Cambridge IGCSE · Additional Mathematics 0606 · Notes

Circular measure

Read online at **pastopic.com/cambridge/additional-mathematics-0606/notes/circular-measure**

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What you need to know

By the end of this topic you should be able to:

1. **Use radians.** Measure angles in radians as well as degrees, and convert between them. In any question about arcs and sectors the angle is in radians, and your answers for angles should be too.
2. **Find arc lengths and sector areas** with $s = r\theta$ and $A = \frac{1}{2}r^2\theta$. Neither formula is printed in the exam, so you must know them.
3. **Solve problems with compound shapes**: regions made by adding or taking away sectors, triangles, segments, rectangles and circles, where you often have to find a length or an angle first.

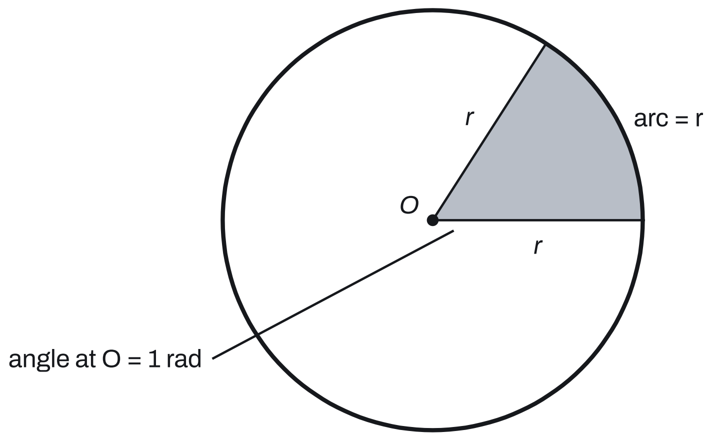
That is the whole syllabus for this topic. Solving trigonometric equations and the graphs of $\sin x$ and $\cos x$ belong to the Trigonometry topic.

Understand it

What a radian is

Degrees split a full turn into 360 parts, a number chosen long ago for convenience. Radians measure an angle using the circle itself.

Take a circle of radius r and mark off an arc that is exactly as long as the radius. The angle this arc makes at the centre is **1 radian**.



a full turn = 2π rad = 360°

The whole circumference is $2\pi r$, so 2π of these arcs fit round the circle. A full turn is therefore 2π radians, and

$$\pi \text{ radians} = 180^\circ, \qquad 1 \text{ radian} = \frac{180^\circ}{\pi} \approx 57.3^\circ.$$

To convert, multiply by $\frac{\pi}{180}$ (degrees to radians) or by $\frac{180}{\pi}$ (radians to degrees):

- $60^\circ = 60 \times \frac{\pi}{180} = \frac{\pi}{3}$ and $150^\circ = \frac{5\pi}{6}$;
- $\frac{3\pi}{4} = \frac{3}{4} \times 180^\circ = 135^\circ$, $\frac{\pi}{4} = 45^\circ$, and $0.4 \text{ rad} = 0.4 \times \frac{180}{\pi} \approx 22.9^\circ$.

Learn the common ones by heart: $\frac{\pi}{6} = 30^\circ$, $\frac{\pi}{4} = 45^\circ$, $\frac{\pi}{3} = 60^\circ$, $\frac{\pi}{2} = 90^\circ$, $\pi = 180^\circ$. When an angle has no π in it, such as 1.2, it is still in radians: 1.2 rad is about 68.8°.

Set your calculator to radian mode before using $\sin$, $\cos$ or $\tan$ on these angles. $\sin 1.2$ in degree mode gives the sine of 1.2°, which is wrong.

