1		$BDF = 70°$	4	B1	may be marked on diagram
		Alternate segment theorem		B1	reason, the angle between a tangent and a chord is equal to the angle subtended in the alternate segment
		$EFB = 180 - (70 + 40) = 70$ opposite angles in a cyclic quadrilateral		B1	Angle EFB with reason, opposite angles in a cyclic quadrilateral sum to 180°
		$CBF = EFB$ alternate angles therefore EF is parallel to ABC		B1	conclusion, alternate angles are equal
					Total 4 marks

2	(a) (i)		40	2	B1	cao (may be written on the diagram)
	(ii)		Angles in same segment (are equal)		B1	**or** angles at the circumference from the same arc of the circle **or** angles on the same arc of the circle **Alternatively**: (two applications of) Opposite angles of a cyclic quadrilateral sum to 180°
	(b)		140	1	B1	cao (may be written on the diagram)
						Total 3 marks

3	$ADC = 180 - 58$ (= 122) **or** $EDF = 122$ **or** $CDE = 58$ **or** $ADF = 58$			M1	may be seen marked on the diagram
	e.g. $DEF = 58 \div 2$ **or** $DEF = (180 - 122) \div 2$			M1	complete method to find angle DEF
		29		A1	
			5	B2	dep on M2 for fully correct reasons for their method (B1 dep on M1 for one correct reason stated and used) e.g. Allied angles, co-interior angles, Alternate angles, Corresponding angles, Vertically opposite angles are equal (or Vertically opposite angles are equal), Angles on a straight line add up to 180°(or angles on a straight line add to 180°), Sum of two angles in a triangle are equal to opposite exterior angle, Angles in a triangle add up to 180°(or Angles in a triangle add up to 180°), Base angles in an isosceles triangle Angles in a quadrilateral add up to 360. (accept "4-sided shape"or parallelogram) Opposite angles of a parallelogram are equal
					Total 5 marks

4	$CB = 13\sin 40$ (= 8.3562...)			M1
	$\frac{1}{2}\times 6\times "8.35..."\times \sin ACB = 22$			M1
	Acute version of $ACB = \sin^{-1}\left(\frac{22}{\frac{1}{2}\times 6\times "8.35..."}\right)$ (= 61.35…)			M1
	$ACB = 180 -$ "61.353…" (= 118.647...)			M1
	$AB^2 = 6^2 + "8.35..."^2 - 2\times 6\times "8.35..."\times \cos "118.64"$ (= 153.98...)			M1
		12.4	6	A1 accept 12.3 – 12.5
				Total 6 marks

5	*ORQ* = 90 – 60 (=30) **or** *OQR* = 30 **or** *PQR* = 0.5 × (360 – 238) (= 61) **or** *QPR* = 60 **or** *OPR* = $\frac{180-(360-238)}{2}$ (= 29)		4	M1	The correct working or the correct angle for *ORQ* **or** *OQR* **or** *PQR* **or** *QPR* **or** *OPR*. Must be clearly stated as the correct angle or shown on the diagram in correct position. (eg just seeing 30 in working without a label is not sufficient for the award of this mark)
	Working not required, so correct answer scores M1A1 (unless from obvious incorrect working)	31		A1	if not on answer line, may be seen on diagram or clearly labelled
	NB: degrees symbol not essential for reasons *We will allow the symbol* *Δ for 'triangle'* *∠ for angle* *Σ for sum*	full reasons for method used		B2	(dep on a fully correct method that should lead to the answer) for fully correct reasons for method used (underlined words **must** be seen) eg Angle between tangent and radius is 90° Angles around a point total 360° Angle at centre is twice angle at circumference/edge Total of angles in triangle is 180° / triangle 180° Base angles in an isosceles triangle (or 2 sides equal, so 2 angles equal) Angles in a quadrilateral total 360° or quadrilateral 360° / Accept "4-sided shape" or "quad" Alternate segment theorem (B1 dep on M1 for at least one reason for method used)
					Total 4 marks

