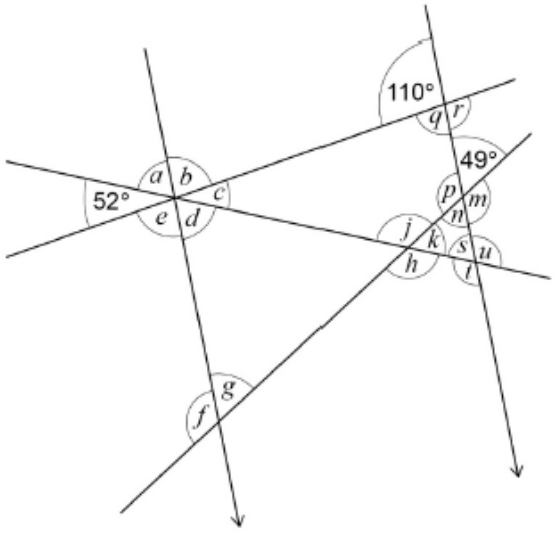
1	**Alternative method 1: using the radius**		
	$2\pi r$	M1	
	$2\pi r \times \frac{x}{360}$	M1dep	oe length of arc
	$2\pi r = 2\pi r \times \frac{x}{360} + 2r$ or $\pi = \frac{\pi x}{360} + 1$ or $2\pi = \frac{2\pi x}{360} + 2$	M1dep	oe equation
	$\frac{360(\pi - 1)}{\pi}$ or $\frac{360\pi - 360}{\pi}$ or $360 - \frac{360}{\pi}$	A1	oe expression in π with r cancelled throughout
	Alternative method 2: using the diameter		
	πd	M1	oe
	$\pi d \times \frac{x}{360}$	M1dep	oe length of arc
	$\pi d = \pi d \times \frac{x}{360} + d$ or $\pi = \frac{\pi x}{360} + 1$	M1dep	oe equation
	$\frac{360(\pi - 1)}{\pi}$ or $\frac{360\pi - 360}{\pi}$ or $360 - \frac{360}{\pi}$	A1	oe expression in π with d cancelled throughout
	Additional Guidance		
	Ignore attempts to simplify, cancel or expand a correct expression		M1M1M1A1

<table>
<tr><th>Q</th><th>Answer</th><th>Mark</th><th>Comments</th></tr>
<tr><td rowspan="5">2</td><td colspan="3">Using these letters for the unknown angles
 
</td></tr>
<tr><td>73</td><td>B3</td><td>B2 $180 - 110 + 52 - 49$ oe calculation
or
$h = 107$ or $j = 107$ or $k = 73$
or
$g = 49$ and $d = 58$
or
$g = 49$ and $e = 70$
or
$f = 131$ and $d = 58$
B1 any angle correct (others may be incorrect)</td></tr>
<tr><td colspan="3">Additional Guidance</td></tr>
<tr><td colspan="2">Angles will usually be seen on the diagram</td><td></td></tr>
<tr><td colspan="2">Angles must be unambiguously linked to the correct position
eg 131 seen in working but not on the diagram or in wrong position</td><td>B0</td></tr>
<tr><td colspan="2">$a = 58$ $b = 70$ $c = 52$ $d = 58$ $e = 70$
$f = 131$ $g = 49$ $h = 107$ $j = 107$ $k = 73$
$m = 131$ $n = 49$ $p = 131$ $q = 70$ $r = 110$
$s = 58$ $t = 122$ $u = 122$</td><td></td></tr>
</table>

Q	Answer	Mark	Comments
3	105	B1	may be seen on the diagram
	$12^2 + 28^2 - 2 \times 12 \times 28 \times \cos$ their 105 or [1101, 1102]	M1	oe eg 144 + 784 – 672 cos their 105 or 928 – 672 cos their 105 their 105 cannot be 0 or 90 their 105 must be < 180
	$\sqrt{\text{their } [1101, 1102]}$	M1dep	
	[33.19, 33.2] or 33	A1ft	ft B0M2
	Additional Guidance		
	Follow through answers must be rounded to 2 sf or better		

