

A level Mathematics Practice Paper – Integration – Mark scheme

Question	Scheme	Marks
1(a)	$1 = A(3x-1)^2 + Bx(3x-1) + Cx$	B1
	$x \rightarrow 0 \quad (1 = A)$	M1
	$x \rightarrow \frac{1}{3} \quad 1 = \frac{1}{3}C \Rightarrow C = 3 \quad \text{any two constants correct}$	A1
	Coefficients of x^2	
	$0 = 9A + 3B \Rightarrow B = -3 \quad \text{all three constants correct}$	A1
		(4)
1(b)	(i) $\int \left(\frac{1}{x} - \frac{3}{3x-1} + \frac{3}{(3x-1)^2} \right) dx$	
	$= \ln x - \frac{3}{3} \ln(3x-1) + \frac{3}{(-1)3} (3x-1)^{-1} \quad (+C)$	M1 A1ft A1ft
	$\left(= \ln x - \ln(3x-1) - \frac{1}{3x-1} \quad (+C) \right)$	
	(ii) $\int_1^2 f(x) dx = \left[\ln x - \ln(3x-1) - \frac{1}{3x-1} \right]_1^2$	
	$= \left(\ln 2 - \ln 5 - \frac{1}{5} \right) - \left(\ln 1 - \ln 2 - \frac{1}{2} \right)$	M1
	$= \ln \frac{2 \times 2}{5} + \dots$	M1
	$= \frac{3}{10} + \ln \left(\frac{4}{5} \right)$	A1
		(6)
		(10 marks)

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Question	Scheme		Marks
2	$\int x \sin 2x \, dx = -\frac{x \cos 2x}{2} + \int \frac{\cos 2x}{2} \, dx$		M1 A1 A1
	$= \quad \dots \quad + \frac{\sin 2x}{4}$		M1
	$\left[\quad \dots \quad \right]_0^{\frac{\pi}{2}} = \frac{\pi}{4}$		M1 A1
			(6 marks)
3(a)	$\int \frac{1}{x^3} \ln x \, dx, \quad \left\{ \begin{array}{l} u = \ln x \Rightarrow \frac{du}{dx} = \frac{1}{x} \\ \frac{dv}{dx} = x^{-3} \Rightarrow v = \frac{x^{-2}}{-2} = \frac{-1}{2x^2} \end{array} \right\}$		
	$= \frac{-1}{2x^2} \ln x - \int \frac{-1}{2x^2} \cdot \frac{1}{x} \, dx$	In the form $\frac{\pm \lambda}{x^2} \ln x \pm \int \mu \frac{1}{x^2} \cdot \frac{1}{x}$	M1
		$\frac{-1}{2x^2} \ln x$ simplified or un-simplified.	<u>A1</u>
		$-\int \frac{-1}{2x^2} \cdot \frac{1}{x}$ simplified or un-simplified.	<u>A1</u>
	$\left\{ = \frac{-1}{2x^2} \ln x + \frac{1}{2} \int \frac{1}{x^3} \, dx \right\}$		
	$= -\frac{1}{2x^2} \ln x + \frac{1}{2} \left(-\frac{1}{2x^2} \right) \{+c\}$	$\pm \int \mu \frac{1}{x^2} \cdot \frac{1}{x} \rightarrow \pm \beta x^{-2}.$	dM1
		Correct answer, with/without + c	A1
			(5)
3(b)	$\left\{ \left[-\frac{1}{2x^2} \ln x - \frac{1}{4x^2} \right]_1^2 \right\} = \left(-\frac{1}{2(2)^2} \ln 2 - \frac{1}{4(2)^2} \right) - \left(-\frac{1}{2(1)^2} \ln 1 - \frac{1}{4(1)^2} \right)$		
	Applies limits of 2 and 1 to their part (a) answer and subtracts the correct way round.		M1
	$= \frac{3}{16} - \frac{1}{8} \ln 2 \quad \text{or} \quad \frac{3}{16} - \ln 2^{\frac{1}{8}} \quad \text{or} \quad \frac{1}{16}(3 - 2 \ln 2), \text{ etc, or awrt } 0.1 \text{ or equivalent.}$		A1
			(2)
			(7 marks)