Arc length and sector area

A **sector** is a slice of a circle between two radii. If its angle is θ radians, it is the fraction $\frac{\theta}{2\pi}$ of the whole circle. So

$$\text{arc length } s = \frac{\theta}{2\pi} \times 2\pi r = r\theta, \qquad \text{sector area } A = \frac{\theta}{2\pi} \times \pi r^2 = \frac{1}{2} r^2 \theta.$$

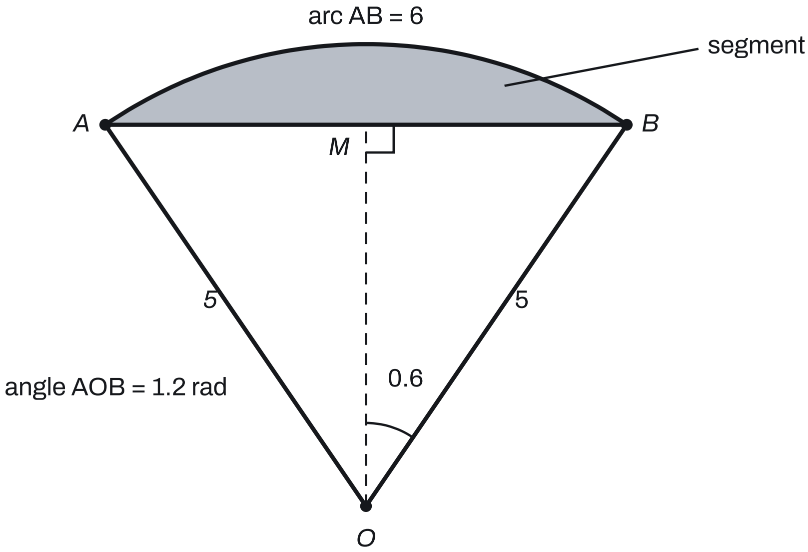
This is why radians are used: the formulas lose all their πs and 360s. For a sector of radius 5 and angle 1.2: arc $= 5 \times 1.2 = 6$, and area $= \frac{1}{2} \times 25 \times 1.2 = 15$.

The **perimeter** of a sector is the arc plus the two radii: $2r + r\theta$. Here that is $10 + 6 = 16$.

Minor and major. Two radii split a circle into two sectors. The smaller one is the **minor** sector; the bigger one is the **major** sector, with angle $2\pi - \theta$. For the angle 1.2 above, the major sector's angle is $2\pi - 1.2 \approx 5.083$. The same words are used for arcs and segments.

Triangles and segments

A **chord** is a straight line joining two points on a circle. It cuts a sector into a triangle and a **segment** (the piece between the chord and the arc).



The triangle OAB has two sides equal to r with the angle θ between them, so its area is $\frac{1}{2}r^2 \sin\theta$ (the formula $\frac{1}{2}ab\sin C$). Then

$$\text{segment area} = \text{sector} - \text{triangle} = \frac{1}{2}r^2\theta - \frac{1}{2}r^2\sin\theta = \frac{1}{2}r^2(\theta - \sin\theta).$$

For the diagram: triangle $= \frac{1}{2} \times 25 \times \sin 1.2 \approx 11.65$, so the segment is $15 - 11.65 = 3.35$.

The chord length. Triangle OAB is isosceles, so the line from O to the midpoint M of AB is at right angles to AB and cuts θ in half. In the right-angled triangle OMB:

$$MB = r\sin\frac{\theta}{2}, \quad \text{so} \quad AB = 2r\sin\frac{\theta}{2} = 2 \times 5\sin 0.6 \approx 5.65.$$

The cosine rule gives the same: $AB^2 = 5^2 + 5^2 - 2(5)(5)\cos 1.2$. The segment's perimeter is the arc plus the chord: $6 + 5.65 = 11.65$.

Working backwards, if you know the chord and the radius, $\sin\frac{\theta}{2} = \frac{\text{half the chord}}{r}$ gives the angle.

Tangents

A **tangent** touches the circle at one point, and it is **at right angles to the radius** there. This gives you a right-angled triangle whenever a tangent appears, so you can use Pythagoras and $\sin$, $\cos$, $\tan$. Two tangents drawn from the same outside point are the same length, and together with the two radii they make a **kite** that is symmetric about the line from the centre to that point.

