

Goal: Explain why moving in a circle at steady speed needs a force towards the centre, and how that force depends on speed, mass and radius.

— force — velocity

01 The big picture

An object moving round a circle at steady speed keeps changing direction, so its velocity changes: it is accelerating, even though its speed is constant.

That needs a resultant force towards the centre, at 90° to the velocity: the centripetal force. It changes the direction of motion but not the speed.

The force always comes from a real force: tension (a ball on a string), friction (a car on a bend) or gravity (the Moon, satellites, planets). Remove it and the object carries on in a straight line along the tangent.

More force gives a higher speed at the same radius, or a tighter circle at the same speed. More mass needs more force for the same speed and radius.

Fig. 1 · Velocity and force

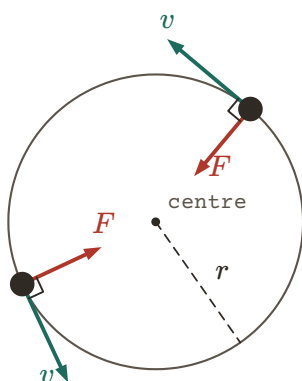
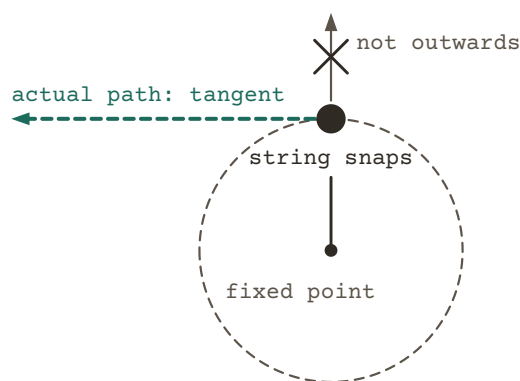


Fig. 2 · If the string breaks



Velocity is along the tangent; the resultant force points to the centre, always at 90° to it. Same-length arrows: steady speed, changing direction.

No inward force, so nothing turns the ball: it moves off in a straight line along the tangent (Newton's first law), not outwards.

Motion in a circle (syllabus) Supplement (Extended) only

[syllabus wording]

"Describe, qualitatively, motion in a circular path due to a force perpendicular to the motion as: (a) speed increases if force increases, with mass and radius constant; (b) radius decreases if force increases, with mass and speed constant; (c) an increased mass requires an increased force to keep speed and radius constant."

Average orbital speed (syllabus)

Supplement (Extended) only [syllabus wording]

"Defined by $v = 2\pi r/T$, where r is the average radius of the orbit and T is the orbital period."

Centripetal force [paraphrase]

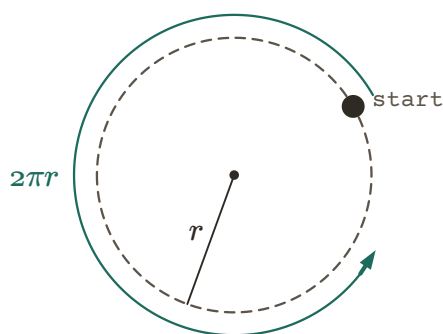
The resultant force on an object moving in a circle. It acts towards the centre, at 90° to the velocity.

02 Deriving the equations

D1 Speed round a circle Supplement (Extended) only

Average speed is distance ÷ time. In one period T the object goes once round the circle.

Fig. 3 · One lap



one lap in time T

1. The distance for one lap is the circumference:

$$d = 2\pi r$$

2. The time for one lap is the period T :

$$v = \frac{d}{t} = \frac{2\pi r}{T}$$

RESULT

$$v = \frac{2\pi r}{T}$$

In one period T the object travels once round: a distance equal to the circumference $2\pi r$.

D2 Rearranging for T and r Supplement (Extended) only

Exam questions often give the speed and ask for the period or the radius.

1. For T : T is in the denominator and v is the lone term on the other side, so swap them in one step (cross-multiplication).

$$v = \frac{2\pi r}{T} \implies T = \frac{2\pi r}{v}$$

2. For r : multiply both sides by T and divide both by 2π .

$$v = \frac{2\pi r}{T} \implies r = \frac{vT}{2\pi}$$

RESULT

$$T = \frac{2\pi r}{v} \quad r = \frac{vT}{2\pi}$$

D3 Why statements (a)–(c) are true Not examined in 0625 · A Level Ch.16

At A Level the force needed is $F = mv^2/r$. You will not be asked to use it, but it shows where (a)–(c) come from.

1. (a) Same m and r : a bigger F goes with a bigger v .
2. (b) Same m and v : a bigger F goes with a smaller r .
3. (c) Same v and r : a bigger m needs a bigger F .

RESULT

$$F = \frac{mv^2}{r}$$

03 Key equations

Average orbital speed

Supplement (Extended) only

$$v = \frac{2\pi r}{T}$$

recall and use it: it is not given

Rearranged for the period

Supplement (Extended) only

$$T = \frac{2\pi r}{v}$$

Rearranged for the radius

Supplement (Extended) only

$$r = \frac{vT}{2\pi}$$

Centripetal force

Not examined in 0625

$$F = \frac{mv^2}{r}$$

A Level Ch.16

Symbols and units

v	speed (average orbital speed)	m s^{-1}	r	radius of the circle or orbit	m	T	period: time for one complete circle	s
F	resultant (centripetal) force	N	m	mass	kg			

04 Sample problems with solutions

Sample 1 • Orbital period from speed and radius

Supplement (Extended) only

A satellite orbits in a circle of radius $7.0 \times 10^6 \text{ m}$ at a steady $7.5 \times 10^3 \text{ m/s}$. Calculate the time for one orbit.