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Question	Scheme	Marks
4(a)	$\int x \sin 3x \, dx = -\frac{1}{3}x \cos 3x - \int -\frac{1}{3} \cos 3x \{dx\}$	M1 A1
	$= -\frac{1}{3}x \cos 3x + \frac{1}{9} \sin 3x \{+ c\}$	A1
		(3)
4(b)	$\int x^2 \cos 3x \, dx = \frac{1}{3}x^2 \sin 3x - \int \frac{2}{3}x \sin 3x \{dx\}$	M1 A1
	$= \frac{1}{3}x^2 \sin 3x - \frac{2}{3} \left(-\frac{1}{3}x \cos 3x + \frac{1}{9} \sin 3x \right) \{+ c\}$	A1 isw
	$\left\{ = \frac{1}{3}x^2 \sin 3x + \frac{2}{9}x \cos 3x - \frac{2}{27} \sin 3x \{+ c\} \right\}$	
	<i>Ignore subsequent working</i>	(3)
		(6 marks)
5(a)	$y = 4x - x e^{\frac{1}{2}x}, x \geq 0$	
	$\left\{ y = 0 \Rightarrow 4x - x e^{\frac{1}{2}x} = 0 \Rightarrow x(4 - e^{\frac{1}{2}x}) = 0 \Rightarrow \right\}$	
	$e^{\frac{1}{2}x} = 4 \Rightarrow x_A = 4 \ln 2$	M1
		A1
		(2)
5(b)	$\left\{ \int x e^{\frac{1}{2}x} \, dx \right\} = 2x e^{\frac{1}{2}x} - \int 2e^{\frac{1}{2}x} \{dx\}$	M1
		A1
	$= 2x e^{\frac{1}{2}x} - 4e^{\frac{1}{2}x} \{+ c\}$	A1
		(3)
5(c)	$\left\{ \int 4x \, dx \right\} = 2x^2$	B1
	$\left\{ \int_0^{4 \ln 2} (4x - x e^{\frac{1}{2}x}) \, dx \right\} = \left[2x^2 - \left(2x e^{\frac{1}{2}x} - 4e^{\frac{1}{2}x} \right) \right]_0^{4 \ln 2 \text{ or } \ln 16 \text{ or their limits}}$	
	$= \left(2(4 \ln 2)^2 - 2(4 \ln 2)e^{\frac{1}{2}(4 \ln 2)} + 4e^{\frac{1}{2}(4 \ln 2)} \right) - \left(2(0)^2 - 2(0)e^{\frac{1}{2}(0)} + 4e^{\frac{1}{2}(0)} \right)$	M1
	$= (32(\ln 2)^2 - 32(\ln 2) + 16) - (4)$	
	$= 32(\ln 2)^2 - 32(\ln 2) + 12$	A1
		(3)
		(8 marks)

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Question	Scheme		Marks
6(a)	1.154701		B1 cao
			(1)
6(b)	Area $\approx \frac{1}{2} \times \frac{\pi}{6} \times [1 + 2(1.035276 + \text{their } 1.154701) + 1.414214]$		B1 <u>M1</u>
	$= \frac{\pi}{12} \times 6.794168 = 1.778709023... = 1.7787 \text{ (4 dp)}$	1.7787 or awrt 1.7787	A1
			(3)
6(c)	$V = \pi \int_0^{\frac{\pi}{2}} \left(\sec\left(\frac{x}{2}\right) \right)^2 dx$	For $\pi \int \left(\sec\left(\frac{x}{2}\right) \right)^2$ Ignore limits and dx. Can be implied.	B1
	$= \{\pi\} \left[2 \tan\left(\frac{x}{2}\right) \right]_0^{\frac{\pi}{2}}$	$\pm \lambda \tan\left(\frac{x}{2}\right)$	M1
		$2 \tan\left(\frac{x}{2}\right)$ or equivalent	A1
	$= 2\pi$	2π	A1 cao cso
			(4)
			(8 marks)

