CSSA

2023

TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

MARKING GUIDELINES

Mathematics Advanced

The Marking Guidelines show the criteria to be applied to responses along with the marks to be awarded in line with the quality of responses. These guidelines are suggested and not prescriptive. This is not intended to be an exhaustive list but rather an indication of the considerations that students could include in their responses.

Section I
10 marks

Questions 1-10 (1 mark each)

Question	Answer	Outcomes Assessed	Targeted Performance Bands
1	A	MA11-1, MA12-1	2-3
2	B	MA12-8	2-3
3	A	MA12-8	4
4	C	MA12-4	4
5	D	MA12-1	4-5
6	C	MA12-4	4-5
7	B	MA11-7, MA12-1	5
8	D	MA12-5	5
9	C	MA11-3, MA12-1	5-6
10	B	MA12-7	5-6

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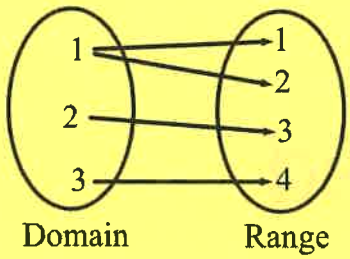
Question 1

Sample Answer:

Consider option A graphically:



The element (1) in the domain maps to two distinct elements (1 and 2) in the range, as seen by the two arrows pointing from the element 1 to the elements 1 and 2.

Elements (2) and (3) in the domain map to elements (3) and (4) in the range respectively.

Looking at this in reverse, from each element in the range, there is <u>at most</u> one arrow pointing back to an element in the domain, hence $(1, 1), (1, 2), (2, 3), (3, 4)$ represents a one-to-many relationship.

Options B, C and D represents a many-to-one, one-to-one and a many-to-many relationship respectively.

$\therefore$ Answer is option A

Question 2

Sample Answer:

Comparing the relative weights of the students, A is to the left of B, hence student A weighs less than student B which implies the answer could be either options B or D.

Comparing the relative heights of the students, A is above B, hence student A is taller than student B, which implies the answer could be either options A or B.

$\therefore$ Answer is option B.

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Question 3

Sample Answer:

Representing the information given on a box-and-whisker plot:

From the information given, $Q_1 = 40$,$Q_3 = 86$ and the max. score is 96.

Since the distribution is symmetrical with no outliers, the median is in the centre of Q_1 and Q_3.

$(40 + 86) \div 2 = 63$ ∴The median is 63

The distribution is symmetrical, hence the max. score $- Q_3$ is equal to $Q_1 -$ the min. score.

$96 - 86 = 40 -$ min. score ∴The minimum score is 30.

∴ Answer is option A.

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Question 4

Sample Answer:

The fourth term of the series may be found by

$T_4 = S_4 - S_3$

$= 36 - 21$

$= 15$

The sum of the first four terms is 36 and the fourth term is 15, hence the first term of the series may found by applying the sum of an arithmetic series formula $S_n = \frac{n}{2}(a + l)$ and solving for the first term a where $n = 4$, the last term $l = 15$ and $S_4 = 36$.

$$36 = \frac{4}{2}(a + 15)$$

$$18 = a + 15$$

$$\therefore a = 3$$

The common difference, d may be found by solving the equation $T_4 = a + (n - 1)d$.

$$15 = 3 + 3d$$

$$\therefore d = 4$$

The sum of the first five terms of the series is given by the formula

$$S_n = \frac{n}{2}(2a + (n - 1)d$$

$$S_5 = \frac{5}{2}(2 \times 3 + (5 - 1) \times 3) = 55$$

∴ Answer is option C.

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Question 5

Sample Answer:

Consider $f(g(x)) = \sqrt{\frac{1}{x-1}}$. The domain is $x > 1$ and the range is $y > 0$.

Consider $g(f(x)) = \frac{1}{\sqrt{x}-1}$. The domain is $0 \leq x < 1$ or $x > 1$ and the range is all real $y, y \neq 0$.

The domain that applies to both $f(g(x))$ and $g(f(x))$ is the intersection of their respective domains. Hence the intersection of $x > 1$ and $0 \leq x < 1$ or $x > 1$ is $x > 1$.

The range that applies to both $f(g(x))$ and $g(f(x))$ is the intersection of their respective ranges. Hence the intersection of $y > 0$ and all real $y, y \neq 0$ is $y > 0$.

$\therefore$ Answer is option D.

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Question 6

Sample Answer:

Let a be the first term and r be the common ratio of the geometric series.

The limiting sum is given by $\frac{a}{1-r} = \frac{10}{9}$ **[1]**.
The sum of the first three terms is given by $a + ar + ar^2 = a(1 + r + r^2) = \frac{26}{25}$ **[2]**.

Solve equations **[1]** and **[2]** simultaneously by expressing a in terms of r in **[1]** and substitute a for its equivalent expression in r in **[2]**.

From **[1]**: $a = \frac{10}{9}(1 - r)$.

From **[2]**: $\frac{10}{9}(1 - r)(1 + r + r^2) = \frac{26}{25}$ **[3]**.

Solve **[3]** for r by dividing both sides by $\frac{10}{9}$ then expanding the LHS and collect the like terms.

$$(1 - r)(1 + r + r^2) = \frac{117}{125}$$

$$1 + r + r^2 - r - r^2 - r^3 = \frac{117}{125}.$$

Collect the like terms on the LHS and make r^3 the subject:

$$1 - r^3 = \frac{117}{125} \rightarrow r^3 = \frac{8}{125}$$

Taking the cube root of both sides, $r = \frac{2}{5} = 0.4$.

∴ Answer is option C.

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Question 7

Sample Answer:

This is a two-stage experiment without replacement, hence

$$P(2 \text{ red}) = \frac{7}{n} \times \frac{6}{n-1}$$

$$= \frac{42}{n(n-1)}.$$

It is given that $P(2 \text{ red}) = \frac{21}{55}$.

Hence, $\frac{42}{n(n-1)} = \frac{21}{55}$. Expanding the brackets and cross-multiplying:

$$\frac{42}{n^2 - n} = \frac{21}{55}$$

$21n^2 - 21n = 2310$ which simplifies to $n^2 - n = 110$.

Moving all terms to the LHS, the quadratic equation is $n^2 - n - 110 = 0$.

∴ Answer is option B.

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Question 8

Sample Answer:

The particle is stationary at the maximum and minimum displacement, hence

One full period may be found by $\frac{17\pi}{12} - \frac{5\pi}{12} = \pi$. Hence $a = \frac{2\pi}{\pi} = 2$ and $x = k\cos(2t + b)$.

The velocity equation is $\dot{x} = -2k\sin(2t + b)$ and $\dot{x} = 0$ at time $t = \frac{5\pi}{12}$.

Solving for b: $-2k\sin(2 \times \frac{5\pi}{12} + b) = 0$

$$\sin\left(\frac{5\pi}{6} + b\right) = 0 \therefore b = \frac{\pi}{6}$$

The acceleration equation is $x = -4k\cos\left(2t + \frac{\pi}{6}\right)$.