Step 1. T is in the denominator and v is the lone term on the other side: swap them in one step.

$$v = \frac{2\pi r}{T} \implies T = \frac{2\pi r}{v}$$

Step 2. Substitute, with units:

$$T = \frac{2\pi \times 7.0 \times 10^6 \text{ m}}{7.5 \times 10^3 \text{ m s}^{-1}} = 5864 \text{ s}$$

Step 3. The data are to 2 s.f., so give 2 s.f. Dividing by 60 s per minute is a sense check: low orbits take about 1½ hours.

$$T = 5.9 \times 10^3 \text{ s} \approx 98 \text{ min}$$

Answer: $T = 5.9 \times 10^3 \text{ s}$ (about 98 minutes)

Unit check: $\frac{\text{m}}{\text{m s}^{-1}} = \text{s} \checkmark$

Sample 2 • Orbital speed of the Moon

Supplement (Extended) only

The Moon orbits the Earth at an average radius of $3.84 \times 10^8 \text{ m}$ with a period of 27.3 days. Calculate its average orbital speed.

Step 1. Convert the period to seconds first:

$$T = 27.3 \times 24 \times 3600 \text{ s} = 2.359 \times 10^6 \text{ s}$$

Step 2. Substitute into $v = 2\pi r/T$:

$$v = \frac{2\pi \times 3.84 \times 10^8 \text{ m}}{2.359 \times 10^6 \text{ s}} = 1023 \text{ m s}^{-1}$$

Answer: $v = 1.02 \times 10^3 \text{ m/s}$ (3 s.f., like the data)

Unit check: $\frac{\text{m}}{\text{s}} = \text{m s}^{-1} \checkmark$

04 Sample problems with solutions (continued)

Sample 3 · Describing the force on a car

A car drives round a roundabout at constant speed. Explain why it needs a resultant force, state what provides it, and describe how the force needed changes if the car goes faster round the same circle.

Step 1. Its direction of travel keeps changing, so its velocity changes: it is accelerating, and acceleration needs a resultant force.

Step 2. The force acts towards the centre of the roundabout. Friction between the tyres and the road provides it.

Step 3. Same mass and radius, higher speed: statement (a) says a larger force goes with a larger speed.

Answer: A larger friction force towards the centre is needed.

05 Practice problems

P1 In which direction does the resultant force on an object in uniform circular motion act?

Answer: Towards the centre, at 90° to the velocity.

P3 Mass and radius stay the same but the force increases. What happens to the speed?

Answer: It increases.

P5 A stone on a string is whirled in a horizontal circle and the string snaps. Describe its path just after.

Answer: A straight line along the tangent at the point of release.

P7 A satellite has an orbital radius of 6.7×10^6 m and a period of 90 minutes. Calculate its orbital speed.

Answer: 7.8×10^3 m/s

P2 What provides the centripetal force that keeps the Moon in orbit?

Answer: The gravitational attraction of the Earth.

P4 Mass and speed stay the same but the force increases. What happens to the radius?

Answer: It decreases.

P6 Calculate the speed of a point 0.30 m from the centre of a wheel that turns once every 0.50 s.

Answer: 3.8 m/s

P8 The Earth orbits the Sun at 30 km/s, once every 365 days. Calculate the radius of its orbit.

Answer: 1.5×10^{11} m

06 Other useful information

Common mistakes

✗ **Wrong:** Constant speed means no acceleration.

✓ **Right:** The direction changes, so the velocity changes: it accelerates towards the centre.

✗ **Wrong:** A released ball flies outwards along the radius.

✓ **Right:** It moves off along the tangent at the point of release.

✗ **Wrong:** Use the diameter in $v = 2\pi r/T$, or T in minutes.

✓ **Right:** r is the radius in metres; T is the period in seconds.

✗ **Wrong:** A "centrifugal force" pushes the object outwards.

✓ **Right:** The resultant force points inwards. Feeling thrown out is your body carrying on in a straight line.

✗ **Wrong:** Draw centripetal force as an extra arrow beside tension or gravity.

✓ **Right:** It is the resultant of those real forces, not another force.

Exam tips

- "Explain" questions: velocity changes direction → acceleration → resultant force towards the centre → name what provides it.
- "Describe" questions on (a)–(c): say which two quantities stay constant, then how the force and the third one change.

Explore

- [Circular Motion Lab \(simulation\)](#)
- [IGCSE practice questions for this lesson](#)

What the syllabus asks

- 0625 1.5.1 (Supplement): describe circular motion qualitatively, statements (a)–(c). The syllabus adds: " $F = mv^2/r$ is not required."
- 0625 6.1.1 (Supplement): define average orbital speed by $v = 2\pi r/T$, and recall and use it.
- Going further: A Level Chapter 16 adds $F = mv^2/r$, vertical circles and conical pendulums.