RECOGNISING ACHIEVEMENT

GCE

Mathematics

Advanced GCE

Unit **4727:** Further Pure Mathematics 3

Mark Scheme for January 2011

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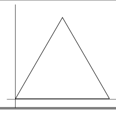
1	**(i)**	Integrating factor. $e^{\int x\,dx} = e^{\frac{1}{2}x^2}$	B1	For correct IF
		$\Rightarrow \frac{d}{dx}\left(y e^{\frac{1}{2}x^2}\right) = x e^{x^2}$	M1	For $\frac{d}{dx}(y.\text{their IF}) = x e^{\frac{1}{2}x^2}.\text{their IF}$
		$\Rightarrow y e^{\frac{1}{2}x^2} = \frac{1}{2}e^{x^2} (+c)$	A1	For correct integration both sides
		$\Rightarrow y = e^{-\frac{1}{2}x^2}\left(\frac{1}{2}e^{x^2} + c\right) = \frac{1}{2}e^{\frac{1}{2}x^2} + c\,e^{-\frac{1}{2}x^2}$	A1 **4**	For correct solution **AEF** as $y = f(x)$
	(ii)	$(0, 1) \Rightarrow c = \frac{1}{2}$	M1	For substituting (0, 1) into their GS, solving for c and obtaining a solution of the DE
		$\Rightarrow y = \frac{1}{2}\left(e^{\frac{1}{2}x^2} + e^{-\frac{1}{2}x^2}\right)$	A1 **2**	For correct solution **AEF** Allow $y = \cosh\left(\frac{1}{2}x^2\right)$
			[6]	
2	**(i)**	$\mathbf{n} = [2, 1, -3] \times [-1, 2, 4]$	M1	For using × of direction vectors
		$= [10, -5, 5] = k[2, -1, 1]$	A1	For correct **n**
		$(1, 3, 4) \Rightarrow 2x - y + z = 3$	A1 **3**	For substituting $(1, 3, 4)$ and obtaining **AG** (Verification only M0)
	(ii)	METHOD 1 distance = $\frac{21-3}{\lvert\mathbf{n}\rvert}$ *OR* $\frac{\lvert[1, 3, 4].[2, -1, 1] - 21\rvert}{\lvert\mathbf{n}\rvert}$	M1	For 21 – 3 *OR* $[1, 3, 4].[2, -1, 1] - 21$ *OR* $\lvert([1, 3, 4] - [a, b, c]).[2, -1, 1]\rvert$ soi
		OR $\frac{\lvert([1, 3, 4] - [a, b, c]).[2, -1, 1]\rvert}{\lvert\mathbf{n}\rvert}$ where (a, b, c) is on q	B1	For $\lvert\mathbf{n}\rvert = \sqrt{6}$ soi
		$= \frac{18}{\sqrt{6}} = 3\sqrt{6}$	A1 **3**	For correct distance **AEF**
		METHOD 2 $[1+2t, 3-t, 4+t]$ on q	M1	For forming and solving an equation in t
		$\Rightarrow 2(1+2t) - (3-t) + (4+t) = 21 \Rightarrow t = 3$	B1	For $\lvert\mathbf{n}\rvert = \sqrt{6}$ soi
		$\Rightarrow$ distance $= 3\lvert\mathbf{n}\rvert = 3\sqrt{6}$	A1	For correct distance **AEF**
		METHOD 3 As Method 2 to $t = 3 \Rightarrow (7, 0, 7)$ on q	M1*	For finding point where normal meets q
		distance from $(1, 3, 4)$	M1 (*dep)	For finding distance from $(1, 3, 4)$
		$= \sqrt{(7-1)^2 + (0-3)^2 + (7-4)^2} = \sqrt{54} = 3\sqrt{6}$	A1	For correct distance **AEF**
			[6]	
3	**(i)**	$\sin\theta = \frac{1}{2i}\left(e^{i\theta} - e^{-i\theta}\right)$	B1	z or $e^{i\theta}$ may be used throughout For correct expression for $\sin\theta$ soi
		$\sin^4\theta = \frac{1}{16}\left(z^4 - 4z^2 + 6 - 4z^{-2} + z^{-4}\right)$	M1	For expanding $\left(e^{i\theta} - e^{-i\theta}\right)^4$ (with at least 3 terms and 1 binomial coefficient)
		$\Rightarrow \sin^4\theta = \frac{1}{16}(2\cos 4\theta - 8\cos 2\theta + 6)$	M1	For grouping terms and using multiple angles
		$\Rightarrow \sin^4\theta = \frac{1}{8}(\cos 4\theta - 4\cos 2\theta + 3)$	A1 **4**	For answer obtained correctly **AG**
	(ii)	$\int_0^{\frac{1}{6}\pi} \sin^4\theta\,d\theta = \frac{1}{8}\left[\frac{1}{4}\sin 4\theta - 2\sin 2\theta + 3\theta\right]_0^{\frac{1}{6}\pi}$	M1	For integrating **(i)** to $A\sin 4\theta + B\sin 2\theta + C\theta$
			A1	For correct integration
		$= \frac{1}{8}\left(\frac{1}{8}\sqrt{3} - \sqrt{3} + \frac{1}{2}\pi\right) = \frac{1}{64}\left(4\pi - 7\sqrt{3}\right)$	M1	For completing integration and substituting limits
			A1 **4**	For correct answer **AEF**(exact)
			[8]	