Compound shapes

Exam questions shade a region and ask for its perimeter or area. Every such region is built from pieces you can already handle: sectors, triangles, segments, rectangles and whole circles. The skill is to see the plan:

- **Area:** add the pieces that make up the region, or take a bigger shape and subtract the pieces that are not shaded. "Kite minus sector" and "triangle minus sector" are very common.
- **Perimeter:** walk round the edge of the shaded region and add each piece: every arc ($r\theta$, with the right r and the right θ) and every straight line. Don't include lines that are inside the region.

The angle you need is often not given. Look for a right-angled triangle (from a tangent, or from the perpendicular to a chord), an isosceles triangle with two radii, or use the cosine rule. Angles on a straight line add up to π, and angles round a point add up to 2π.

A sector rolled into a cone

If a paper sector is curled round until its two straight edges meet, it makes a cone with no base. The radius of the sector becomes the **slant height** of the cone, the arc becomes the **circumference of the circular rim**, and the sector's area is the cone's curved surface area. For a sector of radius 10 and angle $\frac{3\pi}{5}$: the arc is 6π, so the rim has radius $\frac{6\pi}{2\pi} = 3$, and by Pythagoras the cone's height is $\sqrt{10^2 - 3^2} = \sqrt{91} \approx 9.54$.

Key facts and formulas

"Given" means it is in the List of formulas on page 2 of the exam paper. "Learn it" means you must remember it. The syllabus says the arc and sector formulas are **not** given.

Formula	Status
π radians $= 180^\circ$; degrees $\to$ radians $\times \frac{\pi}{180}$, radians $\to$ degrees $\times \frac{180}{\pi}$	Learn it
Arc length $s = r\theta$ (θ in radians)	Learn it
Sector area $A = \frac{1}{2}r^2\theta$ (θ in radians)	Learn it
Perimeter of a sector $= 2r + r\theta$	Learn it
Major sector angle $= 2\pi - \theta$	Learn it
Segment area $= \frac{1}{2}r^2(\theta - \sin\theta)$	Learn it
Chord length $= 2r\sin\frac{\theta}{2}$	Learn it
Area of a triangle $= \frac{1}{2}ab\sin C$	Given
Cosine rule $a^2 = b^2 + c^2 - 2bc\cos A$	Given
Sine rule $\dfrac{a}{\sin A} = \dfrac{b}{\sin B} = \dfrac{c}{\sin C}$	Given
Circle: circumference $2\pi r$, area πr^2	Learn it
A tangent is perpendicular to the radius at the point of contact	Learn it

How to do it

In the questions we have tagged for this topic (35 questions, 2021–2025), the types came up this often. 31 of the 35 questions mix two or three types, so the counts add up to more than 35.

Question type	Questions
Perimeter and area of a compound shaded region	26
Finding an angle from a triangle first	13
Exact answers and answers in letters	13
Using a given arc, area or perimeter to find θ or r	10
Sectors with differentiation	6
Sector made into a cone	1

1. Perimeter and area of a compound shaded region (26 questions)

1. **Mark every length and angle you know on the diagram**, including radii that the question doesn't label, and right angles at tangents.
2. **Find any missing angle or length** you need (see type 2). Keep at least 4 significant figures.
3. **Write the plan in words** before any numbers, for example "shaded area = kite $OACB$ – sector OAB" or "perimeter = arc AB + BC + CA".
4. **Work out each piece**, then add or subtract. Use $s = r\theta$ and $\frac{1}{2}r^2\theta$ with the radius **of that arc**, and $\frac{1}{2}ab\sin C$ for triangles.
5. Give the answer to 3 significant figures unless told otherwise.

