

START WITH THE PICTURE

Circular Motion: Kinematics

A short concept-and-practice guide | NEET-UG | Study time: approximately 30 minutes

The idea: A particle can move at constant speed and still accelerate, because its velocity changes direction.

1. What changes in circular motion?

For a circle of radius r , an angular displacement θ (measured in radians) corresponds to an arc length $s = r\theta$. The displacement is the straight-line chord, not the arc.

One revolution: distance = $2\pi r$, but displacement = 0.

2. Angular speed and linear speed

$$\omega = 2\pi/T = 2\pi f \mid f = 1/T \mid v = r\omega$$

T: time period (s) f: frequency (Hz) ω : angular speed (rad/s) v: speed (m/s)

Teacher's checkpoint: On the same rigid rotating disc, all points have the same angular speed. Points farther from the axis have greater linear speed.

3. Read the directions, not just the formulas

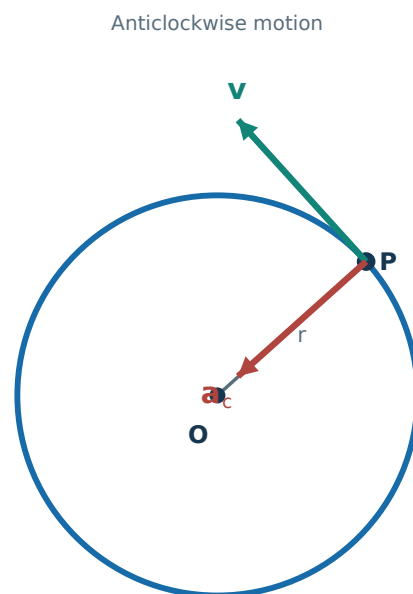
At P in anticlockwise motion:

v is tangent to the circle.

a_c points towards the centre O.

r points from O to P.

The velocity changes direction at every point - even when the speed stays constant.



UNDERSTAND THE ACCELERATION

Uniform and Non-uniform Motion

The same particle can have radial and tangential acceleration for different physical reasons.

4. Uniform circular motion (UCM)

In UCM, the **speed is constant**, but the velocity vector is not. The instantaneous acceleration is **towards the centre**.

$$\text{Centripetal acceleration: } a_c = v^2/r = \omega^2 r$$

For a turn through an angle $\Delta\theta$ at constant speed v :

$$\text{Magnitude of change in velocity: } |\Delta v| = 2v \sin(\Delta\theta/2)$$

Quarter turn: $|\Delta v| = \sqrt{2}v$ Half turn: $|\Delta v| = 2v$ Full turn: $|\Delta v| = 0$

5. Average versus instantaneous

Average velocity = displacement/time; average acceleration = change in velocity/time. Over **one complete revolution**, both averages are zero, although instantaneous acceleration is nonzero throughout the motion.

6. When the speed also changes

Non-uniform circular motion has two perpendicular acceleration components:

Radial: $a_c = v^2/r$ (inward) **Tangential:** $a_t = dv/dt = r\alpha$ (along/opposite v)

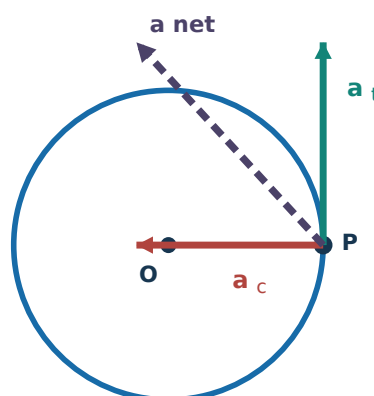
Net acceleration magnitude: $a = \sqrt{a_c^2 + a_t^2}$

At the rightmost point P:

The **inward** component changes velocity direction.

The **tangential** component changes speed.

The **dashed diagonal arrow** is the net acceleration: the vector sum of these two components.



Common mistake: Centripetal acceleration is the inward component of acceleration. The net inward force comes from real forces such as tension or friction - it is not an extra force.

THINK, CALCULATE, CHECK

Five Worked Examples

Different situations, the same small set of fundamental ideas.

01 | Frequency to acceleration

A particle moves in a circle of radius 0.50 m at 2 revolutions per second. Find ω , v and a_c .

Think: $f = 2$ Hz. Then $\omega = 2\pi f = 4\pi$ rad/s; $v = r\omega = 2\pi$ m/s; $a_c = \omega^2 r = 8\pi^2$ m/s².