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Question	Scheme	Marks
7(a)	$\frac{5}{(x-1)(3x+2)} = \frac{A}{x-1} + \frac{B}{3x+2}$	
	$5 = A(3x+2) + B(x-1)$	
	$x \rightarrow 1 \quad 5 = 5A \Rightarrow A = 1$	M1 A1
	$x \rightarrow -\frac{2}{3} \quad 5 = -\frac{5}{3}B \Rightarrow B = -3$	A1
		(3)
7(b)	$\int \frac{5}{(x-1)(3x+2)} dx = \int \left(\frac{1}{x-1} - \frac{3}{3x+2} \right) dx$	
	$= \ln(x-1) - \ln(3x+2) \quad (+C) \quad \text{ft constants}$	M1 A1ft A1ft
		(3)
7(c)	$\int \frac{5}{(x-1)(3x+2)} dx = \int \left(\frac{1}{y} \right) dy$	M1
	$\ln(x-1) - \ln(3x+2) = \ln y \quad (+C)$	M1 A1
	$y = \frac{K(x-1)}{3x+2} \quad \text{depends on first two Ms in (c)}$	M1 dep
	Using (2, 8) $8 = \frac{K}{8} \quad \text{depends on first two Ms in (c)}$	M1 dep
	$y = \frac{64(x-1)}{3x+2}$	A1
		(6)
		(12 marks)

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Question	Scheme	Marks
8(a)	$\frac{3y-4}{y(3y+2)} \equiv \frac{A}{y} + \frac{B}{(3y+2)} \Rightarrow 3y-4 = A(3y+2) + By$ $y=0 \Rightarrow -4 = 2A \Rightarrow A = -2$ $y = -\frac{2}{3} \Rightarrow -6 = -\frac{2}{3}B \Rightarrow B = 9$	M1 A1 A1
	$\int \frac{3y-4}{y(3y+2)} dy = \int \frac{-2}{y} + \frac{9}{(3y+2)} dy$ $= -2\ln y + 3\ln(3y+2) \{+c\}$	M1 A1 ft A1 cao
		(6)
8(b)	$\{x = 4\sin^2 \theta \Rightarrow\} \frac{dx}{d\theta} = 8\sin \theta \cos \theta \quad \text{or} \quad \frac{dx}{d\theta} = 4\sin 2\theta \quad \text{or} \quad dx = 8\sin \theta \cos \theta d\theta$	B1
	$\int \sqrt{\frac{4\sin^2 \theta}{4-4\sin^2 \theta}} \cdot 8\sin \theta \cos \theta \{d\theta\} \quad \text{or} \quad \int \sqrt{\frac{4\sin^2 \theta}{4-4\sin^2 \theta}} \cdot 4\sin 2\theta \{d\theta\}$	M1
	$= \int \underline{\underline{\tan \theta}} \cdot 8\sin \theta \cos \theta \{d\theta\} \quad \text{or} \quad \int \underline{\underline{\tan \theta}} \cdot 4\sin 2\theta \{d\theta\}$	<u><u>M1</u></u>
	$= \int 8\sin^2 \theta d\theta$	A1
	$3 = 4\sin^2 \theta \quad \text{or} \quad \frac{3}{4} = \sin^2 \theta \quad \text{or} \quad \sin \theta = \frac{\sqrt{3}}{2} \Rightarrow \theta = \frac{\pi}{3} \quad \{x=0 \rightarrow \theta=0\}$	B1
		(5)
8(c)	$= \{8\} \int \left(\frac{1-\cos 2\theta}{2} \right) d\theta \quad \left\{ = \int (4-4\cos 2\theta) d\theta \right\}$	M1
	$= \{8\} \left(\frac{1}{2}\theta - \frac{1}{4}\sin 2\theta \right) \quad \{ = 4\theta - 2\sin 2\theta \}$	M1 A1
	$\left\{ \int_0^{\frac{\pi}{3}} 8\sin^2 \theta d\theta = 8 \left[\frac{1}{2}\theta - \frac{1}{4}\sin 2\theta \right]_0^{\frac{\pi}{3}} \right\} = 8 \left(\left(\frac{\pi}{6} - \frac{1}{4} \left(\frac{\sqrt{3}}{2} \right) \right) - (0+0) \right)$	
	$= \frac{4}{3}\pi - \sqrt{3} \text{ o.e.}$	A1
		(4)
		(15 marks)

