Neap

Final Examination 2023

NSW Year 11 Mathematics Extension 1

Solutions and Marking Guidelines

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SECTION I

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 1 **D** **D** is not equal to $\cos 2\theta$ and is therefore the correct response. Substituting the basic trigonometric identity $\left(\sin^2\theta + \cos^2\theta = 1\right)$ into the double angle formula for cosine does not result in $1 - 2\cos^2\theta$; it results in $2\cos^2\theta - 1$. **A** is incorrect. This can be obtained by applying the compound angle formula. **B** and **C** are incorrect. These can be obtained by substituting in values from the basic trigonometric identity $\sin^2\theta + \cos^2\theta = 1$.	ME–T2 Further Trigonometric Identities ME11–3 Band E2
Question 2 **B** $N = Ae^{kt} + 1000$ $\frac{dN}{dt} = k \times Ae^{kt}$ $= k\left(Ae^{kt} + 1000 - 1000\right)$ $= k(N - 1000)$	ME–C1 Rates of Change ME11–4 Band E2
Question 3 **C** **C** is correct. In the equation, the basic curve is shifted left by two and stretched vertically by a factor of two to obtain the correct curve. This is shown in option **C**. **A** is incorrect. This graph represents the equation $y = 0.5\cos^{-1}(x-2)$. **B** is incorrect. This graph represents the equation $y = 2\cos^{-1}(x-2)$. **D** is incorrect. This graph represents the equation $y = 0.5\cos^{-1}(x+2)$.	ME–T1 Inverse Trigonometric Functions ME11–1 Band E2

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Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 4 **D** $\alpha+\beta+\gamma=-\frac{b}{a}$ $=-\frac{-6}{3}$ $=2$ $\alpha\beta+\alpha\gamma+\beta\gamma=\frac{c}{a}=\frac{3}{3}=1$ $\alpha\beta\gamma=-\frac{d}{a}=-\frac{-7}{3}=\frac{7}{3}$ $3\alpha+3\beta+3\gamma+4=3(\alpha+\beta+\gamma)+4$ $=3(2)+4$ $=10$	ME–F2 Polynomials ME11–2 Band E2
Question 5 **A** **A** is correct. Squaring the key points shows that option **A** is the correct graph. When the original graph is –2 (the minimum point), the squared graph will be $(-2)^2 = 4$. **B**, **C** and **D** are incorrect. These do not correctly represent the graph of $(f(x))^2$.	ME–F1 Further Work with Functions ME11–1 Band E3
Question 6 **C** Placing the two instances of the letter S in the first and last position gives: S _ _ _ _ _ _ S Therefore, the number of ways to arrange the remaining letters is $\frac{6!}{2!}$, accounting for the duplicate letter T.	ME–A1 Working with Combinatorics ME11–5 Band E2

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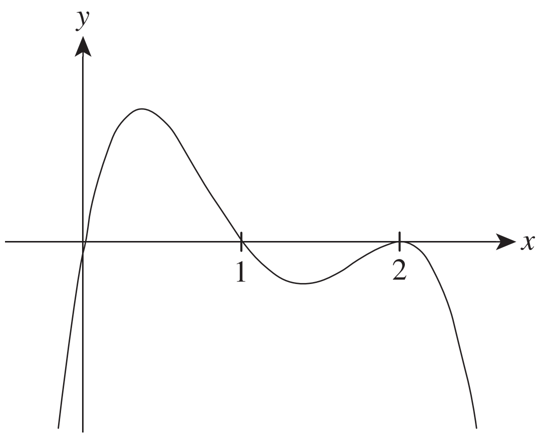
Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 7 **D** **Method 1:** Evaluating $P(1.9)$, $P(2)$ and $P(2.1)$ for each equation gives: A: $P(1.9) > 0$, $P(2) = 0$, $P(2.1) > 0$. B: $P(1.9) > 0$, $P(2) = 0$, $P(2.1) > 0$. C: $P(1.9) < 0$, $P(2) = 0$, $P(2.1) < 0$. D: $P(1.9) < 0$, $P(2) = 0$, $P(2.1) < 0$. Either options **C** or **D** can represent the graph because the curve is below the x-axis at $x = 2$. However, **C** describes an equation of degree 2 and is therefore incorrect. **Method 2:** **D** is correct. The degree of this polynomial is 4, the leading coefficient is negative and there are three roots (with a double root at $x = 2$). Thus, sketching $P(x) = x(1 - x)(x - 2)^2$ gives:  The section of the graph around $x = 2$ matches the sketch given in the question. Therefore, **D** is correct. (continues on next page)	ME–F1 Further Work with Functions ME11–2 Band E2