4	**(i)**	*EITHER* $1+\omega+\omega^2$ $= \text{sum of roots of } (z^3-1=0) = 0$	M1		For result shown by any correct method **AG**
		OR $\omega^3 = 1 \Rightarrow (\omega-1)(\omega^2+\omega+1)=0$ $\Rightarrow 1+\omega+\omega^2 = 0$ (for $\omega \neq 1$)	A1	**2**	
		OR sum of G.P. $1+\omega+\omega^2 = \frac{1-\omega^3}{1-\omega}\left(=\frac{0}{1-\omega}\right)=0$			
		OR  shown on Argand diagram or explained in terms of vectors			
		OR $1+\text{cis}\,\frac{2}{3}\pi+\text{cis}\,\frac{4}{3}\pi = 1+\left(-\frac{1}{2}+\frac{\sqrt{3}}{2}\text{i}\right)+\left(-\frac{1}{2}-\frac{\sqrt{3}}{2}\text{i}\right)=0$			
	(ii)	Multiplication by $\omega \Rightarrow$ rotation through $\frac{2}{3}\pi$ ↺	B1		For correct interpretation of × by ω (allow 120° and omission of, or error in, ↺)
		$z_1 - z_3 = \overrightarrow{CA}$, $z_3 - z_2 = \overrightarrow{BC}$	B1		For identification of vectors soi (ignore direction errors)
		$\overrightarrow{BC}$ rotates through $\frac{2}{3}\pi$ to direction of $\overrightarrow{CA}$	M1		For linking *BC* and *CA* by rotation of $\frac{2}{3}\pi$ *OR* ω
		Δ *ABC* has *BC* = *CA*, hence result	A1	**4**	For stating equal magnitudes ⇒ **AG**
	(iii)	**(ii)** $\Rightarrow z_1+\omega z_2-(1+\omega)z_3=0$	M1		For using $1+\omega+\omega^2=0$ in **(ii)**
		$1+\omega+\omega^2=0 \Rightarrow z_1+\omega z_2+\omega^2 z_3=0$	A1	**2**	For obtaining **AG**
				8	
5	**(i)**	Aux. equation $3m^2+5m-2\ (=0)$	M1		For correct auxiliary equation seen and solution attempted
		$\Rightarrow m = \frac{1}{3}, -2$	A1		For correct roots
		CF $(y=)\ A\text{e}^{\frac{1}{3}x}+B\text{e}^{-2x}$	A1√		For correct CF f.t. from *m* with 2 arbitrary constants
		PI $(y=)\ px+q \Rightarrow 5p-2(px+q)=-2x+13$	M1		For stating and substituting PI of correct form
		$\Rightarrow p=1,\ q=-4$	A1 A1		For correct value of *p*, and of *q*
		GS $(y=)\ A\text{e}^{\frac{1}{3}x}+B\text{e}^{-2x}+x-4$	B1√	**7**	For GS f.t. from their CF+PI with 2 arbitrary constants in CF and none in PI
	(ii)	$\left(0,-\frac{7}{2}\right) \Rightarrow A+B=\frac{1}{2}$	M1		For substituting $\left(0,-\frac{7}{2}\right)$ in their GS and obtaining an equation in *A* and *B*
		$y'=\frac{1}{3}A\text{e}^{\frac{1}{3}x}-2B\text{e}^{-2x}+1$, $(0,0) \Rightarrow A-6B=-3$	M1		For finding y', substituting $(0, 0)$ and obtaining an equation in *A* and *B*
			M1		For solving their 2 equations in *A* and *B*
		$\Rightarrow A=0,\ B=\frac{1}{2}$	A1		For correct *A* and *B* **CAO**
		$\Rightarrow (y=)\ \frac{1}{2}\text{e}^{-2x}+x-4$	B1√	**5**	For correct solution f.t. with their *A* and *B* in their GS
	(iii)	x large $\Rightarrow (y=)\ x-4$	B1√	**1**	For correct equation or function (allow ≈ and →) **WWW** f.t. from **(ii)** if valid
				13	