Variations you will meet:

- **A point outside the circle with tangents.** The two right-angled triangles make a kite. Kite area $= 2 \times \frac{1}{2} \times r \times (\text{tangent length})$. For example, if two tangents to a circle of radius 8 meet at a point 17 from the centre, each tangent is $\sqrt{17^2 - 8^2} = 15$ long and each half of the kite has angle $\cos^{-1}\frac{8}{17} \approx 1.081$ at the centre.
- **Segments.** A region between a chord and an arc is sector – triangle. Two segments, a segment plus a rectangle, or a circle minus segments are all common.
- **Major arcs and sectors.** If the shaded region goes round the far side of the centre, use $2\pi - \theta$. A major segment is the major sector **plus** the triangle.
- **Two or more circles.** Arcs from different centres have different radii and different angles: find each one separately.
- **A point on a radius**, such as C on OB with OC given. Triangle OAC is **not** right-angled unless you are told so: use the cosine rule for AC and $\frac{1}{2}ab\sin C$ for its area.
- **"Use your answer to part (a)"** tells you the angle from part (a) is the one to use.

2. Finding an angle from a triangle first (13 questions)

1. Find a triangle that contains the angle and whose sides you know.
2. **Right-angled** (tangent and radius, or the perpendicular to a chord): use $\sin$, $\cos$ or $\tan$. For a chord, $\sin\frac{\theta}{2} = \frac{\text{half-chord}}{r}$, then double.
3. **Three sides known** (for example two radii and a chord): cosine rule, $\cos\theta = \dfrac{b^2+c^2-a^2}{2bc}$.
4. **Use angle facts**: angles on a straight line sum to π, so the obtuse angle next to 0.9 is $\pi - 0.9$; angles round a point sum to 2π; the angles of a triangle sum to π.
5. Give the angle in radians to at least 3 significant figures (4 is safer to carry on with).

Variations you will meet:

- **"Show that" a rounded angle**, for example that $2\sin^{-1}0.4$ is 0.823 radians to 3 decimal places. Show the method and a value with **more** decimal places than asked ($0.82303\ldots$), then round it. Writing only the given value earns nothing.
- **Special triangles give exact angles.** A chord equal to the radius makes an equilateral triangle, so the angle is $\frac{\pi}{3}$. $\sin\frac{\theta}{2} = \frac{\sqrt{3}}{2}$ gives $\frac{\theta}{2} = \frac{\pi}{3}$, so $\theta = \frac{2\pi}{3}$.
- **An angle at the circumference** (at a point on the circle) is half the angle at the centre standing on the same arc.

3. Exact answers and answers in letters (13 questions)

1. **Keep π and surds** all the way. Use exact values: $\sin\frac{\pi}{6} = \frac{1}{2}$, $\sin\frac{\pi}{3} = \frac{\sqrt{3}}{2}$, $\cos\frac{\pi}{3} = \frac{1}{2}$, $\sin\frac{\pi}{4} = \frac{\sqrt{2}}{2}$, $\tan\frac{\pi}{3} = \sqrt{3}$.
2. **With letters**, such as radius r and angle θ, use the same plans as type 1 but write every piece as an expression: arc $r\theta$, sector $\frac{1}{2}r^2\theta$, triangle $\frac{1}{2}r^2\sin\theta$, chord $2r\sin\frac{\theta}{2}$.
3. Simplify only as far as the question asks, and don't turn exact answers into decimals.

Variations you will meet:

- **"Show that"** an equation linking an angle and its sine, cosine or tangent: write each area or length in the question's letters (not a general r if the question uses a), form the equation the question describes, and simplify step by step to the printed result.
- **An equation from two equal areas or two linked perimeters**, for example "the area of triangle X equals the area of region Y". Write both sides and solve.
- $\sin\theta = k$ **has two answers between** 0 **and** π: θ and $\pi - \theta$. For example, $\sin\theta = \frac{1}{2}$ gives $\frac{\pi}{6}$ or $\frac{5\pi}{6}$. Use another fact from the question (a segment area, or "obtuse") to decide which.
- **"Least possible area"** as a length changes: think about what happens as the length gets as small (or as large) as it is allowed to be.

4. Using a given arc, area or perimeter to find θ or r (10 questions)

1. Write each given fact as an equation: arc $r\theta = \ldots$, area $\frac{1}{2}r^2\theta = \ldots$, perimeter $2r + r\theta = \ldots$.