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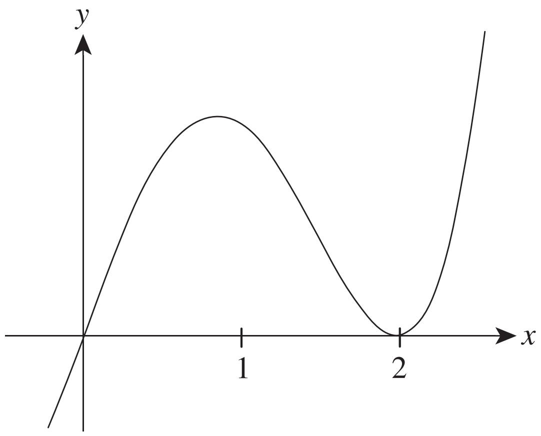
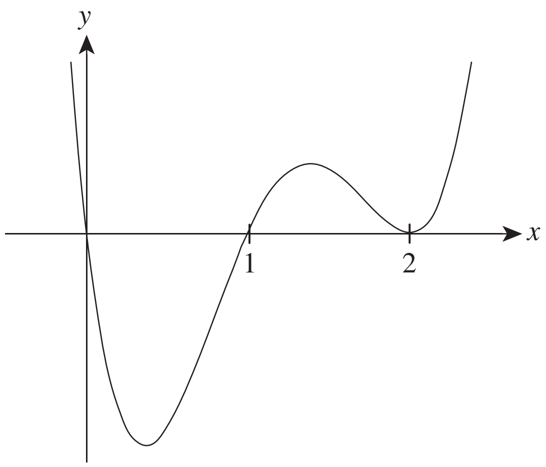
Answer and explanation	Syllabus content, outcomes and targeted performance bands
(continued) **A** is incorrect. Sketching $P(x) = x(x+1)(x-2)^2$ shows that the area around $x = 2$ in this graph is above the x-axis.  **B** is incorrect. Sketching $P(x) = x(x-1)(x-2)^2$ shows that the area around $x = 2$ in this graph is above the x-axis.  **C** is incorrect. This equation has a degree of 2.	
Question 8 **B** $A = \pi r^2$ $\frac{dA}{dr} = 2\pi r$ $\frac{dr}{dt} = 0.5$ $\frac{dA}{dt} = \frac{dA}{dr} \times \frac{dr}{dt}$ $= 2\pi r \times 0.5$ $= \pi r$ Given that $r = 10$ cm, $\frac{dA}{dt} = 10\pi \text{ cm}^2/\text{s}$.	ME–C1 Rates of Change ME11–4 Band E3

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 9 **D** Let the roots be α and 2α. $3\alpha = -\frac{b}{a}$ $= \frac{18}{2}$ $= 9$ $\alpha = 3$ $2\alpha^2 = \frac{c}{a}$ $= \frac{c}{2}$ $2(3)^2 = \frac{c}{2}$ $c = 36$	ME–F2 Polynomials ME11–2 Band E3
Question 10 **A** **A** is correct. The inverse function is the reflection of the graph of the original function across the line $y = x$. This can be seen in graph **A**. **B**, **C** and **D** are incorrect. These graphs do not accurately show the inverse of $f(x)$.	ME–F1 Further Work with Functions ME11–2 Band E3

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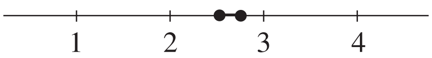
SECTION II