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Question	Scheme		Marks
9(a)	<i>Working parametrically:</i>		
	$x = 1 - \frac{1}{2}t, \quad y = 2^t - 1 \text{ or } y = e^{t \ln 2} - 1$		
	$\{x = 0 \Rightarrow\} 0 = 1 - \frac{1}{2}t \Rightarrow t = 2$	Applies $x = 0$ to obtain a value for t .	M1
	When $t = 2, \quad y = 2^2 - 1 = 3$	Correct value for y .	A1
			(2)
9(b)	$\{y = 0 \Rightarrow\} 0 = 2^t - 1 \Rightarrow t = 0$	Applies $y = 0$ to obtain a value for t . (Must be seen in part (b)).	M1
	When $t = 0, \quad x = 1 - \frac{1}{2}(0) = 1$	$x = 1$	A1
			(2)
9(c)	$\frac{dx}{dt} = -\frac{1}{2}$ and either $\frac{dy}{dt} = 2^t \ln 2$ or $\frac{dy}{dt} = e^{t \ln 2} \ln 2$		B1
	$\frac{dy}{dx} = \frac{2^t \ln 2}{-\frac{1}{2}}$	Attempts their $\frac{dy}{dt}$ divided by their $\frac{dx}{dt}$.	M1
	At A, $t = "2"$, so $m(T) = -8 \ln 2 \Rightarrow m(N) = \frac{1}{8 \ln 2}$	Applies $t = "2"$ and $m(N) = \frac{-1}{m(T)}$	M1
	$y - 3 = \frac{1}{8 \ln 2} (x - 0) \text{ or } y = 3 + \frac{1}{8 \ln 2} x \text{ or equivalent.}$		M1 A1 oe cso
			(5)
9(d)	$\text{Area}(R) = \int (2^t - 1) \cdot \left(-\frac{1}{2}\right) dt$	Complete substitution for both y and dx	M1
	$x = -1 \rightarrow t = 4 \text{ and } x = 1 \rightarrow t = 0$		B1
	$= \left\{ -\frac{1}{2} \right\} \left(\frac{2^t}{\ln 2} - t \right)$ Either $2^t \rightarrow \frac{2^t}{\ln 2}$ or $(2^t - 1) \rightarrow \frac{(2^t)}{\pm \alpha (\ln 2)} - t$ or $(2^t - 1) \rightarrow \pm \alpha (\ln 2)(2^t) - t$		M1*
	$(2^t - 1) \rightarrow \frac{2^t}{\ln 2} - t$		A1
	$\left\{ -\frac{1}{2} \left[\frac{2^t}{\ln 2} - t \right]_4^0 \right\} = -\frac{1}{2} \left(\left(\frac{1}{\ln 2} \right) - \left(\frac{16}{\ln 2} - 4 \right) \right)$		
	Depends on the previous method mark. Substitutes their changed limits in t and subtracts either way round.		dM1*

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Question	Scheme		Marks
	$= \frac{15}{2\ln 2} - 2$	$\frac{15}{2\ln 2} - 2$ or equivalent.	A1
			(6)
			(16 marks)