Q	Answer	Mark	Comments
4	**Alternative method 1**		
	OBD and *OCD* are right angles and *BOC* (obtuse) = $180 - x$	M1	may be on diagram
	BAC = $90 - \frac{x}{2}$	M1dep	oe may be on diagram
	BOC (reflex) = $180 + x$ and *ABO* + *ACO* = $360 - (90 - \frac{x}{2} + 180 + x)$ or $90 - \frac{x}{2}$ and *ABO* = $\frac{1}{2}(90 - \frac{x}{2})$ $= 45 - \frac{x}{4}$ with M2 scored	A1	oe $360 - 90 + \frac{x}{2} - 180 - x$
	All reasons given tangent meets the radius at 90° angles in a quadrilateral add up to 360° angle at the circumference is half the angle at the centre angles around a point add to 360°	A1	

Q	Answer	Mark	Comments
4 cont	**Alternative method 2**		
	OBD and *OCD* are right angles and *BOC* (obtuse) = $180 - x$	M1	may be on diagram
	BAC = $90 - \frac{x}{2}$	M1dep	oe may be on diagram
	BOC (reflex) = $180 + x$ and *BAD* = $\frac{1}{2}(90 - \frac{x}{2})$ or $45 - \frac{x}{4}$ and *ABO* = $180 - (45 - \frac{x}{4}) - (90 + \frac{x}{2})$ $= 45 - \frac{x}{4}$ with M2 scored	A1	
	All reasons given tangent meets the radius at 90° angles in a quadrilateral add up to 360° angle at the circumference is half the angle at the centre angles in a triangle add up to 180°	A1	

Q	Answer	Mark	Comments
4 cont	**Alternative method 3**		
	OBD and OCD are right angles and BOC (obtuse) = $180 - x$	M1	may be on diagram
	$BAC = 90 - \frac{x}{2}$	M1dep	oe may be on diagram
	$ABC = \frac{1}{2}[180 - (90 - \frac{x}{2})]$ $= 45 + \frac{x}{4}$ and $OBC = \frac{1}{2}[180 - (180 - x)]$ $= \frac{x}{2}$ and $ABO = 45 + \frac{x}{4} - \frac{x}{2}$ $= 45 - \frac{x}{4}$ with M2 scored	A1	
	All reasons given tangent meets the radius at 90° angles in a quadrilateral add up to 360° angle at the circumference is half the angle at the centre angles in a triangle add up to 180° (base angles in an) isosceles triangle (are equal)	A1	

Q	Answer	Mark	Comments
4 cont	**Alternative method 4**		
	OBD is a right angle and $BDO = \frac{x}{2}$	M1	may be on diagram
	$BOD = 90 - \frac{x}{2}$	M1dep	may be on diagram
	$OAB + ABO = 90 - \frac{x}{2}$ and $ABO = 45 - \frac{x}{4}$ with M2 scored	A1	
	All reasons given tangent meets the radius at 90° the diagram is symmetrical oe angles in a triangle add up to 180° exterior angle of a triangle is equal to the sum of the opposite interior angles *OA* and *OB* are radii, so triangle *ABO* is isosceles (base angles in an) isosceles triangle (are equal)	A1	
	Additional Guidance		
	Using a value for x		M0M0A0A0

Q	Answer	Mark	Comments
5	interior angle = 150 or exterior angle = 30 or angle $BCN = 120$	B1	method not required may be seen on diagram
	interior angle = 150 with a valid method shown or exterior angle = 30 with a valid method shown or angle $BCN = 120$ with a valid method shown	B1dep	angles may be seen on diagram but methods will be in working lines eg $180 - \frac{360}{12} = 150$ or $\frac{1800}{12} = 150$ or $360 - 120 - 90 = 150$ or $\frac{360}{12} = 30$ or $\frac{180-120}{2} = 30$ or $180 - 150 = 30$ or $360 - 150 - 90 = 120$ or $360 - 240 = 120$ or $180 - 2 \times 30 = 120$
	interior angle = 150 with a valid method shown **and** exterior angle = 30 with a valid method shown **and** angle $BCN = 120$ with a valid method shown	B1dep	angles may be seen on diagram but methods will be in working lines eg $\frac{1800}{12} = 150$ **and** $\frac{180-120}{2} = 30$ **and** $360 - 240 = 120$ angles worked out in any order
	Fully correct working that must show correct progression and show all valid methods Valid methods shown must be appropriate for the approach used A reason must be included in the final step	B1dep	examples of the final step are (i) angle ABC + angle $CBN = 180$ (ii) interior angle = 150 in two different ways (iii) exterior angle = 30 in two different ways (iv) angle $BCN = 120$ in two different ways (v) sum of three angles at $C = 360$ (vi) sum of angles of triangle $BCN = 180$