6	Angle *EBC* or *ECB* = (180 – 44) ÷ 2 (= 68)		5	M1	Could be seen on diagram
	Angle *GBC* = 180 – "68" (= 112) **or** Angle *GBC* = "68" + 44 (= 112) **or** Angle *BGH* = "68" (same as *EBC*) Angle *ABE* = 180 – "68" (= 112) **and** Angle *BGF* = "112" **or** Angle *ABG* = "68" **and** Angle *BGH* = "68" or Angle *FGJ* = "68" **or** Angle *BGF* = 180 – "68"(=112)			M1	for a method to as far as one step away from working out Angle *JGH* (an angle corresponding or vertically opposite to *JGH* or at the same point on a straight line with *JGH*) Could be seen on diagram. (the award of this mark also implies the previous M1)
	Working not required, so correct angle scores 3 marks (unless from obvious incorrect working)	112		A1	Could be seen in correct place on diagram
	NB: reasons must include the underlined words *Accept ∠ for angle(s) and □ for triangle* **For all angles**: They must be clearly stated as the correct angle or shown on the diagram in the correct position. (eg just seeing 68 in working without a label is not sufficient for the award of a mark for angle *EBC*)			B2	for correct answer with full reasons for their method eg isosceles triangle (or 2 equal sides, 2 equal angles) Angles in a triangle sum to 180° or angles in a triangle Angles on a straight line sum to 180° Angles on a straight line sum to 180° Exterior angle in a triangle is equal to the two opposite interior angles. Vertically opposite angles are equal. Vertically opposite angles are equal. Corresponding angles are equal. Alternate angles are equal Allied angles sum to 180° (or co-interior angles) Angles at a point (or full turn) add up to 360° (or angles at a point) (B1 for one correct reason appropriate to their method, dep on M1)
					Total 5 marks

7	*BFD* = 39°	*BED* = 39°		4	B1	
	BDE = 180 – (18 + 39)	*EBD* = 18° **and** *BDE* = 180 – (18 + 39)			M1	
			123		A1	
					B1	dep on M1 for all correct circle theorems relevant for their method e.g. alternate segment theorem **and** opposite angles in a cyclic quadrilateral sum to 180° **or** alternate segment theorem **and** angles in same segment are equal
						Total 4 marks

8	(a) (i)		62	3	B1
	(a) (ii)		118		B1ft 180 – their (a)(i)
	(b)		62		B1
					Total 3 marks

9	*ABC* = 90° **and** *ACB* (= *ADB*) = 180 – 90 – 55 (= 35) **or** *ABO* = 55° **and** *AOB* = 180 – 2 × 55 (= 70) **or** *BDC* = 55°, *ADC* = 90° **and** *ADB* = 90 – 55 (= 35)		4	M1
		35		A1 for *ADB* = 35
	Angles in a semicircle are 90° Angles in a triangle add to 180° (Angles in a triangle add to 180°) Angles in the same segment (are equal) OR angles at the circumference subtend(ed) from the same arc/chord of the circle (are equal) **or** Angles in an isosceles triangle (are equal) Angles in a triangle sum to 180° (Angles in a triangle add to 180°) Angle at the centre is 2 × (double) angle at circumference / angle at circumference is ½ angle at centre **or** Angles in the same segment (are equal) OR angles at the circumference subtend(ed) from the same arc/chord of the circle Angles in a semicircle are 90°			B2 (dep on M1) for all 3 reasons appropriate to their method B1 (dep on M1) for one correct circle theorem appropriate to their method) NB For the third method only 2 reasons are required
				Total 4 marks