The initial acceleration is $6\sqrt{3}$ ms^{-2}.

Solving for k: $-4k\cos\left(\frac{\pi}{6}\right) = 6\sqrt{3}$

$$-4k \times \frac{\sqrt{3}}{2} = 6\sqrt{3} \therefore k = -3$$

The complete displacement equation is $x = -3\cos\left(2t + \frac{\pi}{6}\right)$

∴ Answer is option D.

Question 9

Sample Answer:

The LHS of the equation is already in factor form.

Case 1: $\sin\theta - \frac{\sqrt{2}}{2} = 0$ has solutions $\theta = \frac{\pi}{4}, \frac{3\pi}{4}$.

Case 2: $\tan 2\theta - \frac{\sqrt{3}}{3} = 0$ has solutions $\theta = \frac{\pi}{12}, \frac{7\pi}{12}$.

However, both solutions from case 1 are invalid since $\tan 2\theta$ is undefined at those values. Therefore, there are two solutions in the given interval.

∴ Answer is option C.

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Question 10

Sample Answer:

This question involves definite integrals, so consider the signed areas.

By inspection of the graph and using the fact that $f(x)$ is even and $g(x)$ is odd, the following statements can be made:

$$\int_2^4 g(x)\,dx = \int_{-4}^{-2} f(x)\,dx + \int_2^4 f(x) - g(x)\,dx$$

$$= A + C$$

$$\int_0^2 g(x)\,dx = -\int_{-2}^{0} g(x)\,dx$$

$$= -B$$

Hence,

$$\int_0^4 g(x)\,dx = \int_0^2 g(x)\,dx + \int_2^4 g(x)\,dx = A + C - B$$

$\therefore$ Answer is option B.

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Section II
90 marks

Question 11 (2 marks)
Outcomes Assessed: MA12-8, MA12-10
Targeted Performance Bands: 2-3

Criteria	Marks
• Provides correct solution	2
• Determines the cumulative percentage of issues due to "Internet Speed", "Printer Error" and "Forgotten Password", or equivalent merit	1

Sample Answer:

Cumulative percentage of "Internet Speed", "Printer Error" and "Forgotten Password" is 77% (using the right-hand vertical axis).

The percentage of issues due to "Internet Speed" only is 34%.

The question is asking for the percentage of issues that involve "Printer Error" or "Forgotten Password" only, hence the percentage of issues due to Printer Error or Forgotten Password is $77\% - 34\% = 43\%$

$\therefore$ The percentage of issues due to Printer Error or Forgotten Password is 43%.

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Question 12 (2 marks)
Outcomes Assessed: MA11-1, MA11-5
Targeted Performance Bands: 3

Criteria	Marks
• Provides correct solution	2
• Finds the gradient of the normal at the point where $x = -1$, or equivalent merit	1

Sample Answer:

Differentiate the function to find the gradient function:

$$\frac{d}{dx}(x^3 - 2x) = 3x^2 - 2$$

The gradient of the tangent to the curve at the point where $x = -1$ is $3(-1)^2 - 2 = 1$.
The gradient of the normal at the same point is given by $m_2 = \frac{-1}{m_1}$ where $m_1 = 1$, therefore the gradient of the normal is -1

The equation of the normal is found by applying the point-gradient formula $y - y_1 = m(x - x_1)$ where $m = -1,\ x_1 = -1, y_1 = 1$.

$y - 1 = -1(x + 1)$
$y - 1 = -x - 1$ hence $y = -x$.

∴ The equation of the normal to the curve at the point $(-1, 1)$ is $y = -x$.

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Question 13 (2 marks)
Outcomes Assessed: MA11-1, MA12-1
Targeted Performance Bands: 2-3

Criteria	Marks
• Provides correct solution	2
• Models the scenario using the inverse variation equation and finds the value of k, or equivalent merit	1

Sample Answer:

Let the equation $t = \frac{k}{p}$ model the scenario, where p is the number people assigned to a task and t is the amount of time is takes to complete that task.

It takes five people to complete a task in four hours, hence $4 = \frac{k}{5} \therefore k = 20$.

Assigning eight people to the same task, the amount of time taken to complete the task is $t = \frac{20}{8}$ or 2.5 hours.

$\therefore$ The time it takes eight people to complete the same task is 2.5 hours.

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Question 14 (5 marks)
Question 14 (a) (2 marks)
Outcomes Assessed: MA12-2, MA12-10
Targeted Performance Bands: 3

Criteria	Marks
• Provides correct solution	2
• Determines the correct present value interest factor, or equivalent merit	1

Sample Answer:

Number of periods: $4 \times 12 = 48$
Interest rate per period (as a decimal): $4.2\% \div 12 = 0.0035$

From the table, the correct present value interest factor is 44.11376

The present value may by found by multiplying the monthly contribution with the present value interest factor.

$500 \times 44.11376 = 22056.88$

∴The present value of Anne's annuity is $22 056.88

Question 14 (b) (1 mark)
Outcomes Assessed: MA12-2, MA12-10
Targeted Performance Bands: 2-3

Criteria	Marks
• Provides correct solution	1

Sample Answer:

Apply the compound interest formula using the values from part (a):

$A = 22056.88(1 + 0.0035)^{48}$
$= 26084.23883$

∴The future value of Anne's annuity is $26 084.24

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Question 14 (c) (2 marks)
Outcomes Assessed: MA12-2, MA12-10
Targeted Performance Bands: 3-4

Criteria	Marks
• Provides correct solution	2
• Divides by the correct present value interest factor to determine the value of each monthly repayment, or equivalent merit	1

Sample Answer:

Correct present value interest factor is 41.00219

Monthly repayment is found by dividing the loan amount by the present value interest factor.

$$\text{Monthly repayment} = 49000 \div 41.00219$$
$$= 1195.06$$

$$\text{Total repayment} = 1195.06 \times 46$$
$$= 54972.76$$

$$\text{Total interest paid} = 54972.76 - 49000$$
$$= 5972.76$$

∴ The total amount of interest Trevor repays is $5972.76

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Question 15 (3 marks)
Question 15 (a) (1 mark)
Outcomes Assessed: MA12-6
Targeted Performance Bands: 2-3

Criteria	Marks
• Provides correct solution	1

Sample Answer:

By the chain rule:

$$\frac{dy}{dx} = 2(\ln x) \times \frac{1}{x}$$
$$= \frac{2\ln x}{x}$$

Question 15 (b) (2 marks)
Outcomes Assessed: MA12-7
Targeted Performance Bands: 4

Criteria	Marks
• Provides correct solution	2
• Rearranges the integrand to use the result from part (a), or equivalent merit	1

Sample Answer:

Rearrange the integrand to apply the result from part (a):

$$\int_1^e \frac{\ln(x^2)}{2x}\,dx = \frac{1}{2}\int_1^e \frac{\ln(x^2)}{x}\,dx$$
$$= \frac{1}{2}\int_1^e \frac{2\ln x}{x}$$

