

Exercise walk-through

4.2

Circular motion (statements 87–91)

Pearson Edexcel · International A-Level · Physics

Scattering links observation to a model

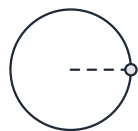
Observation / symbol	Supported conclusion
Most pass nearly straight	Most atomic volume is empty
Rare large deflections	Tiny, dense, positive nucleus
A_ZX	Proton number Z ; nucleon number A ; neutrons $A - Z$

The quark–lepton model organises particles

Family	Constituents / example
Baryon	Three quarks; proton uud
Meson	Quark + antiquark; pion
Lepton / antilepton	Electron / positron
Photon	Electromagnetic quantum

Exercise 2.1

2.1 A point moves around a circle of radius 0.40 m at 90 revolutions per minute. Calculate angular speed, tangential speed and centripetal acceleration. [5]

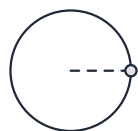


0.40 m

90 rev/min

Exercise 2.1

2.1 A point moves around a circle of radius 0.40 m at 90 revolutions per minute. Calculate angular speed, tangential speed and centripetal acceleration. [5]



0.40 m

90 rev/min

2.1 Convert to frequency.

$$f = \frac{N}{t} = \frac{90}{60 \text{ s}} = 1.50 \text{ Hz}$$

$$\omega = 2\pi f = 2\pi \times 1.50 \text{ s}^{-1} = 9.42 \text{ rad s}^{-1}$$

Angular speed. Use radius for linear speed.

$$v = \omega r = 9.42 \text{ s}^{-1} \times 0.40 \text{ m} = 3.77 \text{ m s}^{-1}$$

Tangential speed.

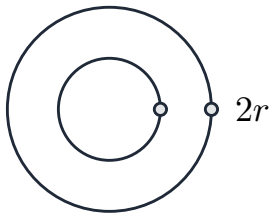
$$a = \omega^2 r = (9.42 \text{ s}^{-1})^2 \times 0.40 \text{ m} = 35.5 \text{ m s}^{-2}$$

Acceleration.

Exercise 2.2

2.2 Two objects rotate on the same rigid disc, at radii r and $2r$. Compare their angular speeds, tangential speeds and accelerations. Explain how an object can accelerate with constant speed. [4]

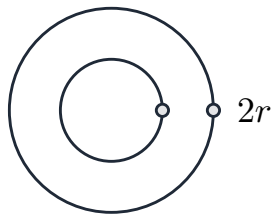
r , inner



Exercise 2.2

2.2 Two objects rotate on the same rigid disc, at radii r and $2r$. Compare their angular speeds, tangential speeds and accelerations. Explain how an object can accelerate with constant speed. [4]

r , inner



2.2 Angular speeds are equal. From $v = \omega r$, outer tangential speed is twice inner. From $a = \omega^2 r$, outer acceleration is twice inner. Velocity direction changes, so its vector changes despite constant magnitude.

Exercise 2.3

2.3 Use a small-angle velocity-vector triangle to derive $a = v^2/r$. Explain why adding the two velocity vectors does not give the change in velocity. [4]

$\mathbf{v}_1$

$\mathbf{v}_2$

Exercise 2.3

2.3 Use a small-angle velocity-vector triangle to derive $a = v^2/r$. Explain why adding the two velocity vectors does not give the change in velocity. [4]



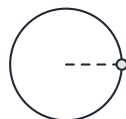
2.3 The change is $\mathbf{v}_2 - \mathbf{v}_1$, drawn between the tips of vectors with a common tail. Similar small-angle triangles give $\Delta v/v \approx \Delta s/r$. With $\Delta s \approx v\Delta t$, divide by time and take the limit:

$$a = \lim_{\Delta t \rightarrow 0} \frac{\Delta v}{\Delta t} = \frac{v^2}{r}$$

The change is inward; addition instead describes a different vector and does not compare final with initial velocity.