2. Solve. With one unknown, rearrange. With two unknowns, divide one equation by the other, or substitute.

For example, an arc of 9 and an area of 27: $\frac{1}{2}r^2\theta \div r\theta = \frac{r}{2} = \frac{27}{9} = 3$, so $r = 6$ and $\theta = \frac{9}{6} = 1.5$.

Variations you will meet:

- **The angle is given in degrees** or as a fraction of π: convert to radians first.
- **A ratio of radii**, such as $OP : OQ = 2 : 3$ with $OQ = 12$: find $OP = 8$ from the ratio before anything else. The ratio compares the whole lengths OP and OQ, not OP and the gap PQ.
- **Two concentric arcs** (the same centre): the shaded band's area is the big sector minus the small one, $\frac{1}{2}(R^2 - r^2)\theta$.

5. Sectors with differentiation (6 questions)

These join this topic to differentiation.

1. **Use the fixed fact to remove θ.** For a sector of fixed area 16: $\frac{1}{2}r^2\theta = 16$, so $r\theta = \frac{32}{r}$.
2. **Write the quantity in one variable.** Perimeter $P = 2r + r\theta = 2r + \frac{32}{r}$. This step is often a "show that".
3. **Differentiate** ($\frac{d}{dr}r^n = nr^{n-1}$), set the derivative to 0 and solve, keeping only positive r.
4. **Find the value** by substituting back, and **show its nature**: $\frac{d^2P}{dr^2}$ positive means minimum, negative means maximum. State the sign, then the conclusion.

Variations you will meet:

- A logo or shape made of several sectors: write the total perimeter and area as expressions, then use the given perimeter to get one variable in terms of the other.
- A rectangle with quarter-circles removed: the curved edges are arcs with $\theta = \frac{\pi}{2}$.
- Rates of change (for example water filling a cone made from a sector) use the chain rule; the circular-measure part is only finding the cone's measurements, as in type 6.

6. Sector made into a cone (1 question)

1. The sector's **radius** is the cone's **slant height**.
2. The **arc length** $r\theta$ equals the **circumference** $2\pi R$ of the cone's rim, so the rim's radius is $R = \frac{r\theta}{2\pi}$.
3. The sector's **area** $\frac{1}{2}r^2\theta$ is the cone's **curved surface area**.
4. The cone's **height** comes from Pythagoras: $h = \sqrt{r^2 - R^2}$.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

A garden bed is a sector of a circle with angle 75°. The bed is edged all the way round with 30 m of edging.

(a) Write 75° in radians, as an exact multiple of π. **[1]**

(b) Find the radius of the bed. **[3]**

(c) Find the area of the bed. **[2]**

(a) $75 \times \dfrac{\pi}{180} = \dfrac{5\pi}{12}$. **B1**

(b) The edging is the perimeter: two radii and the arc. **M1** for $2r + r\theta$:

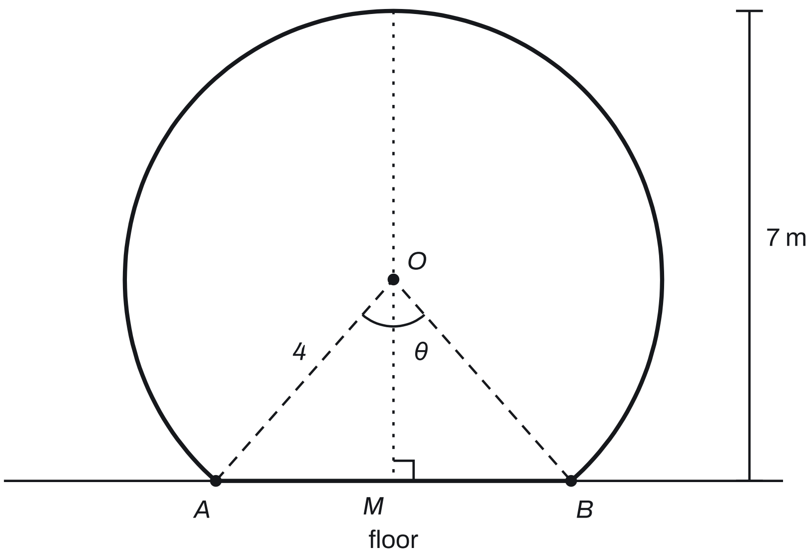
$$2r + \frac{5\pi}{12}r = 30 \;\Rightarrow\; r\left(2 + \frac{5\pi}{12}\right) = 30.$$