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 11	
(a) $\frac{3}{2x-5} > 6$ $3(2x-5) > 6(2x-5)^2$ $3(2x-5) - 6(2x-5)^2 > 0$ $3(2x-5)(1-2(2x-5)) > 0$ $3(2x-5)(1-4x+10) > 0$ $3(2x-5)(11-4x) > 0$ The LHS describes a concave down parabola with zeros at 2.75 and 2.5. The curve is greater than 0 between the zeros. $\therefore \frac{5}{2} < x < \frac{11}{4}$ (or $2.5 < x < 2.75$) 	ME–F1 Further Work with Functions ME11–2 Band E2 • Provides the correct solution . . . . . . 3 • Provides the correct critical points but incorrect region(s). . . . . . 2 • Shows some understanding of the problem 1
(b) $x = \sqrt{2t+4}$ $x^2 = 2t+4$ $x^2 - 4 = 2t$ $t = \frac{x^2-4}{2}$ $y = 2t+1$ $y = 2\left(\frac{x^2-4}{2}\right)+1$ $= x^2 - 4 + 1$ $= x^2 - 3$ The domain for t is $-2 \le t \le 6$. Finding the domain for x: When $t = -2$, $x = 0$. When $t = 6$, $x = 4$. $\therefore y = x^2 - 3, 0 \le x \le 4$	ME–F1 Further Work with Functions ME11–2 Band E3 • Provides the correct solution . . . . . . 3 • Provides the correct solution but gives the incorrect domain. . . . . 2 • Shows some understanding of the problem 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(c) (i) **Method 1:** Arranging 8 people in a line with 10 positions gives: $^{10}P_8 = 1\,814\,400$ **Method 2:** Selecting 8 people from 10 people and arranging them in a line gives: $^{10}C_8 \times 8! = 1\,814\,400$	ME–A1 Working with Combinatorics ME11–5 Band E2 • Provides the correct solution 1
(ii) The four unrestricted friends can be arranged to act as 'barriers' for Ahmad and the group of three friends. These 'barriers' form 5 positions to place Ahmad and the group of three friends. Ahmad can be placed in any of the 5 positions, and the group of three can then be placed in any of the remaining 4 positions. Finally, the group of three can be permuted amongst themselves in 3! ways. Thus, the number of ways to arrange all the friends is: $4! \times 5 \times 4 \times 3! = 2800$	ME–A1 Working with Combinatorics ME11–5 Band E3 • Provides the correct solution . . . . . . 2 • Shows some understanding of the problem 1
(d) $\sin\frac{5\pi}{4} = -\frac{1}{\sqrt{2}}$ $\cos^{-1}\left(-\frac{1}{\sqrt{2}}\right) = \frac{3\pi}{4}, 0 \le x \le \pi$	ME–T1 Inverse Trigonometric Functions ME11–5 Band E2 • Provides the correct solution . . . . . . 2 • Shows some understanding of the problem 1
(e) (i) $\cos 105° = \cos(60° + 45°)$ $= \cos 60° \cos 45° - \sin 60° \sin 45°$ $= \left(\frac{1}{2}\right)\left(\frac{1}{\sqrt{2}}\right) - \left(\frac{\sqrt{3}}{2}\right)\left(\frac{1}{\sqrt{2}}\right)$ $= \frac{1-\sqrt{3}}{2\sqrt{2}}$ $= \frac{\sqrt{2}-\sqrt{6}}{4}$	ME–T2 Further Trigonometric Identities ME11–3 Band E3 • Provides the correct solution . . . . . . 2 • Makes some progress using $\cos(\alpha + \beta)$. OR • Shows some understanding of the problem 1