Reversing the result from part (a) to find the anti-derivative of the integrand:

$$= \frac{1}{2}[(\ln x)^2]_1^e$$
$$= \frac{1}{2}[(\ln e)^2 - (\ln 1)^2]$$
$$= \frac{1}{2}$$

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Question 16 (3 marks)
Outcomes Assessed: MA11-4, MA12-3, MA12-7
Targeted Performance Bands: 3-4

Criteria	Marks
• Provides correct solution	3
• Correctly integrates and attempts to find the constant of integration in exact form, or equivalent merit	2
• Applies a trigonometric identity to change the function into an integrable form, or equivalent merit	1

Sample Answer:

$$\int \tan^2 x \, dx = \int \sec^2 x - 1 \, dx$$

$$= \tan x - x + C$$

Finding the constant of integration C, given that the graph of the primitive function, $y = F(x)$, crosses the x-axis at $x = \frac{\pi}{3}$: i.e. $F\left(\frac{\pi}{3}\right) = 0$

$$\tan\frac{\pi}{3} - \frac{\pi}{3} + C = 0$$

$$C = \frac{\pi}{3} - \tan\frac{\pi}{3}$$

$$= \frac{\pi}{3} - \sqrt{3}$$

$$\therefore F(x) = \tan x - x + \frac{\pi}{3} - \sqrt{3}$$

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Question 17 (3 marks)
Question 17 (a) (1 mark)
Outcomes Assessed: MA11-4, MA12-10
Targeted Performance Bands: 4

Criteria	Marks
• Provides correct solution	1

Sample Answer:

$\sin\theta$ is odd, hence $-\sin\theta = \sin(-\theta)$.

$$f(x) = -\sin\left(\frac{1}{2}(x-\pi)\right)$$
$$= -\sin\left(\frac{x}{2} - \frac{\pi}{2}\right)$$
$$= \sin\left(\frac{\pi}{2} - \frac{x}{2}\right)$$
$$= \cos\left(\frac{x}{2}\right)$$

Which is an even function since $\cos\theta = \cos(-\theta)$, where $\theta = \frac{x}{2}$.

Question 17 (b) (2 marks)
Outcomes Assessed: MA12-7
Targeted Performance Bands: 3-4

Criteria	Marks
• Provides correct solution	2
• Correctly integrates either $\cos\left(\frac{x}{2}\right)$ or $-\sin\left(\frac{1}{2}(x-\pi)\right)$, or equivalent merit	1

Sample Answer:

The curve $y = \cos\left(\frac{x}{2}\right)$ has x-intercepts at $-\pi$ and π, and is above the x-axis in the interval $(-\pi, \pi)$.

$$\int_{-\pi}^{\pi} -\sin\left(\frac{1}{2}(x-\pi)\right)dx = 2\int_{0}^{\pi} \cos\left(\frac{x}{2}\right)dx$$
$$= 4\left[\sin\left(\frac{x}{2}\right)\right]_0^{\pi}$$
$$= 4\left[\sin\left(\frac{\pi}{2}\right) - \sin(0)\right]$$
$$= 4$$

$\therefore$ The area bounded by the curve and x-axis in the interval $[-\pi,\ \pi]$ is 4 square units.

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Alternatively,

$$\int_{-\pi}^{\pi} -\sin\left(\frac{1}{2}(x-\pi)\right)dx = 2\left[\cos\left(\frac{x}{2}-\frac{\pi}{2}\right)\right]_{-\pi}^{\pi}$$
$$= 2\left[\cos\left(\frac{\pi}{2}-\frac{\pi}{2}\right)-\cos\left(\frac{-\pi}{2}-\frac{\pi}{2}\right)\right]$$
$$= 4$$

∴ The area bounded by the curve and x-axis in the interval $[-\pi,\ \pi]$ is 4 square units.

Question 18 (5 marks)
Question 18 (a) (1 mark)
Outcomes Assessed: MA11-7
Targeted Performance Bands: 2-3

Criteria	Marks
• Provides correct solution	1

Sample Answer:

The sum of the probabilities of all the outcomes in the discrete probability distribution equals 1.

Hence, $0.75 + m + 0.03 + 0.002 + 0.001 + 0.0001 = 1$

$\therefore m = 0.2169$

Question 18 (b) (2 marks)
Outcomes Assessed: MA11-7, MA12-10
Targeted Performance Bands: 3-4

Criteria	Marks
• Provides correct solution	2
• Calculates $E(X)$, or equivalent merit	1

Sample Answer:

$E(X)$ represents the average amount of money won each time this lottery is played.

$$E(X) = (0 \times 0.75) + (20 \times 0.2169) + (100 \times 0.03) + (500 \times 0.002) + (5000 \times 0.001) + (10000 \times 0.0001)$$
$$= 14.338$$

The average amount of money won each time the lottery is played is \$14.34

However, each ticket costs \$20, hence the average loss is $20 - 14.34 = 5.66$.

∴ Jason loses \$5.66 on average every time he plays this lottery.

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Question 18 (c) (2 marks)
Outcomes Assessed: MA11-7
Targeted Performance Bands: 3-4

Criteria	Marks
• Provides correct solution	2
• Some progress toward the correct solution, such as using STAT mode to get σ without squaring to get Var(X), or working toward manually finding Var(X) using the formula.	1

Sample Answer:

$$\begin{aligned}\text{Var}(X) &= E(X^2) - \big(E(X)\big)^2 \\ &= (0^2 \times 0.75) + (20^2 \times 0.2169) + (100^2 \times 0.03) + (500^2 \times 0.002) + (5000^2 \times 0.001) \\ &\quad + (10000^2 \times 0.0001) - 14.388^2 \\ &= 35\,679.74546\ldots\end{aligned}$$

Alternatively,

Using STAT mode on the calculator, $\sigma = 188.8908\ldots$

$$\begin{aligned}\text{Var}(X) &= \sigma^2 \\ &= (188.8908\ldots)^2 \\ &= 35679.74546\ldots\end{aligned}$$

$\therefore$ The variance is 35 679.74, correct to two decimal places.

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Question 19 (7 marks)

Question 19 (a) (1 mark)

Outcomes Assessed: MA11-6, MA12-1

Targeted Performance Bands: 2-3

Criteria	Marks
• Provides correct solution	1

Sample Answer:

Evaluate T at time $t = 0$:

$$T = 175 - 150 \times (0.9)^{0.2 \times 0}$$
$$= 25$$

$\therefore$ Initial temperature of the oven was 25°C.

Question 19 (b) (3 marks)

Outcomes Assessed: MA12-1

Targeted Performance Bands: 3-4

Criteria	Marks
• Provides correct solution	3
• Attempts to use the two-point gradient formula with some incorrect values, or equivalent merit	2
• States that the average rate of change of temperature is the gradient between the two points given, or equivalent merit	1

Sample Answer:

Average rate of change of temperature is the gradient between the points where $t = 25$ and $t = 75$.

