A-LEVEL PHYSICS • EXERCISE SHEET

12.1 Kinematics of uniform circular motion

Name: ______________ Class: __________ Date: ____________ **Total: 16 marks**

Objective

Build the skills to answer exam questions on **circular motion kinematics** —radians, angular speed, $v = r\omega$, and **connected** wheels.

You must be able to:

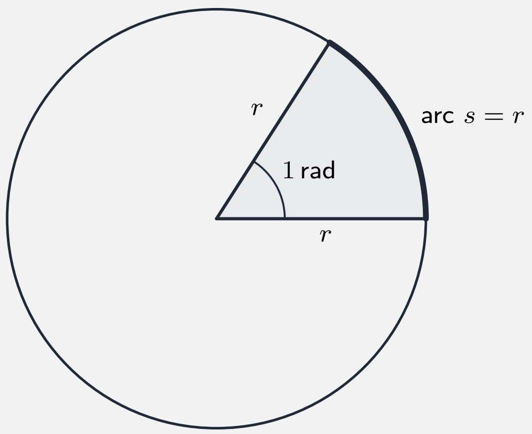
- define the **radian** and convert between radians and degrees
- use **angular speed** $\omega = \theta/t = 2\pi/T = 2\pi f$ and $v = r\omega$
- handle **connected wheels** (same axle → same ω; linked by a belt/chain → same rim speed)

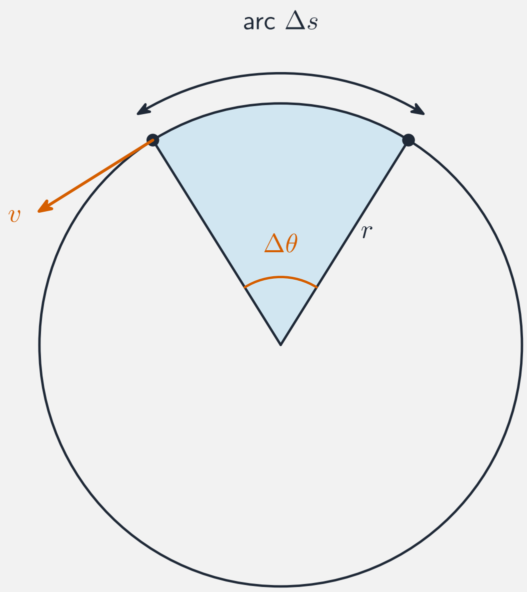
1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

Radians

One **radian** is the angle whose arc length equals the radius: $\theta = s/r$:





Angular speed in uniform circular motion

A full circle = 2π rad; 1 rad = $180°/\pi \approx 57.3°$. **Use radian mode** on your calculator.

■ Angular speed

$$\omega = \frac{\theta}{t} = \frac{2\pi}{T} = 2\pi f \quad (\text{rad s}^{-1}), \qquad v = r\omega.$$

Worked example. A point on the equator (radius 6.4×10^6 m, period 24 h): $\omega = \dfrac{2\pi}{24 \times 3600} = 7.3 \times 10^{-5}$ rad s^{-1}; $v = r\omega = 465$ m s^{-1}.

■ Connected wheels

Exam questions often link wheels, cogs or pulleys. Two rules:

- **Fixed on the same axle** → they turn with the **same** ω (but different rim speeds if the radii differ).
- **Linked by a belt or chain** (no slipping) → the **rim speeds are equal**: $r_1\omega_1 = r_2\omega_2$.

Worked example. A belt links pulley A (radius 0.10 m, $\omega_A = 30$ rad s^{-1}) to pulley B (radius 0.050 m). Rim speed $v = r_A\omega_A = 0.10 \times 30 = 3.0$ m s^{-1}; so $\omega_B = \dfrac{v}{r_B} = \dfrac{3.0}{0.050} = 60$ rad s^{-1} (the smaller pulley spins faster).

2 Practice

Now apply the methods above.

2.1 Define the **radian**. [1]

2.2 Convert 90° to **radians**. [1]

2.3 A wheel turns at 2.0 revolutions per second. Find its **angular speed**. [2]

2.4 Two pulleys are linked by a belt. State what is **equal** for the two pulleys. [1]

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3 Exam-style questions

3.1 A full circle, in radians, is: [1]

- **A** π
- **B** 2π
- **C** 360
- **D** 1

3.2 A car travels around a circular track of radius 50 m at 20 m s^{-1}. Find its **angular speed**. [2]

3.3 A bicycle moves in a straight line at 8.0 m s^{-1}. Its rear wheel has radius 0.35 m. A small cog of radius 0.040 m is fixed to the rear wheel; a chain links it to the pedal cog of radius 0.10 m.

(a) Calculate the angular speed of the **rear wheel**. [2]

(b) Hence calculate the angular speed of the **pedals**. [3]

3.4 Convert 1.5 rad to **degrees**. [1]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **12.1 Kinematics of uniform circular motion** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/42 J25 —Q1 (connected cogs, $v = r\omega$)
- 9702/42 N25 —Q1 (angular speed, calculation)
- 9702/42 M25 —Q1 (circular-motion kinematics)
- 9702/41 N25 —Q1 (uniform circular motion, structured)

Solutions

2.1 The angle subtended at the centre of a circle by an arc whose **length equals the radius**.

2.2 $90° = \dfrac{\pi}{2}$ rad ≈ 1.57 rad.

2.3 $\omega = 2\pi f = 2\pi \times 2.0 = 4\pi = 12.6$ rad s^{-1}.

2.4 Their **rim speeds** ($v = r\omega$) are equal (the belt does not slip).

3.1 **B** —2π.

3.2 $\omega = v/r = 20/50 = 0.40$ rad s^{-1}.

3.3 (a) $\omega_{\text{wheel}} = \dfrac{v}{r} = \dfrac{8.0}{0.35} = 22.9$ rad s^{-1}.

3.3 (b) The small cog shares the wheel's axle, so $\omega = 22.9$ rad s^{-1}; its rim speed $v = r\omega = 0.040 \times 22.9 = 0.915$ m s^{-1}; the chain gives the pedal cog the same rim speed, so $\omega_{\text{pedal}} = \dfrac{0.915}{0.10} = 9.2$ rad s^{-1}.

3.4 $1.5 \times \dfrac{180}{\pi} = 86°$.