M1 for factorising and dividing: $r = \dfrac{30}{3.309\ldots} = 9.07$ m (3 s.f.). **A1**

(c) Area $= \frac{1}{2}r^2\theta = \frac{1}{2} \times 9.066\ldots^2 \times \frac{5\pi}{12}$. **M1** using the unrounded r.

Area $= 53.8$ m². **A1** (Rounding r to 9.1 first gives 54.2, which loses the mark.)

Example 2



The diagram shows the cross-section of a tunnel. The curved roof is a major arc of a circle with centre O and radius 4 m, and the floor AB is horizontal. The tunnel is 7 m tall at its highest point.

(a) Show that angle AOB is 1.445 radians, correct to 3 decimal places. **[2]**

(b) Find the perimeter of the cross-section. **[3]**

(c) Find the area of the cross-section. **[3]**

(a) The top of the tunnel is 4 m above O, so the floor is $7 - 4 = 3$ m below O: $OM = 3$. In the right-angled triangle OMB, $\cos(\text{angle } MOB) = \frac{3}{4}$. **M1**

Angle $AOB = 2\cos^{-1}\frac{3}{4} = 2 \times 0.72273\ldots = 1.44547\ldots = 1.445$ (3 d.p.). **A1**, with the extra decimals shown.

(b) $MB = \sqrt{4^2 - 3^2} = \sqrt{7}$, so $AB = 2\sqrt{7} = 5.29$. **B1**

The roof is the **major** arc, with angle $2\pi - 1.44547 = 4.8377$. **M1** for $4 \times (2\pi - \theta)$: arc $= 19.35$.

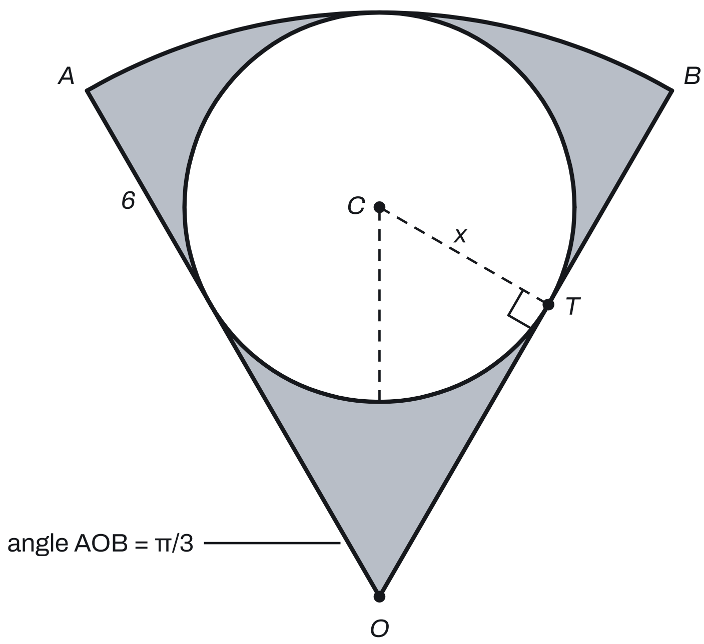
Perimeter $= 19.35 + 5.29 = 24.6$ m. **A1**

(c) The cross-section is the major sector **plus** triangle OAB, because O is inside the tunnel. **M1** for the plan.