Apply the two-point gradient formula to find the gradient of the chord between the given points:

$$m = \frac{T(75) - T(25)}{75 - 25}$$
$$= \frac{144.1163302 - 86.4265}{50}$$
$$= 1.15379 \ldots$$

$\therefore$ The average rate of change of temperature is 1.15°C per minute, correct to two decimal places.

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Question 19 (c) (3 marks)

Outcomes Assessed: MA11-6, MA12-1

Targeted Performance Bands: 4

Criteria	Marks
• Provides correct solution	3
• Correctly differentiates T but incorrectly solves for t, or equivalent merit	2
• Attempts to differentiate T and solve for t the equation $T' = 1$, or equivalent merit	1

Sample Answer:

Differentiate T and solve for t the equation $T' = 1$.

$T' = -150 \times 0.2 \times \ln(0.9) \times (0.9)^{0.2t}$

Let $T' = 1$ and solve for t.

$-150 \times 0.2 \times \ln(0.9) \times (0.9)^{0.2t} = 1$

$(0.9)^{0.2t} = 1 \div (-150 \times 0.2 \times \ln(0.9))$
$= 0.3163740527$

$\ln(0.9^{0.2t}) = \ln 0.3163740527$

$0.2 \times t \times \ln 0.9 = \ln 0.3163740527$

$t = \ln 0.3163740527 \div \ln 0.9 \div 0.2$
$= 54.61391524 \ldots$
$= 55$

Earliest time that Ben can place the cake in the oven is 55 minutes past 10:30 am

$\therefore$ The earliest time Ben can place the cake in the oven is 11:25 am

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Question 20 (3 marks)
Outcomes Assessed: MA11-7, MA12-1
Targeted Performance Bands: 4

Criteria	Marks
• Provides correct solution	3
• Finds the value of x by applying conditional probability, or equivalent merit	2
• Attempts to use conditional probability to find the value of x, or equivalent merit	1

Sample Answer:

From the information given, $P(\text{cat}|\text{dog}) = 0.6$.

From the table, $A + 32$ students own a dog, of which A students own a cat

Forming an appropriate equation to solve for A:

$$\frac{A}{A+32} = 0.6$$

$$A = 0.6A + 19.2$$

$0.4A = 19.2 \therefore A = 48$ which represents the number of students that own both a cat and a dog.

The total number of students surveyed is $48 + 32 + 45 + 35 = 160$

$$P(\text{cat and dog}) = \frac{48}{160}$$
$$= \frac{3}{10}$$
$$= 30\%$$

$\therefore$ The probability of a student chosen randomly that owns both a cat and a dog is 30%.

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Question 21 (2 marks)
Outcomes Assessed: MA11-6, MA12-10
Targeted Performance Bands: 4

Criteria	Marks
• Provides correct solution	2
• Attempts to solve the logarithmic equation for the ratio $\frac{N}{N_0}$, or equivalent merit	1

Sample Answer:

Let $R = 8$ and solve for the ratio $\frac{N}{N_0}$

$$20 \log_{10}\left(\frac{N}{N_0}\right) = 8$$

$$\log_{10}\left(\frac{N}{N_0}\right) = 0.4$$

$$\frac{N}{N_0} = 10^{0.4} = 2.511886 \ldots$$

$\therefore$ The noise level approximately 2.5 times the maximum noise level permitted.

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Question 22 (3 marks)
Question 22 (a) (1 mark)
Outcomes Assessed: MA12-8
Targeted Performance Bands: 3-4

Criteria	Marks
• Provides correct solution	1

Sample Answer:

$P(z > -1.2) = P(z < 1.2)$ due to the symmetry of the normal distribution.

From the table, $P(z < 1.2) = 0.885$.

∴ The probability that the random variable lies above -1.2 is 0.885, or 88.5%.

(b) (2 marks)
Outcomes Assessed: MA12-8
Targeted Performance Bands: 4

Criteria	Marks
• Provides correct solution	2
• Calculates appropriate z-scores, or equivalent merit	1

Sample Answer:

z-score corresponding to 599 mL is given by

$$z = \frac{599 - 602}{2.5}$$
$$= -1.2$$

z-score corresponding to 604 mL is given by

$$z = \frac{604 - 602}{2.5}$$
$$= 0.8$$

$$P(-1.2 < z < 0.8) = P(-1.2 < z < 0) + P(0 < z < 0.8)$$
$$= (0.885 - 0.5) + (0.788 - 0.5)$$
$$= 0.673$$

∴The percentage of bottles that contain between 599 mL and 604 mL of water is 67.3%

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Question 23 (5 marks)
Outcomes Assessed: MA12-8, MA12-9
Targeted Performance Bands: 4-5

Criteria	Marks
• Provides correct solution	5
• Finds both equations for income and expenses, and correctly graphs one of the lines, or equivalent merit	4
• Finds both equations for income and expenses, or equivalent merit	3
• Finds the equation of the least-squares regression line for Ivy's income, or equivalent merit	2
• Finds the equation of Ivy's expenses, or equivalent merit	1

Sample Answer:

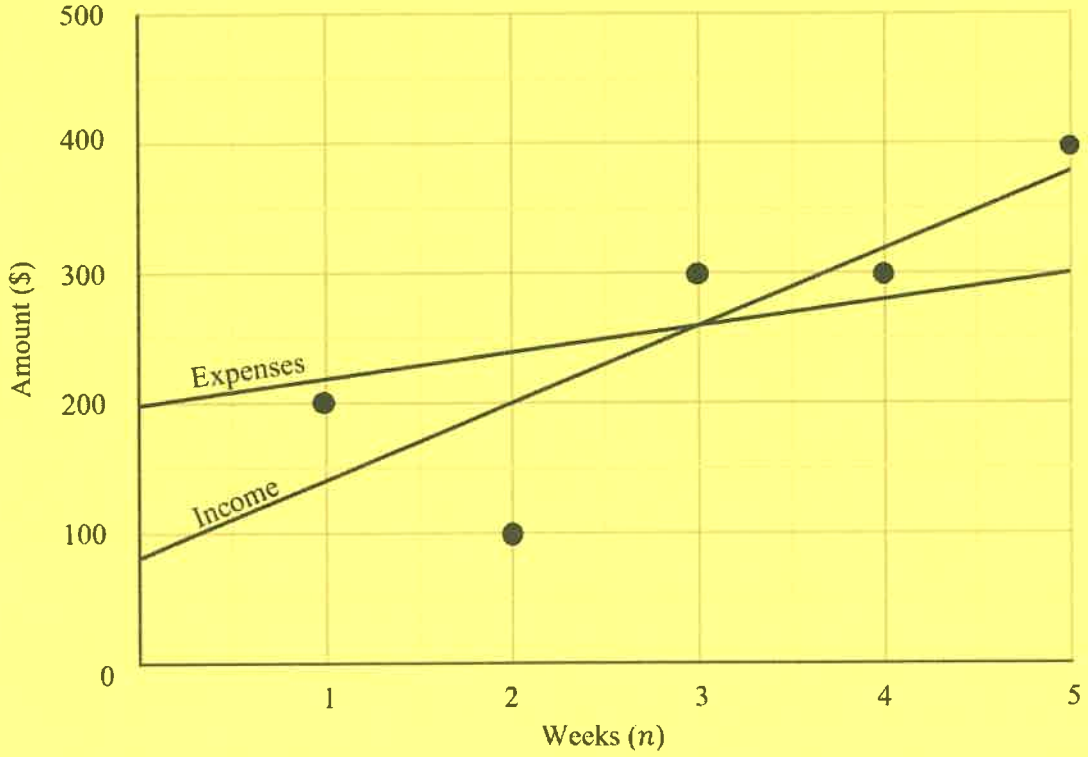
Using STAT mode on the calculator and the bivariate data provided from the graph, the equation of the least-squares regression line is

