Exercise walk-through

Circular Motion ▪ 2.10

eXercise

You must be able to

- use the **centripetal acceleration 向心加速度**: $a_c = \dfrac{v^2}{r}$
- use the **centripetal force 向心力**: $F_c = \dfrac{mv^2}{r}$, directed toward the centre
- identify which real force provides the centripetal force (gravity, tension, friction, normal)
- explain that speed can be constant while velocity changes direction

Method — Centripetal acceleration and force

An object moving in a circle of radius r at speed v accelerates toward the centre:

$$a_c = \frac{v^2}{r}, \qquad F_c = m a_c = \frac{m v^2}{r}.$$

For $m = 2$ kg, $v = 4$ m s^{-1}, $r = 8$ m: $F_c = \dfrac{2(4)^2}{8} = 4$ N.

Method — A real force supplies it

Centripetal force is not a new force – it is provided by tension (a ball on a string), gravity (a satellite), friction (a car turning), or the normal force.

Method — Constant speed, changing velocity

In uniform circular motion the speed is constant, but the direction keeps changing, so the velocity changes – there is an acceleration toward the centre.

Practice 2.1 ▪ 1 mark

State the direction of the centripetal acceleration.

Solution 2.1

Worked steps

Toward the centre of the circle B1.

Practice 2.2 ▪ 2 marks

A 3 kg ball moves in a circle of radius 2 m at 4 m s^{-1}. Find the centripetal force.

Solution 2.2

Method: Centripetal acceleration and force

Worked steps

$$F_c = \frac{mv^2}{r} = \frac{3(4)^2}{2} = 24 \text{ N}$$ M1 A1.

Practice 2.3 ▪ 1 mark

Name the force that keeps a car turning on a flat road.

Solution 2.3

Method: A real force supplies it

Worked steps

Friction (between the tyres and the road) B1.

Practice 2.4 ▪ 2 marks

An object has $v = 6$ m s^{-1} and $r = 3$ m. Find its centripetal acceleration.

Solution 2.4

Method: Centripetal acceleration and force

Worked steps

$$a_c = \frac{v^2}{r} = \frac{6^2}{3} = 12 \text{ m s}^{-2}$$ M1 A1.

Exam-style 3.1 ▪ 1 mark

For uniform circular motion, the net force points

A along the velocity

B toward the centre

C away from the centre

D upward

Solution 3.1

Method: Constant speed, changing velocity

A along the velocity

B toward the centre ✓

C away from the centre

D upward

Worked steps

B — the centripetal force points toward the centre.

Exam-style 3.2 ▪ 1 mark

Doubling the speed of an object in a fixed circle changes the centripetal force by a factor of

A 2

B 4

C $1/2$

D 1

Solution 3.2

Method: Centripetal acceleration and force

A 2

B 4 ✓

C 1/2

D 1

Worked steps

B — $F_c \propto v^2$, so doubling v gives $2^2 = 4$ times.

Exam-style 3.3 ▪ 2 marks

A 0.5 kg ball on a string moves in a horizontal circle of radius 1 m at 3 m s^{-1}.
(a) Find the centripetal force.
(b) State what provides this force.

Solution 3.3

Method: Centripetal acceleration and force

Worked steps

(a) $F_c = \dfrac{0.5(3)^2}{1} = 4.5$ N M1 A1. (b) The tension in the string B1.

Exam-style 3.4 ▪ 2 marks

A car of mass 1000 kg rounds a curve of radius 50 m at 10 m s^{-1}.
(a) Find the centripetal acceleration.
(b) Find the friction force needed to keep it on the curve.

Solution 3.4

Method: Centripetal acceleration and force

Worked steps

(a) $a_c = \dfrac{10^2}{50} = 2$ m s^{-2} M1 A1. (b) $F = ma_c = 1000 \times 2 = 2000$ N B1.