<table>
<tr><td>6</td><td>(i)</td><td>$a^4 = r^6 = e \Rightarrow a$ has order 4, a^2 has order 2
$\left(a^3\right)^4 = a^{12} = e \Rightarrow a^3$ has order 4

$\left(r^2\right)^3 = e \Rightarrow r^2$ has order 3</td><td>M1
A1
A1
B1</td><td>

4</td><td>For considering powers of a
For order of any one of $a,\ a^2, a^3$ correct
For all correct
For order of r^2 correct</td></tr>
<tr><td></td><td>(ii)</td><td>G order 4
<table><tr><td>Order of element</td><td>1</td><td>2</td><td>(4)</td></tr><tr><td>Number of elements</td><td>1</td><td>3</td><td>(0)</td></tr></table>H order 6
<table><tr><td>Order of element</td><td>1</td><td>2</td><td>3</td><td>(6)</td></tr><tr><td>Number of elements</td><td>1</td><td>3</td><td>2</td><td>(0)</td></tr></table>G and H are the only non-cyclic groups of order which divides 12
Q has 1 element of order 2, G and H have 3, so no non-cyclic subgroups in Q</td><td>M1

A1
A1
B1

B1</td><td>

5</td><td>For top line in either table
Allow inclusion of 4 and 6 respectively (and other orders if 0 appears below)
For order 4 table
For order 6 table
For stating that only G and H need be considered AEF
For argument completed by elements of order 2 AG
SR Allow equivalent arguments for B1 B1</td></tr>
<tr><td></td><td></td><td></td><td>9</td><td></td><td></td></tr>
<tr><td>7</td><td>(i)</td><td>$[1, 1, -2] \times [1, -1, 3] = (\pm)[1, -5, -2]$

$[1, -1, 3] \times [1, 5, -12] = (\pm)[-3, 15, 6]$

$[-3, 15, 6] = k\,[1, -5, -2] \Rightarrow$ parallel</td><td>M1
A1
M1
A1
A1</td><td>