10	$\frac{\sin Q}{4.2} = \frac{\sin 18}{1.6}$ oe or $1.6^2 = 4.2^2 + RQ^2 - 2\times 4.2\times RQ\times\cos 18$ oe		6	M1 correct sine ratio - could be rearranged or correct substitution into the cosine rule using angle *R*
	$\sin^{-1}\left(4.2\times\frac{\sin 18}{1.6}\right)$ (= 54.2) **or** $\sin^{-1}(0.811...)$ $\frac{2\times 4.2\times\cos 18 \pm\sqrt{(2\times 4.2\times\cos 18)^2 - 4\times 1\times 15.08}}{2}$			M1
	180 – "54.2" (=125.8) or *RQ* = 3.0585.. and 4.933…			M1 This can be implied by the correct value(s) (125.8 or 3.0585…) used later
	(*P* =) 180 –"125.8" – 18 (=36.2) **or** $RQ = \sqrt{4.2^2 + 1.6^2 - 2\times 4.2\times 1.6\times\cos\text{"}36.2\text{"}}$ (= 3.0585…) or 3.0585 chosen as value from cosine rule above **or** perpendicular height = 4.2sin"36.2" (= 2.4805…) (where "36.2" comes from correct working)			M1
	(Area =) $\frac{1}{2}\times 4.2\times 1.6\times\sin(\text{"}36.2\text{"})$ **or** (Area =) $\frac{1}{2}\times 4.2\times\text{"}3.0585...\text{"}\times\sin 18$ **or** (Area =) $\frac{1}{2}\times 1.6\times\text{"}2.4805...\text{"}$			M1
		1.98		A1 awrt 1.98
				Total 6 marks

11	*SCD* = 128° **or** *BCS* = 32° **or** *TSC* = 180 – 128 (= 52)		4	M1	angles need to be identified or may be seen marked on the diagram	M2 for (*BCD* =) 128 + 32 (= 160) **or** (*DCV* =) 52 – 32 (= 20) (may be seen marked on the diagram). To award these marks 160 or 20 must be clearly used or identified as the interior or exterior angle.
	eg $(\text{int}\angle =)128+32(=160)$ **or** $(\text{ext}\angle =)180-(128+32)(=20)$ **or** $(\text{ext}\angle =)"52"-32(=20)$			M1	(dep on previous M1) for method to find the size of one interior or exterior angle, may be seen marked on the diagram.	
	eg $180(n-2)="160"n$ **or** 360 ÷ "20"			M1	for setting up an equation for the sum of interior angles **or** 360 ÷ "20"	
	Working required	18		A1	dep on M2	
						Total 4 marks

12	3 × 180 (= 540) or 360 – [(180 – 90) + (180 – 135) + (180 – 67) + (180 – 119)] (= 51) or 360 – (90 + 45 + 113 + 61) (= 51)		3	M1
	90 + 135 + 67 + 119 + *x* = "540" oe 411 + *x* = "540" oe or "540" – (90 + 135 + 67 + 119) or 3 × 180 – (90 + 135 + 67 + 119) oe or 540 – 411 or 180 – "51" oe			M1
	Correct answer scores full marks (unless from obvious incorrect working)	129		A1
				Total 3 marks

13	$\cos 50=\frac{18}{(AB)}$ or $\sin 40=\frac{18}{(AB)}$ or $\frac{(AB)}{\sin 90}=\frac{18}{\sin 40}$		5	M1	M2 for $(AB=)\sqrt{18^2+(18\tan 50)^2}$ oe (= 28.0030…) or 28
	$(AB=)\frac{18}{\cos 50}(=28.0030...)$ oe or 28 or $(AB=)\frac{18}{\sin 40}(=28.0030...)$ oe or 28			M1	
	$\frac{1}{2}\times\pi\times"28.0030..."(=43.9...)$ oe or 44 $\pi\times"28.0030..."(=87.9...)$ oe or 88			M1 for use of πd or $\frac{1}{2}\pi d$ oe Allow any value of *AB* > 18 if M2 not scored	
	"28…" + "43.9…" (= 71.9900…) or "28" + "44"			M1ft from previous M1 Allow *their d* + *their* $\frac{1}{2}\pi d$	
	Correct answer scores full marks (unless from obvious incorrect working)	72		A1 awrt 72	
					Total 5 marks

14	$\frac{\sin ABC}{24}=\frac{\sin 64}{31}$ oe		5	M1
	$(ABC=)\sin^{-1}\left(\frac{24\times\sin 64}{31}\right)(=44.…)$			M1
	180 – "44.…" – 64 (= 71.9…)			M1 accept 72
	$(DE^2=)16^2+19^2-2\times16\times19\times\cos"71.9..."$ or $(DE=)\sqrt{16^2+19^2-2\times16\times19\times\cos"71.9..."}$ or $(DE=)\sqrt{617-181.8...}$ or $\sqrt{428.166...}$			M1 for DE^2 or *DE*
	Correct answer scores full marks (unless from obvious incorrect working)	20.7		A1 awrt 20.7
				Total 5 marks