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Question	Scheme	Marks
10(a)	$A = \int_0^3 \sqrt{(3-x)(x+1)} \, dx, \quad x = 1 + 2\sin\theta$	
	$\frac{dx}{d\theta} = 2\cos\theta$	B1
	$\left\{ \int \sqrt{(3-x)(x+1)} \, dx \text{ or } \int \sqrt{(3+2x-x^2)} \, dx \right\}$	
	$= \int \sqrt{(3-(1+2\sin\theta))((1+2\sin\theta)+1)} \, 2\cos\theta \, \{d\theta\}$	M1
	$= \int \sqrt{(2-2\sin\theta)(2+2\sin\theta)} \, 2\cos\theta \, \{d\theta\}$	
	$= \int \sqrt{(4-4\sin^2\theta)} \, 2\cos\theta \, \{d\theta\}$	
	$= \int \sqrt{(4-4(1-\cos^2\theta))} \, 2\cos\theta \, \{d\theta\} \text{ or } \int \sqrt{4\cos^2\theta} \, 2\cos\theta \, \{d\theta\}$	M1
	$= 4 \int \cos^2\theta \, d\theta, \quad \{k=4\}$	A1
	$0 = 1 + 2\sin\theta \text{ or } -1 = 2\sin\theta \text{ or } \sin\theta = -\frac{1}{2} \Rightarrow \theta = -\frac{\pi}{6}$ and $3 = 1 + 2\sin\theta \text{ or } 2 = 2\sin\theta \text{ or } \sin\theta = 1 \Rightarrow \theta = \frac{\pi}{2}$	B1
		(5)
10(b)	$\left\{ k \int \cos^2\theta \, \{d\theta\} \right\} = \{k\} \int \left(\frac{1+\cos 2\theta}{2} \right) \{d\theta\}$	M1
	$= \{k\} \left(\frac{1}{2}\theta + \frac{1}{4}\sin 2\theta \right)$	M1
	$\left\{ \text{So } 4 \int_{-\frac{\pi}{6}}^{\frac{\pi}{2}} \cos^2\theta \, d\theta = \left[2\theta + \sin 2\theta \right]_{-\frac{\pi}{6}}^{\frac{\pi}{2}} \right\}$ $= \left(2\left(\frac{\pi}{2}\right) + \sin\left(\frac{2\pi}{2}\right) \right) - \left(2\left(-\frac{\pi}{6}\right) + \sin\left(-\frac{2\pi}{6}\right) \right)$	
	$\left\{ = \left(\pi \right) - \left(-\frac{\pi}{3} - \frac{\sqrt{3}}{2} \right) \right\} = \frac{4\pi}{3} + \frac{\sqrt{3}}{2}$	A1 cao cso
		(3)
		(8 marks)

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Question	Scheme	Marks
11(a)	$x = 3\theta \sin \theta, \quad y = \sec^3 \theta, \quad 0 \leq \theta < \frac{\pi}{2}$	
	$\{\text{When } y = 8,\} \quad 8 = \sec^3 \theta \Rightarrow \cos^3 \theta = \frac{1}{8} \Rightarrow \cos \theta = \frac{1}{2} \Rightarrow \theta = \frac{\pi}{3}$ $k \text{ (or } x) = 3\left(\frac{\pi}{3}\right) \sin\left(\frac{\pi}{3}\right)$	M1
	so $k \text{ (or } x) = \frac{\sqrt{3}\pi}{2}$	A1
		(2)
11(b)	$\frac{dx}{d\theta} = 3 \sin \theta + 3\theta \cos \theta$	B1
	$\left\{ \int y \frac{dx}{d\theta} \{d\theta\} \right\} = \int (\sec^3 \theta)(3 \sin \theta + 3\theta \cos \theta) \{d\theta\}$	M1
	$= 3 \int \theta \sec^2 \theta + \tan \theta \sec^2 \theta \, d\theta$	A1 *
	$x = 0 \text{ and } x = k \Rightarrow \underline{\alpha = 0} \text{ and } \underline{\beta = \frac{\pi}{3}}$	B1
		(4)
11(c)	$\left\{ \int \theta \sec^2 \theta \, d\theta \right\} = \theta \tan \theta - \int \tan \theta \{d\theta\}$	M1
		dM1
	$= \theta \tan \theta - \ln(\sec \theta) \quad \text{or} \quad = \theta \tan \theta + \ln(\cos \theta)$	A1
	$\left\{ \int \tan \theta \sec^2 \theta \, d\theta \right\} = \frac{1}{2} \tan^2 \theta \text{ or } \frac{1}{2} \sec^2 \theta$	M1
	or $\frac{1}{2u^2}$ where $u = \cos \theta$	A1
	or $\frac{1}{2}u^2$ where $u = \tan \theta$	
	$\{\text{Area}(R)\} = \left[3\theta \tan \theta - 3 \ln(\sec \theta) + \frac{3}{2} \tan^2 \theta \right]_0^{\frac{\pi}{3}} \text{ or } \left[3\theta \tan \theta - 3 \ln(\sec \theta) + \frac{3}{2} \sec^2 \theta \right]_0^{\frac{\pi}{3}}$	
	$= \left(3\left(\frac{\pi}{3}\right) \sqrt{3} - 3 \ln 2 + \frac{3}{2}(3) \right) - (0) \text{ or } \left(3\left(\frac{\pi}{3}\right) \sqrt{3} - 3 \ln 2 + \frac{3}{2}(4) \right) - \left(\frac{3}{2}\right)$	
	$= \frac{9}{2} + \sqrt{3}\pi - 3 \ln 2 \text{ or } \frac{9}{2} + \sqrt{3}\pi + 3 \ln\left(\frac{1}{2}\right) \text{ or } \frac{9}{2} + \sqrt{3}\pi - \ln 8 \text{ or } \ln\left(\frac{1}{8} e^{\frac{9}{2} + \sqrt{3}\pi}\right)$	A1 o.e.
		(6)
		(12 marks)

