

3 Further Mechanics – Part 1

Name: _____ Class: _____ Date: _____

Vocabulary

Write each word three times.

English

Write it 3 times (English)

projectile

angular speed

centripetal accel-
eration

Recall

In AS Mechanics you used the suvat equations and $F = ma$. Bring this with you:

- free fall has a constant downward acceleration g ;
- a velocity has a size and a direction (it is a vector).

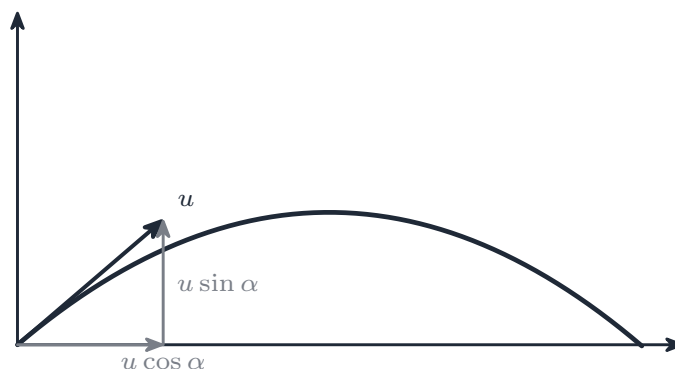
Further Mechanics adds motion in **two directions** (projectiles) and motion in a **circle**.
(Take $g = 10 \text{ m s}^{-2}$.)

New ideas

■ 1 Projectile motion

A **projectile** moves freely under gravity: a constant downward acceleration g , and **no** horizontal acceleration. Treat the horizontal and vertical motions **separately** (they share the same time t).

Launched at speed u and angle α : the path is a parabola, the range on level ground is $\frac{u^2 \sin 2\alpha}{g}$, and the greatest height is $\frac{u^2 \sin^2 \alpha}{2g}$.



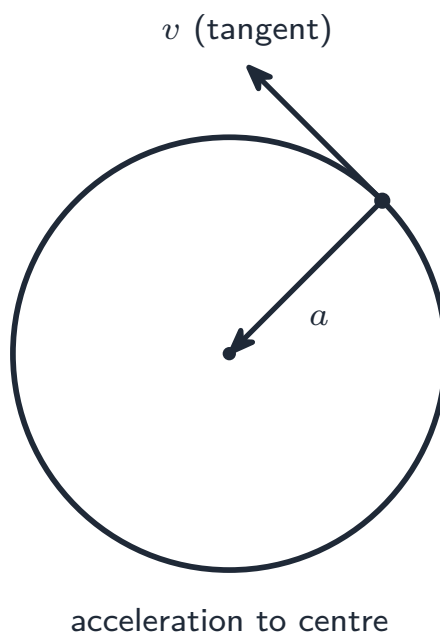
Worked example. $u = 20 \text{ m s}^{-1}$ at $\alpha = 30^\circ$: $\text{range} = \frac{20^2 \sin 60^\circ}{10} = 34.6 \text{ m}$.

Micro-check. A projectile is launched. State its horizontal acceleration. [1]

■ 2 Circular motion

For a particle moving in a circle of radius r , the **angular speed** ω links to the speed by $v = r\omega$. The acceleration points **towards the centre** – the **centripetal acceleration** :

$$a = r\omega^2 = \frac{v^2}{r}.$$



Worked example. $r = 2 \text{ m}$, $\omega = 3 \text{ rad s}^{-1}$: $v = r\omega = 6 \text{ m s}^{-1}$ and $a = r\omega^2 = 18 \text{ m s}^{-2}$.

Micro-check. A particle moves in a circle with $r = 4 \text{ m}$ and $\omega = 2 \text{ rad s}^{-1}$. Find its speed v . [1]

Watch out: a projectile's **horizontal** acceleration is zero – gravity acts only vertically, so the horizontal speed never changes. The centripetal acceleration points **towards the centre**, not along the motion, and $v = r\omega$ needs ω in radians per second.

Practice

3.1 Explain why the horizontal and vertical motions of a projectile can be treated **separately**. [2]

3.2 A ball is launched at $u = 30 \text{ m s}^{-1}$ at $\alpha = 30^\circ$. Find the range ($\sin 60^\circ = 0.866$). [2]

3.3 A particle moves in a circle of radius 3 m with angular speed 4 rad s^{-1} . Find its speed. [2]

3.4 Using the particle in 3.3, find its centripetal acceleration ($a = r\omega^2$). [2]

3.5 State the **direction** of the centripetal acceleration. [1]

3.6 Challenge. A ball is thrown **horizontally** at 15 m s^{-1} from a height of 20 m. Find the time it takes to land and how far it travels horizontally. (Take $g = 10 \text{ m s}^{-2}$.) [3]