15	eg (6 – 2) × 180 (= 720)		4	M1	for a method to find the sum of the interior angles for a hexagon
	eg $"720"-(90+95+149+104+57)(=225)$			M1	for a method to find the missing angle in the hexagon
	eg $\frac{360}{"225"-180}$ **or** $\frac{360}{"45"}$ **or** $\frac{180(n-2)}{n}=360-"225"$ oe **or** $\frac{180(n-2)}{n}="135"$			M1	for a complete method
	Working required	8		A1	cao dep on M2 NB: the answer of 8 can be gained from assuming that *AB* splits reflex *GBC* into 2 equal angles – without gaining the first 2 method marks [M0M0 is awarded] Award SCB1 for the student who gains an answer of 8 from this assumption or trial and improvement or no method shown
					Total 4 marks

16	eg $\frac{1}{2}(2x-1)(2x+1)\sin 30 = x^2+x-3.75$ oe		6	M1	for equating area of triangle with the given area
		3.5		A1	for the value of *x*
	$(BC^2=)"6"^2+"8"^2-(2\times"6"\times"8"\times\cos 30)(=16.8(615...))$ oe or $(BC=)\sqrt{"16.8..."}(=4.10(628…))$			M1	ft dep on M1 for a correct method to find BC^2 or *BC* (*AB* = 6 and *AC* = 8)
	$\frac{\sin(ABC)}{"8"}=\frac{\sin 30}{\sqrt{"16.8"}}$ oe or $\frac{\sin(BCA)}{"6"}=\frac{\sin 30}{\sqrt{"16.8"}}$ oe or $"6"^2="8"^2+\left(\sqrt{"16.8"}\right)^2-\left(2\times"8"\times\sqrt{"16.8"}\times\cos(BCA)\right)$ oe or $"8"^2="6"^2+\left(\sqrt{"16.8"}\right)^2-\left(2\times"6"\times\sqrt{"16.8"}\times\cos(ABC)\right)$ oe			M1	ft dep on previous M1 for a correct method to find angle *ABC* or angle *BCA*
	$(\sin ABC=)\frac{\sin 30\times"8"}{\sqrt{"16.8"}}(=0.974...)$ oe or $ABC=76.9…$ or $(\sin BCA=)\frac{\sin 30\times"6"}{\sqrt{"16.8"}}(=0.730...)$ oe or $BCA=46.9…$ or $(\cos BCA=)\frac{"8"^2+\left(\sqrt{"16.8"}\right)^2-"6"^2}{2\times"8"\times\left(\sqrt{"16.8"}\right)}(=0.682...)$ oe or $BCA=46.9…$ or $(\cos ABC=)\frac{"6"^2+\left(\sqrt{"16.8"}\right)^2-"8"^2}{2\times"6"\times\left(\sqrt{"16.8"}\right)}(=-0.226...)$ oe or $ABC=103.0…$			M1	ft dep on previous M1 for a correct rearrangement for sin *ABC* or sin *BCA* or cos *BCA* or cos *ABC*
	Correct answer scores full marks (unless from obvious incorrect working)	103		A1	accept awrt 103
					Total 6 marks

17	180 – 78 – 78 oe or (90 – 78) × 2 oe		2	M1 for a complete **correct** method to find angle *ABC*. This is not awarded if the angles are incorrectly labelled unless they have clearly started again (Ignore incorrect angles on the diagram if a student shows a correct method leading to the required answer)
	Correct answer scores full marks (unless from obvious incorrect working)	24		A1 award full marks if 24 is seen in the correct place on the diagram unless contradicted on the answer line
				Total 2 marks