	Additional Guidance	
5 cont	Condone incorrect use of equals signs throughout eg interior angle = 12 – 2 = 10 × 180 = 1800 ÷ 12 = 150	B1B1
	interior angle may be seen as angle *ABC* or angle *BCD* exterior angle may be seen as angle *CBN*	
	It must be clear which angle they are working out eg1 Do not accept 150 if it is not correctly identified or not in the correct position on diagram eg2 Do accept 150 if it is identified as an interior angle or angle *ABC* or is in the correct position on the diagram	
	Do not accept incorrect statements eg1 exterior angle = 150 (even if 150 in correct position on the diagram) eg2 angle *ACB* = 150 (even if 150 in correct position on the diagram)	
	Ignore reasons for the first three marks	
	Angles on the diagram with no valid methods can score a maximum of B1B0B0B0	
	For the 2nd and 3rd marks the methods shown do not have to show progression	
	Example of fully correct working for (i) interior angle = $\frac{1800}{12} = 150$ angle *BCN* = 360 – 150 – 90 = 120 angle *CBN* = $\frac{180-120}{2} = 30$ 150 + 30 = 180 angles on a (straight) line	B1B1 B1 B1
	Example of fully correct working for (ii) exterior angle = $\frac{360}{12} = 30$ angle *BCN* = 180 – 2 × 30 = 120 interior angle = 360 – 120 – 90 = 150 interior angle = $\frac{1800}{12} = 150$ (interior) angle of polygon	B1B1 B1 B1

Q	Answer	Mark	Comments
6	**Alternative method 1 – using angles around *O* and angles inside arrowhead**		
	$ACO = 90 - 83$ or $ACO = 7$	M1	may be seen on diagram
	Acute $BOC = 2 \times 28$ or acute $BOC = 56$	M1	may be seen on diagram
	Reflex $BOC = 360 -$ their 56 or reflex $BOC = 304$	M1dep	may be seen on diagram dep on 2nd M1
	$ABO = 360 -$ their 304 – their 7 – 28 or $ABO = 21$	M1dep	may be seen on diagram dep on M3
	$ABO = 21$ and $ACO = 7$ and 21 : 7 = 3 : 1	A1	all angle values must be seen
	Alternative method 2 – with line *OA* added		
	$ACO = 90 - 83$ or $ACO = 7$	M1	may be seen on diagram
	$OAC = 7$ or $ABO + ACO = 28$	M1dep	may be seen on diagram
	$OAB = 28 - 7$ or $OAB = 21$ or $ABO = 28 - 7$	M1dep	may be seen on diagram dep on M2
	$ABO = 21$	M1dep	may be seen on diagram dep on M3
	$ABO = 21$ and $ACO = 7$ and 21 : 7 = 3 : 1	A1	all angle values must be seen

Q	Answer	Mark	Comments
6 cont	**Alternative method 3 – using alternate segment theorem**		
	$ACO = 90 - 83$ or $ACO = 7$	M1	may be seen on diagram
	Acute $BOC = 2 \times 28$ or acute $BOC = 56$	M1	may be seen on diagram
	$ABC = 83$	M1	may be seen on diagram
	$OBC = \frac{180 - \text{their } 56}{2}$ or $OBC = 62$ and $ABO = 83 - \text{their } 62$ or $ABO = 21$	M1dep	may be seen on diagram, dep on 2nd and 3rd M1
	$ABO = 21$ and $ACO = 7$ and $21 : 7 = 3 : 1$	A1	all angle values must be seen

Q	Answer	Mark	Comments
6 cont	**Alternative method 4 – using triangles *OBC* and *ABC***		
	$ACO = 90 - 83$ or $ACO = 7$	M1	may be seen on diagram
	Acute $BOC = 2 \times 28$ or acute $BOC = 56$	M1	may be seen on diagram
	$OBC = \frac{180 - \text{their } 56}{2}$ or $OBC = 62$	M1dep	may be seen on diagram or angle OCB dep on 2nd M1
	$ABO = 180 - 28 - 62 - 62 - 7$ or $ABO = 21$	M1dep	oe may be seen on diagram dep on M3
	$ABO = 21$ and $ACO = 7$ and $21 : 7 = 3 : 1$	A1	all angle values must be seen
	Additional Guidance		
	If angles are not correctly positioned on the diagram they must be correctly identified in the working, eg $BOC = 56$ is M0 if not correctly positioned on the diagram and not identified as acute		
	$ACO = 7$ and $ABO : ACO = 21 : 7$ with no other correct working		M1M0M0M0A0