Exercise 3.1

3.1 A 0.15 kg piece of clothing follows a vertical drum of radius 0.30 m at constant speed 3.0 m s^{-1} . Calculate the drum's reaction at bottom and top. Explain why these differ even though the required centripetal resultant is equal. State the initial direction of motion if contact and all inward constraint are removed at a point. [6]

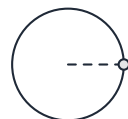


0.30 m

$m = 0.15 \text{ kg}; v = 3.0 \text{ m/s}$

Exercise 3.1

3.1 A 0.15 kg piece of clothing follows a vertical drum of radius 0.30 m at constant speed 3.0 m s^{-1} . Calculate the drum's reaction at bottom and top. Explain why these differ even though the required centripetal resultant is equal. State the initial direction of motion if contact and all inward constraint are removed at a point. [6]



0.30 m

$m = 0.15 \text{ kg}; v = 3.0 \text{ m/s}$

3.1 Use the resultant of actual forces.

$$R_b = \frac{mv^2}{r} + mg = \frac{0.15 \text{ kg} \times (3.0 \text{ m s}^{-1})^2}{0.30 \text{ m}} + 0.15 \text{ kg} \times 9.81 \text{ m s}^{-2} = 5.97 \text{ N}$$

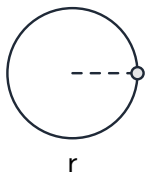
Bottom reaction.

$$R_t = \frac{mv^2}{r} - mg = \frac{0.15 \text{ kg} \times (3.0 \text{ m s}^{-1})^2}{0.30 \text{ m}} - 0.15 \text{ kg} \times 9.81 \text{ m s}^{-2} = 3.03 \text{ N}$$

Top equation and result. Weight opposes the required inward resultant at the bottom but contributes at the top, so reaction differs. Initial velocity is tangent; gravity can bend the later trajectory.

Exercise 3.2

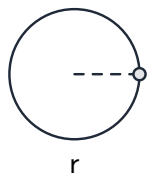
3.2 A small block rests on a horizontal turntable rotating at 2.0 rad s^{-1} . Maximum friction is $mg/20$. Derive and calculate its largest allowed radius. Explain whether doubling the mass changes this radius under the given model. [5]



$$\omega = 2.0 \text{ rad/s}$$

Exercise 3.2

3.2 A small block rests on a horizontal turntable rotating at 2.0 rad s^{-1} . Maximum friction is $mg/20$. Derive and calculate its largest allowed radius. Explain whether doubling the mass changes this radius under the given model. [5]



$\omega = 2.0 \text{ rad/s}$

3.2 Friction provides the inward resultant; use its limiting value.

$$mr\omega^2 \leq \frac{mg}{20} \quad \Rightarrow \quad r_{\max} = \frac{g}{20\omega^2}$$

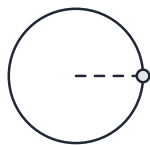
Rearranged limit.

$$r_{\max} = \frac{g}{20\omega^2} = \frac{9.81 \text{ m s}^{-2}}{20(2.0 \text{ s}^{-1})^2} = 0.123 \text{ m}$$

Calculation. Required and limiting forces both scale with mass, so mass cancels and doubling it leaves the radius unchanged.

Exercise 3.3

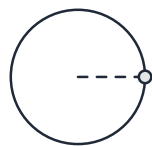
3.3 A student calls centripetal force “an extra inward force” and says doubling rotational frequency doubles the needed force. Correct both statements using equations. Then determine the minimum speed for a small object to remain in contact at the top of the inside of a vertical circular track of radius 0.50 m. [5]



vertical track

Exercise 3.3

3.3 A student calls centripetal force “an extra inward force” and says doubling rotational frequency doubles the needed force. Correct both statements using equations. Then determine the minimum speed for a small object to remain in contact at the top of the inside of a vertical circular track of radius 0.50 m. [5]



0.50 m

vertical track

3.3 Centripetal force is the resultant of real forces, not another force. At fixed mass/radius, $F = 4\pi^2 mr f^2$, so doubling frequency quadruples force. At the limiting top speed the reaction is zero.

$$mg = \frac{mv_{\min}^2}{r} \Rightarrow v_{\min} = \sqrt{gr}$$

$$v_{\min} = \sqrt{gr} = \sqrt{9.81 \text{ m s}^{-2} \times 0.50 \text{ m}} = 2.21 \text{ m s}^{-1}$$

Minimum speed.