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Question	Scheme		Marks
12(a)	$1 = A(5 - P) + BP$	Can be implied.	M1
	$A = \frac{1}{5}, B = \frac{1}{5}$	Either one.	A1
	giving $\frac{\frac{1}{5}}{P} + \frac{\frac{1}{5}}{(5 - P)}$		A1 cao, aef
			(3)
12(b)	$\int \frac{1}{P(5 - P)} dP = \int \frac{1}{15} dt$		B1
	$\frac{1}{5} \ln P - \frac{1}{5} \ln(5 - P) = \frac{1}{15} t \quad (+ c)$		M1*
			A1ft
	$\{t = 0, P = 1 \Rightarrow\} \quad \frac{1}{5} \ln 1 - \frac{1}{5} \ln(4) = 0 + c \quad \left\{ \Rightarrow c = -\frac{1}{5} \ln 4 \right\}$		dM1*
	e.g.: $\frac{1}{5} \ln \left(\frac{P}{5 - P} \right) = \frac{1}{15} t - \frac{1}{5} \ln 4$	Using any of the subtraction (or addition) laws for logarithms CORRECTLY	dM1*
	$\ln \left(\frac{4P}{5 - P} \right) = \frac{1}{3} t$		
	e.g.: $\frac{4P}{5 - P} = e^{\frac{1}{3}t}$ or e.g.: $\frac{5 - P}{4P} = e^{-\frac{1}{3}t}$	Eliminate ln's correctly.	dM1*
	gives $4P = 5e^{\frac{1}{3}t} - Pe^{\frac{1}{3}t} \Rightarrow P(4 + e^{\frac{1}{3}t}) = 5e^{\frac{1}{3}t}$		
	$P = \frac{5e^{\frac{1}{3}t}}{(4 + e^{\frac{1}{3}t})} \quad \left\{ \begin{array}{l} (\div e^{\frac{1}{3}t}) \\ (\div e^{\frac{1}{3}t}) \end{array} \right\}$	Make P the subject.	dM1*
	$P = \frac{5}{(1 + 4e^{-\frac{1}{3}t})}$ or $P = \frac{25}{(5 + 20e^{-\frac{1}{3}t})}$ etc.		A1
			(8)
12(c)	$1 + 4e^{-\frac{1}{3}t} > 1 \Rightarrow P < 5$. So population cannot exceed 5000.		B1
			(1)
			(12 marks)

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	Source paper	Question number	New spec references	Question description	New AOs
1	C4 2012	1	2.10, 8.6	Partial fractions, Integration	1.1b
2	C4 Jan 2011	1	8.4, 5.3	Integration	1.1b
3	C4 Jan 2013	2	8.2, 8.5	Integration	1.1b
4	C4 Jan 2012	2	8.2, 8.5	Integration	1.1b,
5	C4 2015	3	6.3, 8.5	Integration	1.1b, 2.1, 3.1a
6	C4 2013	3	8.2, 8.5, 6.4	Integration	1.1b, 2.1
7	C4 Jan 2011	3	2.10, 8.6, 8.7	Algebra and functions, Integration	1.1b, 3.1a
8	C4 2016	6	8.5, 8.6	Integration	1.1b, 2.1, 3.1a
9	C4 Jan 2013	5	3.3, 7.3, 7.5, 8.3, 8.5	Parametric curves and equations, Parametric differentiation, Integration	1.1b, 3.1a
10	C4 2015	6	8.2, 8.3, 8.5	Integration	1.1b, 2.1
11	C4 2017	8	5.4, 7.4, 8.3, 8.5	Parametric curves and equations, Integration	1.1b, 2.1, 3.1a
12	C4 Jan 2012	8	2.10, 8.6, 8.7, 8.8, 2.11	Partial fractions, Integration	1.1b, 2.1, 3.1a, 3.4