$$\text{Income} = 60n + 80$$

Equation for Ivy's expenses is

$$\text{Expenses} = 20n + 200$$

The graphs of the lines representing income and expenses are shown below.



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Question 24 (3 marks)
Question 24 (a) (2 marks)
Outcomes Assessed: MA12-7
Targeted Performance Bands: 4

Criteria	Marks
• Provides correct solution	2
• Attempts to use the Trapezoidal rule, or equivalent merit	1

Sample Answer:

The distance between the parallel sides of each trapezium is 1 unit, hence $h = 1$.

$$\text{Volume} \approx \frac{1}{2}(10 + 2 \times 3.68 + 2 \times 2.43 + 1.77)$$

$$\approx 11.995$$

$\therefore$ The volume of air in the balloon at time $t = 3$ by the Trapezoidal rule is 11.995 cubic units.

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Question 24 (b) (1 mark)
Outcomes Assessed: MA12-10
Targeted Performance Bands: 4-5

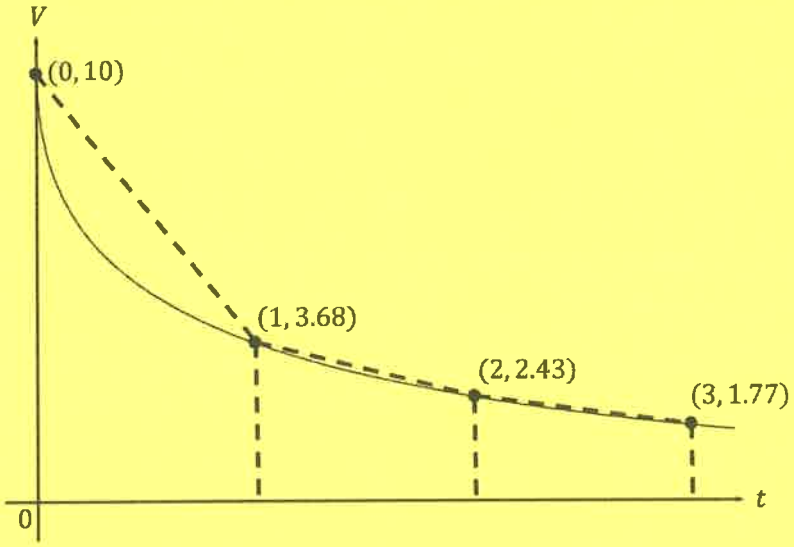
Criteria	Marks
• Graphically references the concavity of the graph and deduces that the Trapezoidal rule overestimates the volume of air OR • Draws the trapeziums over the graph and observes that the sum of the area of the trapeziums is greater than the area under the curve OR • Finds V' and shows that the curve is monotonic decreasing for $t > 0$ and hence the Trapezoidal rule will overestimate the area under the curve	1

Sample Answer:

The graph is concave up from $t = 0$ to $t = 3$, hence the Trapezoidal rule will overestimate the actual volume of air in the balloon, hence the safety shutoff valve will be activated before the balloon reaches bursting point.

In other words, the actual amount of air in the balloon will be less than what is estimated using the Trapezoidal rule.

Graphically, it can be observed that the Trapezoidal rule will overestimate the volume of air in the balloon as shown.



Alternatively,

$$V'' = \frac{5e^{-\sqrt{t}}\left(\sqrt{t}+1\right)}{2t\sqrt{t}}$$

The curve is concave up since $V'' > 0$ for $t > 0$, hence the Trapezoidal rule will overestimate the actual volume of air in the balloon.

$\therefore$ The Trapezoidal rule is a valid method of estimation in this context.

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Question 25 (6 marks)
Question 25 (a) (2 marks)
Outcomes Assessed: MA12-1, MA12-10
Targeted Performance Bands: 4-5

Criteria	Marks
• Provides correct solution	2
• Some progress toward showing that $A = \pi r^2 + \frac{2V}{\pi}\left(\frac{2+\pi}{r}\right)$	1

Sample Answer:

The volume of a half-cylinder is given by

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

Make h the subject

$$h = \frac{2V}{\pi r^2} \quad [1]$$

The surface area of a closed half-cylinder (half-cylinder with a rectangular lid), in terms of h and r, is given by

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

From **[1]**:

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

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Question 25 (b) (3 marks)
Outcomes Assessed: MA12-3, MA12-6, MA12-10
Targeted Performance Bands: 4-5

Criteria	Marks
• Provides correct solution	3
• Shows that a stationary point exists at $r = \sqrt[3]{\frac{V(2+\pi)}{\pi^2}}$ but does not use the second derivative to show that it is a minimum, or equivalent merit	2
• Attempts to differentiate A in terms of r, or equivalent merit	1

Sample Answer:

$$\frac{dA}{dr} = 2\pi r - \frac{2V}{\pi}\left(\frac{2+\pi}{r^2}\right)$$

Solve for r the equation $\frac{dA}{dr} = 0$:

$$2\pi r - \frac{2V}{\pi}\left(\frac{2+\pi}{r^2}\right) = 0$$
$$2\pi r = \frac{2V}{\pi}\left(\frac{2+\pi}{r^2}\right)$$
$$2\pi r^3 = \frac{2V}{\pi}(2+\pi)$$
$$r^3 = \frac{V}{\pi^2}(2+\pi)$$
$$r = \sqrt[3]{\frac{V(2+\pi)}{\pi^2}}$$
$$\frac{d^2A}{dr^2} = 2\pi + \frac{4V}{\pi}\left(\frac{2+\pi}{r^3}\right)$$
> 0 for all positive values of radius r

$\therefore r = \sqrt[3]{\frac{V(2+\pi)}{\pi^2}}$ minimises the amount of sheet metal used.

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Question 25 (c) (1 mark)
Outcomes Assessed: MA12-1
Targeted Performance Bands: 3-4

Criteria	Marks
• Provides correct solution	1

Sample Answer:

From part (b):

$$r = \sqrt[3]{\frac{10(2+\pi)}{\pi^2}}$$

$$= 1.733535103 \ldots$$

From part (a):

$$V = \frac{1}{2}\pi r^2 h$$

Make h the subject

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

$$= \frac{2 \times 10}{\pi \times 1.733535103^2}$$

$$= 2.1184 \ldots$$

$\therefore$ The height of the tank is 2.12 m, correct to two decimal places.