Q	Answer	Mark	Comments
7	**Alternative method 1 – numerical**		
	1 and 5 and 3 or 9 (parts) or numbers in the ratio 1 : 5 : 3 or (angle sum on a straight line =) 180	M1	oe may be seen in a ratio eg $\frac{1}{5} : 1 : \frac{3}{5}$ or $\frac{1}{3} : \frac{5}{3} : 1$ numbers can be in any order eg 30, 10, 50
	$180 \div (1 + 5 + 3)$ or 20 or $180 \div \frac{9}{5}$	M1dep	oe
	100	A1	
	Alternative method 2 – algebraic		
	x and $5x$ and $3x$ or $9x$ or (angle sum on a straight line =) 180	M1	oe correct terms with any angle as x any letter, any order may be seen on diagram
	Correct equation with correct method to solve for one angle	M1dep	eg $x + 5x + 3x = 180$ and $180 \div (1 + 5 + 3)$
	100	A1	
	Additional Guidance		
	$x + 5x + 3x = 360$ or $360 \div 9$		M1M0A0
	$\frac{1}{5}x + x + \frac{3}{5}x = 180$ and $180 \div \left(\frac{1}{5} + 1 + \frac{3}{5}\right)$		M1M1
	$\frac{1}{3}x + \frac{5}{3}x + x = 180$ and $180 \div \left(\frac{1}{3} + \frac{5}{3} + 1\right)$		M1M1
	Angle *EBD* marked as 100 on the diagram with answer line blank		M1M1A1
	20 and 100 in working with no or incorrect answer chosen		M1M1A0

Q	Answer	Mark	Comments
8	True Not true Not true True	B4	B1 each correct answer
	Additional Guidance		
	Allow a cross if it's the only answer in that row		
	If one tick and one or two crosses are given in a row, mark the tick		

	Answer	Mark	Comment
9	$BOD = 2 \times 32$ or 64	M1	oe eg $BOC = 64$ may be seen on diagram
	$OBD = 90$	M1	may be seen on diagram or implied by further working or answer
	26	A1	
	Additional Guidance		
	90 can be implied by a square angle sign		
	180 – 154 implies M1M1		

Q	Answer	Mark	Comments
10	$\frac{1}{4}x + 15 + \frac{2}{3}x - 44 = 180$	M1	oe equation
	$\frac{1}{4}x + \frac{2}{3}x = 180 - 15 + 44$ or $3x + 180 + 8x - 528 = 2160$	M1dep	oe equation with terms collected eg $\frac{11}{12}x = 209$ or oe equation with fractions eliminated eg $11x = 2508$
	$(x =) 209 \div \frac{11}{12}$ or $(x =) 228$	M1dep	oe calculation that leads to $(x =) 228$ eg $(x =) 2508 \div 11$ implied by 72 and 108
	72 : 108	A1	oe ratio eg 2 : 3 or 1 : 1.5 or $\frac{2}{3}$: 1
	Additional Guidance		
	Ignore simplification attempt after correct ratio seen eg 72 : 108 in working with answer 36 : 52		M3A1
	Accept [0.66, 0.67] for $\frac{2}{3}$		
	Accept [0.91, 0.92] for $\frac{11}{12}$		
	Accept [1.09, 1.1] for $\frac{12}{11}$		

Q	Answer	Mark	Comments
11	**Alternative method 1**		
	$(a=)$ 45 ÷ 3 × 7 or 105	M1	oe may be on diagram
	$(y=)\ \frac{360-45-\text{their}105}{4+1}$ or $\frac{210}{5}$ or 42	M1dep	oe may be on diagram
	$(a=)$ 105 and $(y=)$ 42 or 105 : 42 and $(a:y=)$ 5 : 2 with M2 awarded	A1	
	Alternative method 2		
	$(a=)$ 45 ÷ 3 × 7 or 105	M1	oe may be on diagram
	$(y=)$ their 105 ÷ 5 × 2 or 42	M1dep	oe may be on diagram
	45 + 105 + 42 + 168 = 360 and 42 × 4 = 168 or 360 – 45 – 105 – 42 = 168 and 168 ÷ 4 = 42	A1	
	Additional Guidance		
	105 : 42		M1M1A0