}}\right)\mathrm{d}u$$

where a is a constant to be found.

[5 marks]

Let $u = 2x + 1$

$\frac{du}{dx} = 2 \Rightarrow dx = \frac{1}{2}\,du$

$x = \frac{u-1}{2} \Rightarrow 4x + 1 = 2(u-1) + 1 = 2u - 1$

Limits: $x = 0 \Rightarrow u = 1$, $x = 4 \Rightarrow u = 9$

$\int_0^4 (4x+1)(2x+1)^{1/2}\,dx = \int_1^9 (2u-1)u^{1/2} \times \frac{1}{2}\,du$

$= \frac{1}{2}\int_1^9 (2u^{3/2} - u^{1/2})\,du$

$\therefore a = 1$

Do not write outside the box

18 (b) Hence, or otherwise, show that

$$\int_0^4 (4x+1)(2x+1)^{\frac{1}{2}}\,dx = \frac{1322}{15}$$

[4 marks]

$= \frac{1}{2}\left[\frac{2u^{5/2}}{5/2} - \frac{u^{3/2}}{3/2}\right]_1^9 = \frac{1}{2}\left[\frac{4}{5}u^{5/2} - \frac{2}{3}u^{3/2}\right]_1^9$

$= \frac{1}{2}\left[\left(\frac{4}{5} \times 9^{5/2} - \frac{2}{3} \times 9^{3/2}\right) - \left(\frac{4}{5} - \frac{2}{3}\right)\right]$

$= \frac{1}{2}\left[\left(\frac{4}{5} \times 243 - \frac{2}{3} \times 27\right) - \frac{2}{15}\right]$

$= \frac{1}{2}\left[\frac{972}{5} - 18 - \frac{2}{15}\right]$

$= \frac{1}{2}\left[\frac{2646}{15} - \frac{2}{15}\right] = \frac{1}{2} \times \frac{2644}{15}$

$= \frac{1322}{15}$ as required

Question 18 continues on the next page

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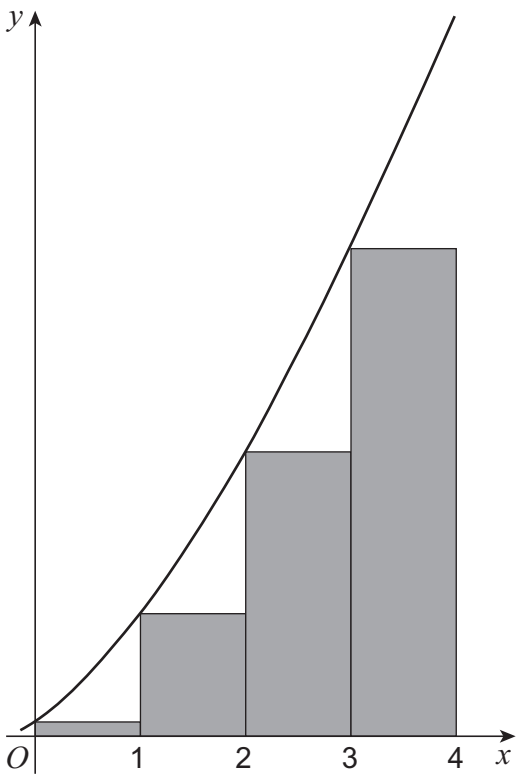
18 (c) A graph has the equation

$$y = (4x + 1)\sqrt{2x + 1}$$

A student uses four rectangles to approximate the area under the graph between the lines $x = 0$ and $x = 4$

The rectangles are all the same width.

All the rectangles are drawn under the curve as shown in the diagram below.



Do not write outside the box

The total area of the four rectangles is A

The student decides to improve their approximation by increasing the number of rectangles used.

Explain why the value of the student's improved approximation will be

greater than A, but less than $\frac{1322}{15}$

[2 marks]

$y = (4x + 1)\sqrt{2x + 1}$ is increasing for $0 \leq x \leq 4$, so the rectangles drawn under the curve leave gaps: A is an underestimate.

Using more rectangles fills more of the area under the curve, so the total area increases: the improved approximation will be greater than A.

But all the rectangles are still under the curve, so the total is still less than the exact area, which is $\int_0^4 (4x + 1)(2x + 1)^{1/2}\, dx = \frac{1322}{15}$

$\therefore$ $A <$ improved approximation $< \frac{1322}{15}$

Turn over for the next question

Do not write outside the box

19 A curve has equation

$$y^3e^{2x} + 2y - 16x = k$$

where k is a constant.

The curve has a stationary point on the y-axis.

Determine the value of k

[7 marks]

$y^3e^{2x} + 2y - 16x = k$

Differentiate implicitly (product rule on y^3e^{2x}):

$3y^2e^{2x}\frac{dy}{dx} + 2y^3e^{2x} + 2\frac{dy}{dx} - 16 = 0$

Stationary point on the y-axis: $x = 0$ and $\frac{dy}{dx} = 0$

$0 + 2y^3e^0 + 0 - 16 = 0$

$2y^3 = 16 \Rightarrow y^3 = 8 \Rightarrow y = 2$

Substitute $x = 0$, $y = 2$ into the equation of the curve:

$2^3e^0 + 2(2) - 16(0) = k$

$k = 8 + 4 = 12$

Do not write outside the box

20 A gardener stores rainwater in a cylindrical container.

The container has a height of 130 centimetres.

The gardener empties the water from the container through a hose.

The hose is attached 5 centimetres from the bottom of the container.

At time t minutes after the hose is switched on, the depth of water, h centimetres, in the container decreases at a rate which is proportional to $h - 5$

Initially the container of water is full, and the depth of water is decreasing at a rate of 1.5 centimetres per minute.

20 (a) Show that

$$\frac{\mathrm{d}h}{\mathrm{d}t} = -0.012(h - 5)$$

[3 marks]

$\frac{dh}{dt} = -k(h - 5)$, where k is a positive constant

Initially $h = 130$ and $\frac{dh}{dt} = -1.5$

$-1.5 = -k(130 - 5) = -125k$

$k = \frac{1.5}{125} = 0.012$

$\therefore \frac{dh}{dt} = -0.012(h - 5)$

Turn over ▶

Do not write outside the box

20 (b) Solve the differential equation

$$\frac{\mathrm{d}h}{\mathrm{d}t} = -0.012(h - 5)$$

to find an expression for h in terms of t

[5 marks]

$\frac{1}{h-5}\frac{dh}{dt} = -0.012$

$\int \frac{1}{h-5}\, dh = \int -0.012\, dt$

$\ln(h-5) = -0.012t + c$

$t = 0,\ h = 130:\quad c = \ln 125$

$\ln(h-5) = -0.012t + \ln 125$

$h - 5 = e^{-0.012t + \ln 125} = 125e^{-0.012t}$

$h = 5 + 125e^{-0.012t}$

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20 (c) Find the time taken for the container to be half empty.

Give your answer to the nearest minute.

[2 marks]

Half empty: $h = \frac{130}{2} = 65$

$5 + 125e^{-0.012t} = 65$

$e^{-0.012t} = \frac{60}{125} = 0.48$

$-0.012t = \ln 0.48$

$t = \frac{\ln 0.48}{-0.012} = 61.164...$

Time taken = 61 minutes

END OF QUESTIONS

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