5.2 Stability, rotation and projectiles

Name: _____ Class: _____ Date: _____ **Total: 30 marks**

KEY WORDS centre of mass • base of support • torque • moment of inertia • angular momentum • projectile

Objective

Build the skills to answer exam questions on **stability** , **torque** , **angular momentum** and **projectile motion** , and on analysing a skill in phases.

You must be able to:

- explain how the centre of mass, base of support and line of gravity affect stability
- calculate torque and explain the conservation of angular momentum
- explain the factors that affect the flight of a projectile
- resolve a release velocity and explain the sequencing of body segments

1 Key knowledge and worked examples

■ Stability, rotation and projectiles

The **centre of mass** (COM) is the point where the body's mass can be thought to act. In a standing person it is about at hip level; it moves when limbs move and can lie outside the body (a high-jumper's arch).

Stability is greater with: a **wide base of support**; a **low** COM; the **line of gravity** near the centre of the base; a large mass. Sprinters in the set position have low stability, so they can move quickly.

Torque (moment) = force × perpendicular distance from the axis (N m).

Angular motion: angular momentum $L = I\omega$ (moment of inertia × angular velocity). In the air, L stays constant (it is **conserved**). Tucking reduces I, so ω rises (faster spin); opening out increases I and slows the spin, ready for entry or landing.

Projectiles: the horizontal distance depends on **release speed** (most important), **release angle** and **release height**, plus air resistance and spin. If release and landing heights are equal and air resistance is ignored, 45° gives the longest distance. If the release point is **above** the landing point (shot put), the best angle is **less** than 45°. Athletes also produce more speed at lower angles.

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Analysing a skill: split it into **phases**: preparation, execution (action) and recovery (follow-through). Fast throws and kicks use a **proximal-to-distal sequence**: large, central segments start first; each segment adds speed to the next (kinetic chain).

AHL – components: a release velocity v at angle θ has horizontal part $v\cos\theta$ and vertical part $v\sin\theta$; time to the top is $v\sin\theta \div g$.

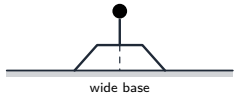
Answer shapes: name the factor, say how it changes the outcome, and give the mechanical reason.

2 Practice

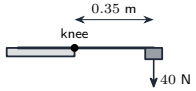
2.1 Define centre of mass, and state where it is for a person standing upright. [2]



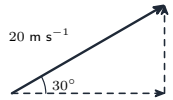
2.2 Explain **three** ways a wrestler can make himself more stable. [3]



2.3 A 40 N ankle weight is 0.35 m from the knee joint, acting at right angles to the shin. Calculate the torque about the knee, and state the torque if the perpendicular distance halves. [3]



2.4 A ball is kicked at 20 m s^{-1} at 30° above the horizontal. Calculate the horizontal and vertical components of the velocity, and the time to reach the highest point. [3]



3 Exam-style questions

3.1 A diver leaves the board, tucks tightly, then opens out before entering the water.

(a) Explain, using angular momentum, why the diver spins faster in the tuck. [3]



(b) State what happens to the rate of spin when the diver opens out. [1]

3.2 A shot-putter releases the shot about 2 m above the ground.

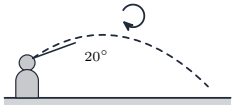
(a) State **three** factors that affect the horizontal distance of the throw. [3]



(b) Explain why the best release angle for the shot put is less than 45°. [3]

3.3 A long jumper takes off at about 20°.

(a) Explain why the take-off angle is much lower than 45°. [2]



(b) Explain why the jumper "cycles" the arms and legs in the air. [2]

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3.4 A basketball player performs a jump shot.

(a) Identify the **three** phases of the skill. [2]

(b) Explain how the sequence of segment movements helps produce a fast, accurate release. [3]



Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

the point where the mass of the body can be considered to be concentrated / where gravity acts; about hip level, behind the navel

2.2

widen his base of support, e.g. feet further apart; lower his centre of mass by bending the knees; keep his line of gravity near the centre of the base, so a push must move it further to topple him

2.3

torque $= 40 \times 0.35 =$ **14** N m; halved distance: **7** N m

2.4

horizontal $= 20\cos 30^\circ \approx$ **17.3** m s^{-1}, vertical $= 20\sin 30^\circ =$ **10** m s^{-1}; time $= 10 \div 9.81 \approx$ **1.0** s

3.1

(a) angular momentum ($L = I\omega$) is constant in the air; tucking brings mass closer to the axis, so moment of inertia falls; so angular velocity must rise

(b) it slows down

3.2

(a) release speed; release angle; release height (also air resistance)

(b) the shot is released above the landing height; so it lands later and further at a lower angle; 45° is best only when release and landing heights are the same; also the athlete can produce more release speed at lower angles, because the muscles push more horizontally

3.3

(a) the jumper arrives at high horizontal speed and has only a short contact time; a steeper take-off would need a large loss of horizontal speed, which matters more for distance

(b) take-off gives the body forward angular momentum, which would rotate it forward; rotating the arms and legs forward takes up this angular momentum, so the trunk stays upright for a good landing

3.4

(a) preparation, execution (release), recovery (follow-through); all three for [2], two for [1]

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(b) movement starts in large, proximal segments (legs, trunk) and moves to small, distal ones (upper arm, forearm, wrist); each segment starts as the previous one reaches its peak speed, so speed is added along the chain; the final wrist flick controls direction and backspin, giving accuracy