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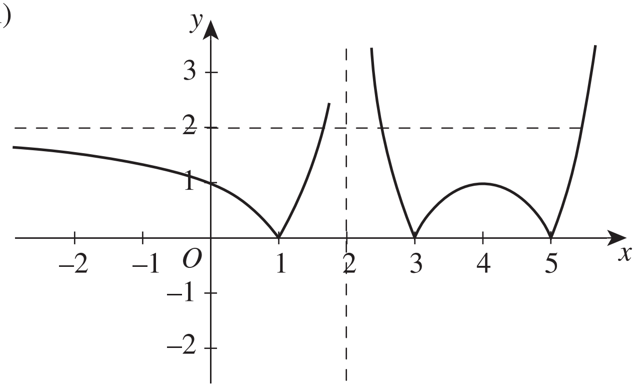
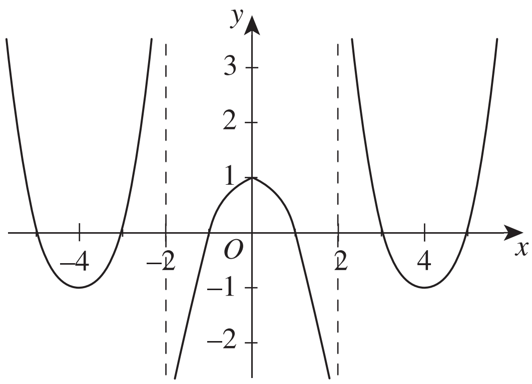
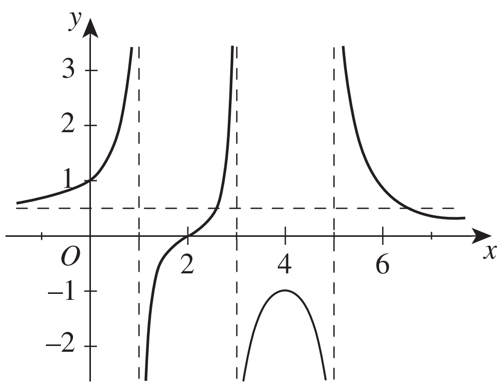
Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(ii) $\cos 105° = \cos(2 \times 52.5°)$ $\frac{\sqrt{2}-\sqrt{6}}{4} = 2\cos^2 52.5° - 1$ $2\cos^2 52.5° = \frac{4+\sqrt{2}-\sqrt{6}}{4}$ $\cos^2 52.5° = \frac{4+\sqrt{2}-\sqrt{6}}{8}$ $\cos 52.5° = \frac{\sqrt{4+\sqrt{2}-\sqrt{6}}}{2\sqrt{2}}$, as $\cos 52.5° > 0$ *Note: Consequential on answer to* ***Question 11(e)(i)***.	ME–T2 Further Trigonometric Identities ME11–3 Band E3 • Provides the correct solution . . . . . .2 • Makes some progress using the double angle formula. OR • Shows some understanding of the problem 1
Question 12	
(a) $P(x) = (x+1)(x-2)Q(x) + 4x + k$ Evaluating $P(-1)$: $-2 = 4x + k$ $k = 2$ $P(2) = 4(2) + 2$ $= 10$	ME–F2 Polynomials ME11–2 Band E3 • Provides the correct solution . . . . . .2 • Makes some progress using the remainder theorem to find k. OR • Shows some understanding of the problem 1
(b) $\sin\left(\theta + \frac{\pi}{6}\right) + \cos\left(\theta + \frac{\pi}{3}\right)$ $= \left(\sin\theta\cos\frac{\pi}{6} + \cos\theta\sin\frac{\pi}{6}\right) + \left(\cos\theta\cos\frac{\pi}{3} - \sin\theta\sin\frac{\pi}{3}\right)$ $= \frac{\sqrt{3}}{2}\sin\theta + \frac{1}{2}\cos\theta + \frac{1}{2}\cos\theta - \frac{\sqrt{3}}{2}\sin\theta$ $= \cos\theta$	ME–T2 Further Trigonometric Identities ME11–3 Band E3 • Provides the correct solution . . . . . .3 • Uses compound angle formulae for BOTH terms . . . . . . .2 • Shows some understanding of the problem 1
(c) Using the binomial theorem: $(1-2x)^5 = 1 - 5(2x) + 10(4x^2) - 10(8x^3) + \ldots$ $= 1 - 10x + 40x^2 - 80x^3 + \ldots$ The term in x^3 is given by: $1(-80x^3) + x(40x^2) + 2x^2(-10x)$ Thus, coefficient of x^3 is: $-80 + 40 - 20 = -60$	ME–A1 Working with Combinatorics ME11–5 Band E3 • Provides the correct solution . . . . . .3 • Expands $(1-2x)^5$ correctly . . . . . .2 • Shows some understanding of the problem 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(d) (i) 	ME–F1 Further Work with Functions ME11–1 Band E2 • Sketches the correct graph . . . . 2 • Provides some correct features of the graph. OR • Equivalent merit 1
(ii) 	ME–F1 Further Work with Functions ME11–1 Band E2 • Sketches the correct graph . . . . 2 • Provides some correct features of the graph. OR • Equivalent merit 1
(iii) 	ME–F1 Further Work with Functions ME11–1 Band E4 • Sketches the correct graph . . . . 3 • Finds the reciprocal of one branch. OR • Finds all asymptotes. OR • Makes other substantial progress. . . 2 • Provides some correct features of the graph. OR • Equivalent merit 1