Major sector $= \frac{1}{2} \times 4^2 \times 4.8377 = 38.70$; triangle $= \frac{1}{2} \times 4^2 \times \sin 1.44547 = 7.937$ (or $\frac{1}{2} \times 2\sqrt{7} \times 3 = 3\sqrt{7}$). **M1** for both pieces.

Area $= 38.70 + 7.937 = 46.6$ m². **A1**

Example 3



The diagram shows a sector OAB of a circle with centre O, radius 6 cm and angle $\frac{\pi}{3}$. A circle with centre C and radius x cm fits inside the sector, touching OA, OB and the arc AB.

(a) Show that $x = 2$. **[3]**

(b) Find the exact area of the shaded region. **[3]**

(c) Find the fraction of the sector that the circle covers. **[1]**

(a) By symmetry C lies on the line that halves angle AOB, so angle $COT = \frac{\pi}{6}$. The circle touches the arc at the far end of this line, so $OC = 6 - x$. **B1**

CT is a radius meeting the tangent OB, so angle OTC is a right angle. **M1** for using the right-angled triangle OTC:

$$\sin\frac{\pi}{6} = \frac{x}{6-x} \;\Rightarrow\; \frac{1}{2}(6-x) = x \;\Rightarrow\; 6 - x = 2x \;\Rightarrow\; x = 2.$$

A1

(b) Sector $= \frac{1}{2} \times 6^2 \times \frac{\pi}{3} = 6\pi$. **B1** Circle $= \pi \times 2^2 = 4\pi$. **B1**

Shaded area $= 6\pi - 4\pi = 2\pi$ cm². **B1**

(c) $\dfrac{4\pi}{6\pi} = \dfrac{2}{3}$. **B1**

Example 4

A farmer builds a pen in the shape of a sector OAB of a circle with centre O and radius r m. The side OA is part of a long straight wall, so it needs no fence. The side OB and the arc AB are fenced with 40 m of fencing in total.

(a) Show that the area of the pen, A m², is $A = 20r - \frac{1}{2}r^2$. **[3]**

(b) Find the value of r that makes the area stationary, and the angle AOB for this r. **[3]**

(c) Find this area and show that it is a maximum. **[2]**

(a) Let angle $AOB = \theta$. Fencing: $r + r\theta = 40$, so $r\theta = 40 - r$. **B1**

$A = \frac{1}{2}r^2\theta = \frac{1}{2}r(r\theta)$ **M1** for eliminating θ:

$$A = \frac{1}{2}r(40 - r) = 20r - \frac{1}{2}r^2.$$

A1, the given answer.

(b) $\dfrac{dA}{dr} = 20 - r = 0 \Rightarrow r = 20$. **M1 A1**

$\theta = \dfrac{40 - 20}{20} = 1$ radian. **B1**

(c) $A = 20(20) - \frac{1}{2}(20)^2 = 200$ m². $\dfrac{d^2A}{dr^2} = -1 < 0$, so this is a **maximum**. **B1 B1**

Common mistakes

- **Working in degrees.** Examiners report every year that candidates who change to degrees rarely reach the right answer, and some mix degrees into $r\theta$. Keep angles in radians throughout.
- **Calculator in degree mode.** $\sin 1.2$ and $\cos^{-1} 0.75$ come out wrong. Check the mode before any trigonometry.
- **Using the fraction-of-a-circle formula instead of $r\theta$.** Writing $\frac{\theta}{2\pi} \times 2\pi r$ each time wastes time and invites slips, such as an extra π in the answer.
- **Rounding too early.** An angle rounded to 0.8 instead of $0.823\ldots$, or a length rounded to 2 figures, often makes the final answer wrong in the third figure. Carry 4 or more significant figures and round only at the end.
- **Assuming a right angle that isn't there.** A triangle with a point part-way along a radius, or angle OBC in a shape with no tangent at B, is not right-angled. Use the cosine rule unless a tangent or a symmetry line gives you the right angle.
- **Leaving out part of the perimeter**, or adding lines inside the region. Trace the edge of the shaded region with your finger and list each piece. A perimeter usually has three or more parts.
- **Adding the wrong pieces for an area**, such as the triangle and the kite together. Say in words what the region is before calculating.