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Question 26 (5 marks)
Question 26 (a) (2 marks)
Outcomes Assessed: MA11-3, MA12-1
Targeted Performance Bands: 3-4

Criteria	Marks
• Provides correct solution	2
• Finds angle AMB and attempts to use the area rule for triangles, or equivalent merit	1

Sample Answer:

$$\angle AMB = 120° - 45°$$
$$= 75°$$

Using the area rule for triangles:

$$10432 = \frac{1}{2} \times 100 \times BM \times \sin 75°$$

$$BM = 10432 \times 2 \div 100 \div \sin 75°$$
$$= 216.000 \ldots$$

$\therefore$The distance between the base of the mast M and the peg at B is 216 m.

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Question 26 (b) (3 marks)
Outcomes Assessed: MA11-3. MA12-1
Targeted Performance Bands: 5

Criteria	Marks
• Provides correct solution	3
• Finds the length of either AT and BT, or equivalent merit	2
• Recognises there are two right-angle triangles with a common height MT and forms a pair of equations involving Pythagoras' theorem, or equivalent merit	1

Sample Answer:

$AT + BT = 380$ since there is a total of 380 m of support wire used.

Consider right-angled triangle AMT: $MT^2 = AT^2 - 100^2$ **[1]**
Consider right-angled triangle BMT: $MT^2 = BT^2 - 216^2$ **[2]**

Equating **[1]** and **[2]** and expressing BT in terms of AT:

$$AT^2 - 100^2 = (380 - AT)^2 - 216^2$$
$$AT^2 - 100^2 = 380^2 - 760AT + AT^2 - 216^2$$
$$760AT = 380^2 - 216^2 + 100^2$$
$$AT = \frac{13468}{95}$$

From **[1]**:

$$MT = \sqrt{\left(\frac{13468}{95}\right)^2 - 100^2} = 100.490\ldots$$

$\therefore$ The height of the tower is 100.49 m, correct to two decimal places.

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Question 27 (4 marks)
Outcomes Assessed: MA12-1
Targeted Performance Bands: 4-5

Criteria	Marks
• Provides correct solution	4
• Finds the equation of the transformed function and attempts to sketch its graph, or equivalent merit	3
• Finds the equation of the transformed function without the sketching its graph, or equivalent merit	2
• Expresses $f(x)$ as perfect square $(x+1)^2$, or establishes that the graph of $f(x)$ is a concave up parabola with vertex at $(-1, 0)$, or equivalent merit	1

Sample Answer:

$f(x) = (x+1)^2$, which is a concave up parabola with vertex at $(-1, 0)$.

Consider the horizontal transformations:

- Horizontal translation to the right by 4 units:
  - $f(x) = (x+1-4)^2 \rightarrow f(x) = (x-3)^2$
- Horizontal dilation by a factor of $\frac{4}{3}$:
  - $f(x) = \left(\frac{3x}{4} - 3\right)^2$

Consider the vertical transformations:

- Vertical dilation by a factor of $\frac{1}{3}$:
  - $f(x) = \frac{1}{3}\left(\frac{3x}{4} - 3\right)^2$
- Vertical translation down by 3 units:
  - $f(x) = \frac{1}{3}\left(\frac{3x}{4} - 3\right)^2 - 3$
- Reflection in the x-axis:
  - $f(x) = -\frac{1}{3}\left(\frac{3x}{4} - 3\right)^2 + 3$

Which is a concave down parabola with vertex at $(4, 3)$, passing through the origin with the other x-intercept at $x = 8$.

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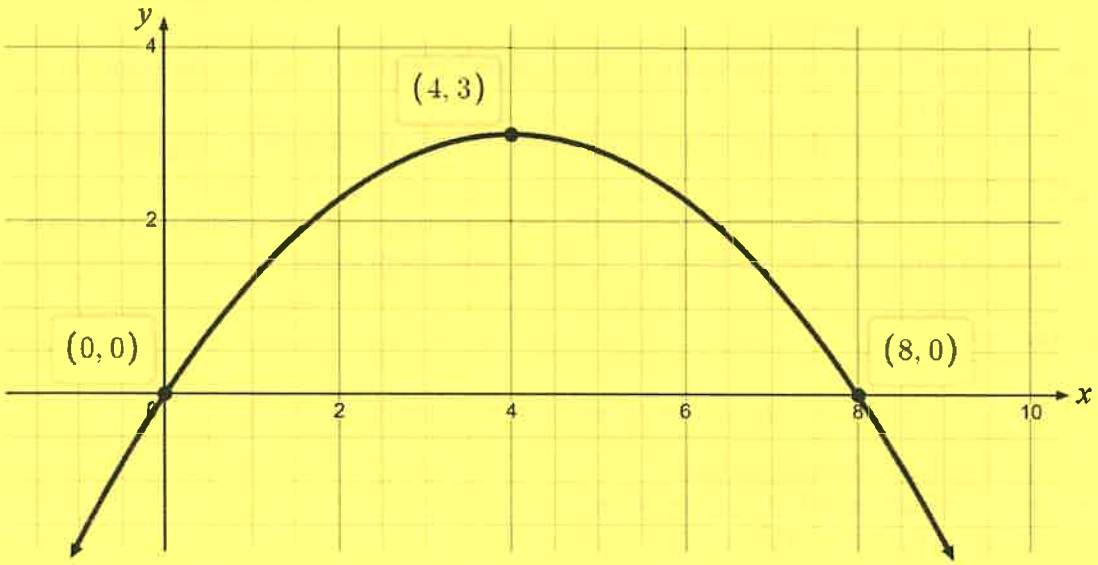
Question 27

The graph of the transformed function is shown below with the vertex and axis intercepts shown.



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Question 28 (7 marks)
Question 28 (a) (2 marks)
Outcomes Assessed: MA12-3
Targeted Performance Bands: 3-4

Criteria	Marks
• Provides correct solution	2
• Correctly differentiates the displacement equation to find an equation for $\dot{x}$, or equivalent merit	1

Sample Answer:

$$\dot{x} = \frac{4t}{t^2+3} - 1$$

The particle is at rest when $\dot{x} = 0$.

$$\frac{4t}{t^2+3} - 1 = 0$$

$$4t - t^2 - 3 = 0$$

$$t^2 - 4t + 3 = 0$$

$$(t-1)(t-3) = 0 \therefore t = 1, 3$$

$\therefore$ The particle is at rest at time $t = 1$ and $t = 3$

Question 28 (b) (2 marks)
Outcomes Assessed: MA12-1, MA12-3
Targeted Performance Bands: 3-4

Criteria	Marks
• Provides correct solution	2
• Forms an expression that represents the distance travelled in the first second which is not in the form specified in the question, or equivalent merit	1

Sample Answer:

Distance travelled is difference between the particle's displacement at time $t = 0$ and $t = 1$.

$$\begin{aligned} x(1) - x(0) &= (2\ln(1^2+3) - 1) - (2\ln(0^2+3) - 0) \\ &= 2\ln 4 - 1 - 2\ln 3 \\ &= \ln 16 - \ln 9 - 1 \\ &= \ln\left(\frac{16}{9}\right) - 1 \end{aligned}$$

$\therefore$ The distance travelled in the first second is $\ln\left(\frac{16}{9}\right) - 1$.