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Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 13	
(a) There are three pairs of repeated letters (A, M and T) and five non-repeated letters (C, E, H, I and S). Case 1: All five letters are different: $\binom{8}{5}\times 5! = 6720$ Case 2: One pair of repeated letters: $\binom{3}{1}\times\binom{7}{3}\times\frac{5!}{2!} = 6300$ Case 3: Two pairs of repeated letters: $\binom{3}{2}\times\binom{6}{1}\times\frac{5!}{2!2!} = 540$ Summing all three cases gives: 6720 + 6300 + 540 = 13 560	ME–A1 Working with Combinatorics ME11–5 Band E4 • Provides the correct solution . . . . . . 4 • Makes substantial progress towards the correct solution. . . . . . . 3 • Recognises the problem involves cases. AND • Makes some progress towards the correct solution. . . . . . . 2 • Shows some understanding of the problem 1
(b) (i) $P(t) = Ae^{kt}$ $P'(t) = k \times Ae^{kt}$ $= k \times P(t)$	ME–C1 Rates of Change ME11–4 Band E2 • Provides the correct solution 1
(ii) $\frac{A}{2} = Ae^{50k}$ $0.5 = e^{50k}$ $\ln 0.5 = 50k$ $k = \frac{\ln 0.5}{50}$ $\approx -1.39\%$ The rate of change is approximately –1.39% per year.	ME–C1 Rates of Change ME11–4 Band E3 • Provides the correct solution . . . . . . 2 • Shows some understanding of the problem 1
(iii) $P(80) = 3000e^{80k}$ $k = \frac{\ln 0.5}{50}$ $P(80) = 3000e^{80\left(\frac{\ln 0.5}{50}\right)}$ ≈ 989 Thus, there will be approximately 989 animals in the population after 80 years.	ME–C1 Rates of Change ME11–4 Band E3 • Provides the correct solution 1

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		Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
	(iv)	Population: $P(t) = 3000e^{\left(\frac{\ln 0.5}{50}\right)t}$, where $\left(\frac{\ln 0.5}{50}\right)$ is negative. As $t \to \infty$, $e^{\left(\frac{\ln 0.5}{50}\right)t} \to 0$, $3000e^{\left(\frac{\ln 0.5}{50}\right)t}$ will also approach 0. Thus, the population will decrease until the animal becomes extinct. Rate of change: $\frac{d}{dt}P(t) = k \times P(t)$ $= \left(\frac{\ln 0.5}{50}\right)e^{\left(\frac{\ln 0.5}{50}\right)t}$ $e^{\left(\frac{\ln 0.5}{50}\right)t}$ will approach 0. This will not be changed by $\left(\frac{\ln 0.5}{50}\right)$. Thus, $\frac{d}{dt}P(t)$ will approach 0 and the rate of change will also approach 0. (If the animal becomes extinct, then the rate of change will be 0 by definition.)	ME–C1 Rates of Change ME11–4 Band E4 • Explains what will happen to the population AND rate of change with reference to limits (or equivalent) . . . . .2 • Shows some understanding of the problem 1
(c)	(i)	$P(t) = 500 + Ce^{kt}$ $P'(t) = k \times Ce^{kt}$ $= k\left(Ce^{kt} + 500 - 500\right)$ $= k\left(P(t) - 500\right)$	ME–C1 Rates of Change ME11–4 Band E2 • Provides the correct solution 1
	(ii)	In the new equation, $P(t) = 500 + Ce^{kt}$, Ce^{kt} will approach 0 because k is negative. Thus, $P(t)$ will approach 500 as $t \to \infty$ because Ce^{kt} will approach 0. $P'(t) = k \times Ce^{kt}$, $P' \to 0$ as $t \to \infty$, since k is negative; thus, the rate of change will be effectively 0. Therefore, the population will become static at around 500 animals.	ME–C1 Rates of Change ME11–4 Band E3 • Explains what will happen to population AND rate of change with reference to limits (or equivalent) . . . . .2 • Shows some understanding of the problem 1