- **Showing a given angle with no extra accuracy.** To show that $2\cos^{-1} 0.3$ is 2.53 to 2 d.p., you must write something like 2.532 before rounding.
- **Treating 2α radians as 2 radians**, or replacing a letter in the question by a number. Keep the letters.
- **Stopping short.** In an optimisation, find the value asked for (the least perimeter, not just the radius) and state its nature.

How to get the marks

- **Method marks need a visible plan.** Write "area = sector – triangle" with the numbers substituted, such as $\frac{1}{2} \times 7^2 \times 0.823$. A correct method with a wrong angle from an earlier part still earns its method marks (follow-through).
- **"Show that"** means the answer is printed. Give every step, and when the answer is rounded, show a more accurate value first.
- **"Exact"** or **"in terms of π"** means no decimals: keep π and surds, and use exact trigonometric values.
- **"Hence"** or **"use your answer to part (a)"** means the earlier result must be used.
- **"Find the angle, giving your answer in radians"**: give it to 3 significant figures, such as 1.18, but keep more figures for later parts.
- **Lengths and areas**: give 3 significant figures unless the question says otherwise (such as "correct to 1 decimal place"), with units if the question uses them.
- **"Determine the nature"** needs the value or sign of the second derivative and the word maximum or minimum.
- **Use the question's letters.** If the radius is called a, write a, not r.

Quick check

1. Write 135° in radians as a multiple of π, and write 2.5 radians in degrees.
2. A sector has angle 0.8 radians and area 40 cm². Find its radius and its perimeter.
3. The minute hand of a clock is 12 cm long. Find the exact distance its tip moves in 25 minutes, and the area it sweeps over. Give both to 1 decimal place too.
4. A sector's perimeter is three times its radius. Find its angle, and show that its area is $\frac{1}{2}r^2$.
5. A square is drawn inside a circle of radius r, with its four corners on the circle. Find, in terms of r and π, the area and the perimeter of one of the four segments outside the square.

Answers

1. $135 \times \frac{\pi}{180} = \frac{3\pi}{4}$. $2.5 \times \frac{180}{\pi} = 143.2^\circ$.
2. $\frac{1}{2}r^2 \times 0.8 = 40 \Rightarrow r^2 = 100 \Rightarrow r = 10$ cm. Arc $= 10 \times 0.8 = 8$, so perimeter $= 10 + 10 + 8 = 28$ cm.
3. In 25 minutes the hand turns $\frac{25}{60} \times 2\pi = \frac{5\pi}{6}$. Distance $= 12 \times \frac{5\pi}{6} = 10\pi \approx 31.4$ cm. Area $= \frac{1}{2} \times 12^2 \times \frac{5\pi}{6} = 60\pi \approx 188.5$ cm².
4. $2r + r\theta = 3r \Rightarrow r\theta = r \Rightarrow \theta = 1$ radian. Area $= \frac{1}{2}r^2 \times 1 = \frac{1}{2}r^2$.
5. Each side of the square subtends a right angle, $\frac{\pi}{2}$, at the centre. Segment area $= \frac{1}{2}r^2 \times \frac{\pi}{2} - \frac{1}{2}r^2 \sin\frac{\pi}{2} = \frac{\pi r^2}{4} - \frac{r^2}{2} = \frac{r^2(\pi-2)}{4}$. Perimeter $=$ arc $+$ chord $= \frac{\pi r}{2} + r\sqrt{2} = r\left(\frac{\pi}{2} + \sqrt{2}\right)$.

Past questions to try

- **0606/12/M/J/24 Q6**: an angle from an arc length, then chords, a perimeter and an area.
- **0606/13/O/N/23 Q10**: a sector's perimeter gives the angle, then tangents and a kite.
- **0606/23/M/J/24 Q7**: two arcs with the same centre, then the cosine rule.
- **0606/21/M/J/25 Q9**: a sector made into a cone, then rates of change.