5</td><td>For using × of direction vectors
For correct direction
For using × of direction vectors
For correct direction
For argument completed AG
($k = -3$ not essential)</td></tr>
<tr><td></td><td>(ii)</td><td>Line of intersection is parallel to l and m</td><td>B1</td><td>1</td><td>For correct statement</td></tr>
<tr><td></td><td>(iii)</td><td>METHOD 1
$\left.\begin{array}{l} x+y-2z=5 \\ x-y+3z=6 \end{array}\right\}$ e.g. $z=0 \Rightarrow \left(\frac{11}{2}, -\frac{1}{2}, 0\right)$ on l
$\left.\begin{array}{l} x-y+3z=6 \\ x+5y-12z=12 \end{array}\right\}$ e.g. $z=0 \Rightarrow (7,\ 1,\ 0)$ on m
$\left.\begin{array}{l} x+y-2z=5 \\ x+5y-12z=12 \end{array}\right\}$ e.g. $z=0 \Rightarrow \left(\frac{13}{4}, \frac{7}{4}, 0\right)$ on l_3
Different points $\Rightarrow$ no common line of intersection</td><td>M1
A1
A1

A1</td><td>

4</td><td>For attempt to find points on 2 lines
For a correct point on one line
For a correct point on another line

For correct answer</td></tr>
<tr><td></td><td></td><td>METHOD 2
$\left.\begin{array}{l} x+y-2z=5 \\ x-y+3z=6 \end{array}\right\}$ e.g. $\Rightarrow z = 11-2x,\ y = 27-5x$
LHS of eqn 3 =
$x + (135-25x) - (132-24x) = 3 \neq 12$
$\Rightarrow$ no common line of intersection</td><td>M1

A1
A1
A1</td><td></td><td>For finding (e.g.) y and z in terms of x OR eliminating one variable
For correct expressions OR equations
For obtaining a contradiction from 3rd equation
For correct answer</td></tr>
<tr><td></td><td></td><td>METHOD 3
LHS $\Pi_3 = 3\Pi_1 - 2\Pi_2$
RHS $3 \times 5 - 2 \times 6 = 3 \neq 12$
$\Rightarrow$ no common line of intersection</td><td>M2
A1
A1</td><td></td><td>For attempt to link 3 equations
For obtaining a contradiction
For correct answer</td></tr>
<tr><td></td><td></td><td>SR Variations on all methods may gain full credit</td><td></td><td></td><td>SR f.t. may be allowed from relevant working</td></tr>
<tr><td></td><td></td><td></td><td>10</td><td></td><td></td></tr>
</table>

8	**(i)**	$((a,b)*(c,d))*(e,f)=(ac,\ ad+b)*(e,f)$	M1		For 3 distinct elements bracketed and attempt to expand
		$=(ace,\ acf+ad+b)$	A1		For correct expression
		$(a,b)*((c,d)*(e,f))=(a,b)*(ce,\ cf+d)$			
		$=(ace,\ acf+ad+b)$	A1	**3**	For correct expression again
	(ii)	$(a,b)*(1,1)=(a,\ a+b)$, $(1,1)*(a,b)=(a,\ b+1)$	M1		For combining both ways round
		$a+b=b+1 \Rightarrow a=1$	M1		For equating components (allow from incorrect pairs)
		$\Rightarrow (1,b)\ \forall\ b$	A1	**3**	For correct elements **AEF**
	(iii)	$(mp,\ mq+n)$ *OR* $(pm,\ pn+q)=(1,0)$	M1		For either element on LHS
		$\Rightarrow (p,q)=\left(\frac{1}{m},-\frac{n}{m}\right)$	A1	**2**	For correct inverse
	(iv)	$(a,b)*(a,b)=(a^2,\ ab+b)=(1,0)$ *OR* $(a,b)=\left(\frac{1}{a},-\frac{b}{a}\right) \Rightarrow a^2=1,\ ab=-b$	M1		For attempt to find self-inverses
		$\Rightarrow$ self-inverse elements $(1,0)$ and $(-1,b)\ \forall\ b$	B1 A1	**3**	For $(1,0)$. For $(-1,b)$ **AEF**
	(v)	$(0,y)$ has no inverse for any $y \Rightarrow$ not a group	B1	**1**	For stating any one element with no inverse. Allow $x \neq 0$ required, provided reference to inverse is made "Some elements have no inverse" B0
				12	

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