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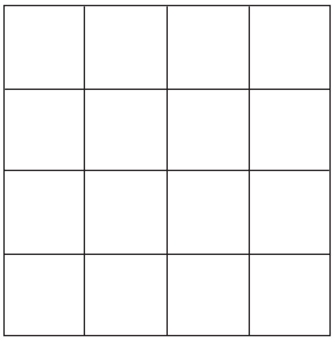
Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(iii) $3000 = 500 + Ce^{k(0)}$ $= 500 + C$ $C = 2500$ $P(t) = 500 + 2500e^{kt}$ The population halves in 50 years: $1500 = 500 + 2500e^{k(50)}$ $\frac{1000}{2500} = e^{50k}$ $\ln\left(\frac{2}{5}\right) = 50k$ $k = \frac{\ln\left(\frac{2}{5}\right)}{50}$ The population after 80 years: $P(80) = 500 + 2500e^{k(80)}$ ≈ 1077 Thus, the population is expected to be around 1077 after 80 years.	ME–C1 Rates of Change ME11–4 Band E4 • Provides the correct solution . . . . . .2 • Shows some understanding of the problem 1

<table>
<tr><th>Sample answer</th><th>Syllabus content, outcomes, targeted performance bands and marking guide</th></tr>
<tr><td>Question 14</td><td></td></tr>
<tr><td>

(a) Since 33 points are to be drawn inside a square with sides of 4 cm, the square must have an area of $4 \times 4 = 16\ \text{cm}^2$.

Dividing the square into 16 equally sized squares of $1\ \text{cm}^2$ gives:



If three or more points are assigned within one of the 16 squares, these points will be guaranteed to form a triangle with an area less than $1\ \text{cm}^2$.

Assigning two points to each square gives 32 points. The 33rd point, regardless of where it is placed, will lie in a square which already has two points. Thus, there will be three points within an area of $1\ \text{cm}^2$.

Thus, it is guaranteed to be possible to find three points that form a triangle with an area less than $1\ \text{cm}^2$.

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ME–A1 Working with Combinatorics
ME11–5 Band E4

- Provides the correct solution 3

- Makes substantial progress towards the correct solution. 2

- Makes some progress towards recognising this as a pigeonhole principle question. . . .1

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(b) Possible integer roots will be factors of –2. Thus, check $P(0)$, $P(1)$, $P(-1)$, $P(2)$ and $P(-2)$.

Of these, it is found that 2 and –1 are roots of the polynomial.

Checking the multiplicity of 2:

$P'(x) = 4x^3 + 3x^2 - 6x - 5$

$P'(2) \neq 0$

Thus, 2 is a root with multiplicity 1.

Checking the multiplicity of –1:

$P'(-1) = 0$

$P''(x) = 12x^2 + 6x - 6$

$P''(-1) = 0$

$P'''(x) = 24x + 6$

$P'''(-1) \neq 0$

Therefore, –1 is a root with multiplicity 3 of $P(x)$.

</td><td>

ME–F2 Polynomials
ME11–2 Band E4

- Provides the correct solution 3

- Differentiates at least once to show the link between differentiation and root multiplicity 2