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Question 28 (c) (3 marks)
Outcomes Assessed: MA12-3, MA12-6
Targeted Performance Bands: 4-5

Criteria	Marks
• Provides correct solution	3
• Finds the time at which the maximum speed occurs	2
• Attempts to use the quotient rule to find an expression for $\ddot{x}$, or equivalent merit	1

Sample Answer:

Use the quotient rule to differentiate the expression for $\dot{x}$ from part (a).

$$\ddot{x} = \frac{4(t^2+3) - 4t \times 2t}{(t^2+3)^2}$$

$$= \frac{-4t^2 + 12}{(t^2+3)^2}$$

The maximum velocity occurs when $\ddot{x} = 0$.

$\ddot{x} = 0$ when the numerator $-4t^2 + 12 = 0$

$4t^2 = 12$

$t^2 = 3$

$t = \sqrt{3}, t \geq 0.$

∴The maximum velocity occurs at time $t = \sqrt{3}$ seconds.

The velocity at time $t = \sqrt{3}$ is given by

$$\dot{x} = \frac{4\sqrt{3}}{\left(\sqrt{3}\right)^2 + 3} - 1$$

$$= 0.1547 \ldots$$

Examining the behaviour of the velocity curve, $\dot{x} \to -1$ as $t \to \infty$ and $\dot{x} = -1$ at $t = 0$.

∴ The maximum velocity is 0.1547 ms^{-1}.

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Question 29 (7 marks)
Question 29 (a) (3 marks)
Outcomes Assessed: MA12-3, MA12-6, MA12-10
Targeted Performance Bands: 5-6

Criteria	Marks
• Provides correct solution	3
• Finds all stationary points and partially determines their nature, or equivalent merit	2
• Correctly differentiates $f(x)$ and finds one of the stationary points, or equivalent merit	1

Sample Answer:

Apply the product rule and chain rule to differentiate $f(x)$:

$$f'(x) = 3\left(1-\frac{x}{4}\right)^3 + 3x \times 3\left(1-\frac{x}{4}\right)^2 \times \left(-\frac{1}{4}\right)$$

$$= 3\left(1-\frac{x}{4}\right)^3 - \frac{9x}{4}\left(1-\frac{x}{4}\right)^2$$

$$= 3\left(1-\frac{x}{4}\right)^2\left(1-\frac{x}{4}-\frac{3x}{4}\right) = 3\left(1-\frac{x}{4}\right)^2(1-x)$$

Solving $f'(x) = 0$, stationary points exist at $x = 1$ and $x = 4$.

$$f(1) = \frac{145}{64}, f(4) = 1$$

Hence the coordinates of the stationary points are $\left(1, \frac{145}{64}\right)$ and $(4, 1)$.

The first derivative may be used to determine the nature of the stationary points by testing values of $f'(x)$ around the stationary points.

x	0	1	2	4	5
$f'(x)$	3	0	$-\frac{3}{4}$	0	$-\frac{3}{4}$
Gradient	↗	→	↘	→	↘

From the table of gradients, the stationary point at $\left(1, \frac{145}{64}\right)$ is a local maximum, and the stationary point at $(4, 0)$ is a horizontal point of inflection.

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Question 29 (b) (1 mark)
Outcomes Assessed: MA12-10
Targeted Performance Bands: 4-5

Criteria	Marks
• Provides correct solution	1

Sample Answer:

Find the values of $f(x)$ at $x = 5$ and $x = 6$.

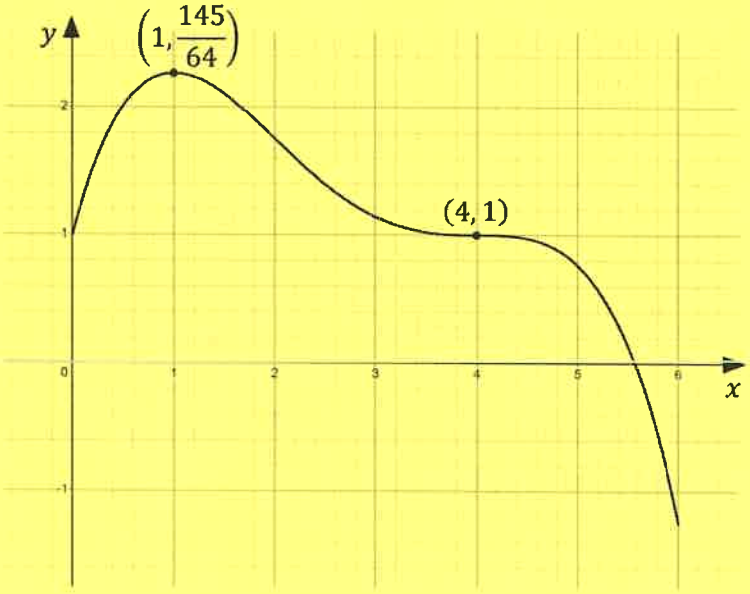
$f(5) = \frac{49}{64}, f(6) = -\frac{5}{4}$

The curve is above the x-axis at $x = 5$ and below the x-axis at $x = 6$. Since the curve is continuous in the interval (no asymptotes or breaks), $f(x) = 0$ somewhere between $x = 5$ and $x = 6$, hence its graph must cross the x-axis at least once in the interval given.

Question 29 (c) (3 marks)
Outcomes Assessed: MA12-1
Targeted Performance Bands: 4-5

Criteria	Marks
• Provides correct solution	3
• Sketches the graph of $y = f(x)$ showing some of the details e.g. correct shape but incorrect location, or stationary points not shown, or axes intercepts not shown, or equivalent merit	2
• Sketches the graph of $y = f(x)$ not showing any details, or equivalent merit	1

Sample Answer:



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Question 30 (5 marks)
Question 30 (a) (2 marks)
Outcomes Assessed: MA12-2, MA12-4
Targeted Performance Bands: 4-5

Criteria	Marks
• Provides correct solution	2
• Finds an expression for A_2, or equivalent merit	1

Sample Answer:

$$A_1 = 500000 \times 1.03 - 25000$$

$$A_2 = A_1 \times 1.03 - 25000 \times 1.05$$
$$= (500000 \times 1.03 - 25000) \times 1.03 - 25000 \times 1.05$$
$$= 500000 \times 1.03^2 - 25000(1.05 + 1.03)$$

$$A_3 = A_2 \times 1.03 - 25000 \times 1.05^2$$
$$= \left(500000 \times 1.03^2 - 25000(1.05 + 1.03)\right) \times 1.03 - 25000 \times 1.05^2$$
$$= 500000(1.03)^3 - 25000(1.05)(1.03) - 25000(1.03)^2 - 25000(1.05)^2$$
$$= 500000(1.03)^2 - 25000(1.05^2 + (1.05)(1.03) + 1.03^2)$$

$\therefore A_3 = 500000(1.03)^2 - 25000(1.05^2 + (1.05)(1.03) + 1.03^2)$ as required.