02 | Changing direction

In UCM, the speed is 10 m/s. Find $|\Delta v|$ after a 90° turn.

Think: equal speeds, different directions. $|\Delta v| = 2v \sin 45^\circ = 10\sqrt{2}$ m/s. It is not zero just because the speed stays constant.

03 | Average velocity versus average acceleration

A particle goes through half a revolution on a circle of radius 2 m at a constant speed of π m/s. Find the magnitudes of average velocity and average acceleration.

Think: travel time = $\pi r/v = 2$ s. Displacement = diameter = 4 m, so $|v_{\text{avg}}| = 2$ m/s. $|\Delta v| = 2\pi$ m/s, so $|a_{\text{avg}}| = \pi$ m/s². Compare: instantaneous $a_c = v^2/r = \pi^2/2 \approx 4.93$ m/s².

04 | Two acceleration components

At one instant $r = 2$ m, $v = 6$ m/s and tangential acceleration = 4 m/s². Find the net acceleration magnitude.

Think: inward $a_c = v^2/r = 18$ m/s². The two components are perpendicular: $a = \sqrt{18^2 + 4^2} = \sqrt{340} \approx 18.44$ m/s².

05 | Two points on one disc

On a rigid rotating disc, a point 25 cm from the axis moves at 5 m/s. Find the speed of a point 10 cm from the axis.

Think: angular speed is shared: $\omega = 5/0.25 = 20$ rad/s. Thus $v = \omega r = 20 \times 0.10 = 2$ m/s. The linear speeds are not the same.

Final check: Speed, direction, average or instantaneous? Decide before choosing your equation.

TEST UNDERSTANDING

10 NEET-Style Questions

Eight single-correct questions plus a statement-based and an assertion-reason challenge.

1. After a complete revolution in UCM, which quantity must be zero?

A. Average velocity • B. Distance travelled • C. Instantaneous acceleration • D. Average speed

2. A particle moves in a circle of radius 0.50 m with a period of 2 s. Its speed is:

A. $\pi/2$ m/s • B. π m/s • C. 2π m/s • D. $1/\pi$ m/s

3. At constant speed v , the magnitude of change in velocity after a quarter-turn is:

A. v • B. $\sqrt{2}v$ • C. $2v$ • D. 0

4. Two points at radii $2r$ and $5r$ lie on one rigid rotating disc. Their speed ratio is:

A. 5:2 • B. 1:1 • C. 2:5 • D. 4:25

5. At fixed radius, doubling the speed changes the centripetal acceleration by a factor of:

A. 2 • B. 4 • C. $1/2$ • D. $1/4$

6. Over one complete revolution in UCM, the magnitude of average acceleration is:

A. 0 • B. v^2/r • C. $2v/T$ • D. v/T

7. At one instant, $a_c = 18 \text{ m/s}^2$ and $a_t = 4 \text{ m/s}^2$. The net magnitude is:

A. $\sqrt{20}$ • B. $\sqrt{340}$ • C. 22 • D. 9 m/s^2

8. Viewed face-on, a wheel spins anticlockwise. The angular-velocity vector is:

A. In the wheel's plane, towards its centre • B. Perpendicular, away from the viewer • C. Tangent to the rim • D. Perpendicular, towards the viewer

9. Statement-based: For a particle in UCM, I: speed is constant. II: acceleration vector is constant. Select:

A. Both true • B. I true, II false • C. I false, II true • D. Both false

10. Assertion (A): UCM has nonzero acceleration despite constant speed. Reason (R): Velocity direction keeps changing.

A. Both true; R explains A • B. Both true; R does not explain A • C. A true, R false • D. A false, R true

ANSWER KEY | One-line reasoning

1 **A** - net displacement zero. 2 **A** - use $2\pi r/T$. 3 **B** - vector difference. 4 **C** - $v \propto r$. 5 **B** - $a_c \propto v^2$.

6 **A** - final velocity = initial velocity. 7 **B** - perpendicular components. 8 **D** - right-hand rule.

9 **B** - acceleration points inward and changes direction. 10 **A** - changing velocity direction produces acceleration.

FAST REVISION $s = r\theta$ • $\omega = 2\pi/T$ • $v = r\omega$ • $a_c = v^2/r$ • $|\Delta v| = 2v \sin(\Delta\theta/2)$

WHAT NEXT? Learn centripetal forces, banking of roads and vertical circles.

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