- Shows some understanding of the problem 1

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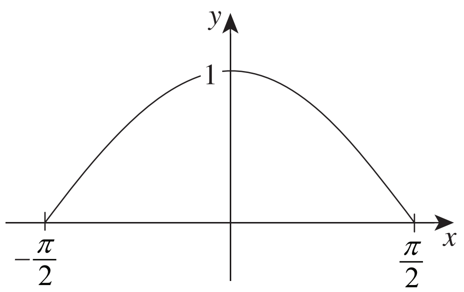
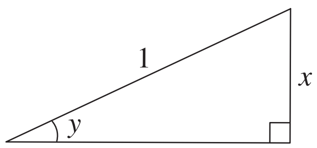
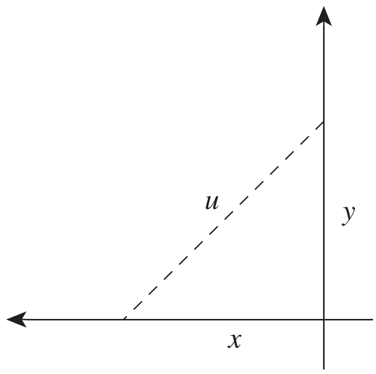
	Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(c) (i)	$y = \sin^{-1} x$ $\cos y = \cos\left(\sin^{-1} x\right)$ Consider $-\frac{\pi}{2} \le \sin^{-1} x \le \frac{\pi}{2}$. Sketching the cosine curve in the region $-\frac{\pi}{2} \le x \le \frac{\pi}{2}$ gives:  $\sin^{-1} x$ will take a value between $-\frac{\pi}{2}$ and $\frac{\pi}{2}$, and $\cos\theta$ for these values will be between 0 and 1; thus, it can be concluded that $0 \le \cos\left(\sin^{-1} x\right) \le 1$.	ME–T1 Inverse Trigonometric Functions ME11–3 Band E4 • Provides the correct solution . . . . . .2 • Shows some understanding of the problem 1
(ii)	As $y = \sin^{-1} x$, $x = \sin y$.  Using Pythagoras' theorem, the third side is equal to $\sqrt{1-x^2}$. Hence, $\cos y = \frac{\sqrt{1-x^2}}{1}$ $= \sqrt{1-x^2}$	ME–T1 Inverse Trigonometric Functions ME11–3 Band E4 • Provides the correct solution . . . . . .3 • Makes substantial progress towards finding the length of the third side . . . . .2 • Shows some understanding of the problem 1
(d) (i)	$\frac{d}{dt} = \frac{d}{dx} \times \frac{dx}{dt}$ $\therefore \frac{d}{dt}\left(x^2\right) = 2x \times \frac{dx}{dt}$	ME–C1 Rates of Change ME11–4 Band E4 • Provides the correct solution 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(ii) Similar to $\frac{d}{dt}\left(x^2\right)=2x\times\frac{dx}{dt}$, $\frac{d}{dt}\left(u^2\right)=2u\times\frac{du}{dt}$ and $\frac{d}{dt}\left(y^2\right)=2y\times\frac{dy}{dt}$. Representing the scenario described in the question gives:  Using Pythagoras' theorem, the distance between the boats is: $u^2=x^2+y^2$ (1) Differentiating (1) in terms of time: $\frac{d}{dt}\left(u^2\right)=\frac{d}{dt}\left(x^2\right)+\frac{d}{dt}\left(y^2\right)$ $2u\times\frac{du}{dt}=2x\times\frac{dx}{dt}+2y\times\frac{dy}{dt}$ $u\frac{du}{dt}=x\frac{dx}{dt}+y\frac{dy}{dt}$ Given that $\frac{dx}{dt}=3$ and $\frac{dy}{dt}=5$: $u\frac{du}{dt}=3x+5y$ (2) (continues on next page)	ME–C1 Rates of Change ME11–4 Band E4 • Provides the correct solution . . . . . . 3 • Makes substantial progress using related rates . . . . 2 • Shows some understanding of the problem, such as finding the distance travelled by each boat OR $u^2=x^2+y^2$ 1

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Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(continued) Finding x, y and u: At 2:30 pm, the first boat has travelled for 2.5 hours at 3 km/h. Thus, it has travelled 7.5 km. At 2:30 pm, the second boat has travelled for 1.5 hours at 5 km/h. Thus, it has also travelled 7.5 km. Since $u^2 = x^2 + y^2$, $x = 7.5$ and $y = 7.5$, using Pythagoras' theorem to find u gives: $u = \frac{\sqrt{225}}{\sqrt{2}}$ $= \frac{15}{\sqrt{2}}$ Substituting 7.5, 7.5 and $\frac{15}{\sqrt{2}}$ into (2): $\frac{15}{\sqrt{2}}\frac{du}{dt} = 3(7.5) + 5(7.5)$ $\frac{du}{dt} \approx 5.64$ km/h Therefore, the rate of change is 5.64 km/h.	

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