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Question 30 (b) (3 marks)
Outcomes Assessed: MA12-2, MA12-4
Targeted Performance Bands: 5-6

Criteria	Marks
• Provides correct solution	3
• Forms an expression for A_n using the formula for the sum of a geometric series, or equivalent merit	2
• Makes some progress toward the solution, such as recognising the pattern beyond $n = 3$, or recognising that the pattern may be modelled using a geometric series with common ratio $\frac{1.05}{1.03}$, or equivalent merit	1

Sample Answer:

Extending the pattern from part (a) to find an expression for A_4:

$$A_4 = 500000(1.03)^4 - 25000(1.05^3 + (1.05)^2(1.03) + (1.05)(1.03)^2 + 1.03^3)$$

$$= 500000(1.03)^4 - 25000(1.03)^3\left(\left(\frac{\mathbf{1.05}}{\mathbf{1.03}}\right)^{\mathbf{3}} + \left(\frac{\mathbf{1.05}}{\mathbf{1.03}}\right)^{\mathbf{2}} + \left(\frac{\mathbf{1.05}}{\mathbf{1.03}}\right) + \mathbf{1}\right)$$

The expression in **bold** is a geometric series with common ratio $\frac{1.05}{1.03}$.

Hence, an expression for A_n may be generalised from A_4:

$$A_n = 500000(1.03)^n - 25000(1.03)^{n-1}\left(\frac{1 - \left(\frac{1.05}{1.03}\right)^n}{1 - \frac{1.05}{1.03}}\right)$$

Let $A_n = 0$ and solve for n:

$$500000(1.03) = 25000\left(\frac{1 - \left(\frac{1.05}{1.03}\right)^n}{1 - \frac{1.05}{1.03}}\right)$$

$$\frac{103}{5}\left(1 - \frac{1.05}{1.03}\right) = 1 - \left(\frac{1.05}{1.03}\right)^n$$

$$\left(\frac{1.05}{1.03}\right)^n = 1 - \frac{103}{5}\left(1 - \frac{1.05}{1.03}\right)$$

$$n = \ln\left(1 - \frac{103}{5}\left(1 - \frac{1.05}{1.03}\right)\right) \div \ln\left(\frac{1.05}{1.03}\right) = 17.496\ldots$$

Value must be rounded down to the nearest integer, as Aida can only withdraw money according to the schedule given in the question for 17 whole years.

∴ Aida can withdraw money for 17 complete years.

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Question 31 (5 marks)
Question 31 (a) (2 marks)
Outcomes Assessed:MA12-7, MA12-8
Targeted Performance Bands: 5

Criteria	Marks
• Provides correct solution	2
• Forms an equation involving the sum of two integrals equal to 1 and attempts to solve for k, or equivalent merit	1

Sample Answer:

$$k\int_1^2 (t-1)^2\,dt + k\int_2^4 \left(2-\frac{t}{2}\right)dt = 1$$

$$k\left[\frac{1}{3}(t-1)^3\right]_1^2 + k\left[2t-\frac{t^2}{4}\right]_2^4 = 1$$

$$\frac{k}{3} + k = 1$$

$$k + 3k = 3$$

$$\therefore k = \frac{3}{4}$$

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Question 31 (b) (3 marks)
Outcomes Assessed: MA12-7, MA12-8
Targeted Performance Bands: 5-6

Criteria	Marks
• Provides correct solution	3
• Finds an appropriate expression for $F(t)$ and attempts to solve for t using the quadratic formula, or equivalent merit	2
• Recognises that $0.88 - F(2.16) = 0.5148$ and $2 < 2.16 < 4$, hence only need to use $f(t) = k\left(2 - \frac{t}{2}\right)$, or equivalent merit	1

Sample Answer:

Let t be the least amount of time taken to produce 88% of the parts.

$0.88 - F(2.16) = 0.5148$, hence only need to use $f(t) = k\left(2 - \frac{t}{2}\right)$ since $2 < 2.16 < 4$.

$$\frac{3}{4}\int_{2.16}^{t}\left(2 - \frac{x}{2}\right)dx = 0.5148$$

$$\frac{3}{4}\left[2x - \frac{x^2}{4}\right]_{2.16}^{t} = 0.5148$$

$$\left[2x - \frac{x^2}{4}\right]_{2.16}^{t} = 0.6864$$

$$\left(2t - \frac{t^2}{4}\right) - \left(2 \times 2.16 - \frac{2.16^2}{4}\right) = 0.6864$$

$$2t - \frac{t^2}{4} = 3.84$$

$$t^2 - 8t + 15.36 = 0$$

Using the quadratic formula, $t = \frac{8 \pm \sqrt{(-8)^2 - 4(1)(15.36)}}{2(1)}$

$t = 3.2, 4.8$, but $1 \leq t \leq 4$ hence $t = 4.8$ is invalid

∴The least amount of time taken to produce 88% of the parts is 3.2 minutes.

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Question 32 (3 marks)
Outcomes Assessed: MA12-3, MA12-6
Targeted Performance Bands: 6

Criteria	Marks
• Provides correct solution	3
• Applies the fact to find $h'(x)$ in terms of t and recognises that $g(1)$ and $g'(1)$ represents the power output and its rate of change from the outlet at time $t = 1$, or equivalent merit	2
• Applies one application of the chain rule to obtain $h'(x) = 2 \times f(x) \times f'(x)$, or equivalent merit	1

Sample Answer:

The rate of change of heat produced is given by $h'(x)$.

$h'(x) = 2 \times f(x) \times f'(x)$, where $x = g(t)$

Apply the fact to express $h'(x)$ in terms of t on the RHS:

$$h'(x) = 2 \times f(x) \times f'\big(g(t)\big) \times g'(t)$$

$$= 2 \times f\big(g(t)\big) \times f'\big(g(t)\big) \times g'(t)$$

$g(1)$ and $g'(1)$ represent the power output and its rate of change from the outlet at time $t = 1$.

Hence, at time $t = 1$:

$g(1) = 3, g'(1) = 4, f(3) = 5$ and $f'(3) = 2$.

$$h'(x) = 2 \times f(g(1)) \times f'\big(g(1)\big) \times g'(1)$$
$$= 2 \times f(3) \times f'(3) \times g'(1)$$
$$= 2 \times 5 \times 2 \times 4$$
$$= 80$$

∴The rate of change of the heat produced at time $t = 1$ is 80 watts per second.

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