18	(radius of large circle =) $\frac{4}{\cos 54}$ **or** $\frac{4}{\sin 36}$ **or** $\frac{8\sin 54}{\sin 72}$ **or** $\sqrt{\frac{8^2}{2-2\cos 72}}$ (= 6.805...) **or** (height of 1 triangle within pentagon =) 4tan54 (=5.505...) oe		6	M1	for a complete method to find the radius of the large circle **or** the perpendicular height of one triangle within the pentagon
	(area of large circle =) $\pi\times(\text{"6.805..."})^2$ (= 145.489...) oe **or** (area of sector =) $\frac{72}{360}\times\pi\times(\text{"6.805..."})^2$ (= 29.097...) oe			M1	for a complete method to find the area of the large circle **or** the area of a sector of the large circle
	(area of pentagon =) 5 × ½ × 8 × "5.505..." (= 80tan54 = 110.11...) **or** 10 × ½ × 4 × "5.505..." (= 80tan54 = 110.11...) **or** 5 × ½ × "6.805..." × "6.805..." × sin72 (= 110.11...) oe **OR** (area of one triangle =) ½ × 8 × "5.505..." (= 22.022...) **or** ½ × "6.805..." × "6.805..." × sin72 (= 22.022...) **or** ½ × "6.805..." × 8 × sin54 (= 22.022...) oe			M1	for a complete method to find the area of the pentagon **OR** the area of one triangle eg *OED* or equivalent
	$\text{"145.489..."}-\text{"110.11..."}+\pi r^2=\text{"110.11..."}-\pi r^2$ oe **or** $5\times(\text{"29.097..."}-\text{"22.022..."})+\pi r^2=5\times\text{"22.022..."}-\pi r^2$ oe			M1	for a correct equation for the radius of the smaller circle
	$2\pi r^2=2\times\text{"110.11..."}-\text{"145.489..."}(=74.731...)$ oe			M1	for a correct rearranged equation with the area of the circle the subject or better
	Correct answer scores full marks (unless from obvious incorrect working)	3.45		A1	accept 3.43 – 3.45
					Total 6 marks

19	(4*x* – 27) + (3*x* + 46) = 180 oe or "expression for C" + (3*x* + 10) = 180 **or** $7x+19=180$ **or** 3*x* + 46 + 4*x* – 27 + 3*x* + 10 + ["180 – (3*x* + 10)"]= 360		4	M1	Sum angles *A* and *B* to 180, or find an expression for *BCD* and sum all angles to 360. [condone missing brackets and condone use of any letter or expression for angle *C* (even *x* or *BCD*)]
				A1	*x* = 23
	eg 3 ×"23" + 46 (= 115) **or** eg 180 – (3 ×"23" + 10) (= 101)			M1ft	dep on M1 using **their *x*** to calculate a value for angle *B* or 'their' *C* (cannot be a negative value and cannot just be *x*)
	Correct answer scores full marks (unless from obvious incorrect working)	115		A1	Allow 3*x* + 46 or *ABC* if 115 is clearly seen in working or on diagram
					Total 4 marks

20	eg *DEK* = $\frac{360}{9}$ **or** 40 **or** interior angle = $\frac{(9-2)\times 180}{9}$ **or** 140 or *OFK* = 140 ÷ 2 (= 70) or *FOK* = $\frac{2}{9}\times 360$ (= 80) or *EDK* = 180 – 0.5 × 140 (=110) Angles marked correctly (any exterior or interior angle) gains this mark		3	M1	method to find interior or exterior angle or correct interior or exterior angle stated or shown correctly on diagram or for using 70° for *OFK* or 80° for *FOK* or 110 for *EDK* If a student has only found an interior or exterior angle and has clearly mixed up interior and exterior angles this mark cannot be awarded but can still award for any of the others angles stated
	EDK = 110 and *DEK* = 40 or *FOK* = 80 and *OFK* = 70 or *ODE* = 70 and *DEK* = 40 or *FED* = 140 and *EDK* = 110 oe			M1	For two correct angles that can lead directly to the answer in a single step (eg 180 – both angles or one angle minus the other)
	Correct answer scores full marks (unless from obvious incorrect working)	30		A1	
					Total 3 marks