The law of conservation of angular momentum

Ross Howitt explains the concepts behind the law of conservation of angular momentum, giving practical examples and tips for exam success

Diver performing a somersault with a low moment of inertia

TopFoto

Angular momentum is the quantity of angular motion that a rotating body has. Angular momentum is measured in $kg\,m^2s^{-1}$ (kilograms × metres squared per second), which reflects two other parameters:

- moment of inertia
- angular velocity

To understand these concepts you need to know that a body can rotate. The body has three imaginary lines running through it around which it can rotate (Figure 1). These are:

- **longitudinal axis**: used in moves such as ice skating spins
- **frontal axis**: used in moves such as a cartwheel
- **horizontal** or **transverse axis**: used in moves such as a front or back somersault

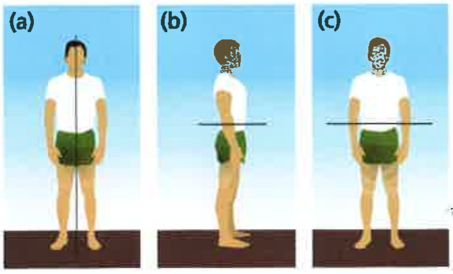

Figure 1 (a) The longitudinal axis, (b) the frontal axis and (c) the transverse axis

In this 'AQA special' I will mainly be referring to basic somersaults (front or back) where the rotation takes place around the transverse axis. In such an action, the axis of rotation is similar to that of the rod running through the hips of a table footballer.

Understanding the law

Before answering questions on the law of conservation of angular momentum, you need to become familiar with the standard diagram used in an exam setting (Figure 2, p. 32). So let's consider what it means.

Although any change in body shape will affect the rotation of a body during a somersault, in an exam setting the main focus is on referring to the biomechanical parameters shown in Figure 2, i.e. the lines.

Moment of inertia

Moment of inertia mainly refers to the distance of the body parts from the axis of rotation. It also takes into account the mass of an object and is basically the resistance a body has to changing its state of angular motion. To understand this we need to look at some practical examples.

In a somersault when the body is tucked tight, the body parts are close to the axis of rotation and therefore the moment of inertia is low. This can be seen in the diver photo. As the body parts are low and a small distance from the transverse axis of rotation, the moment of inertia is low. This is the case in Figure 2 at

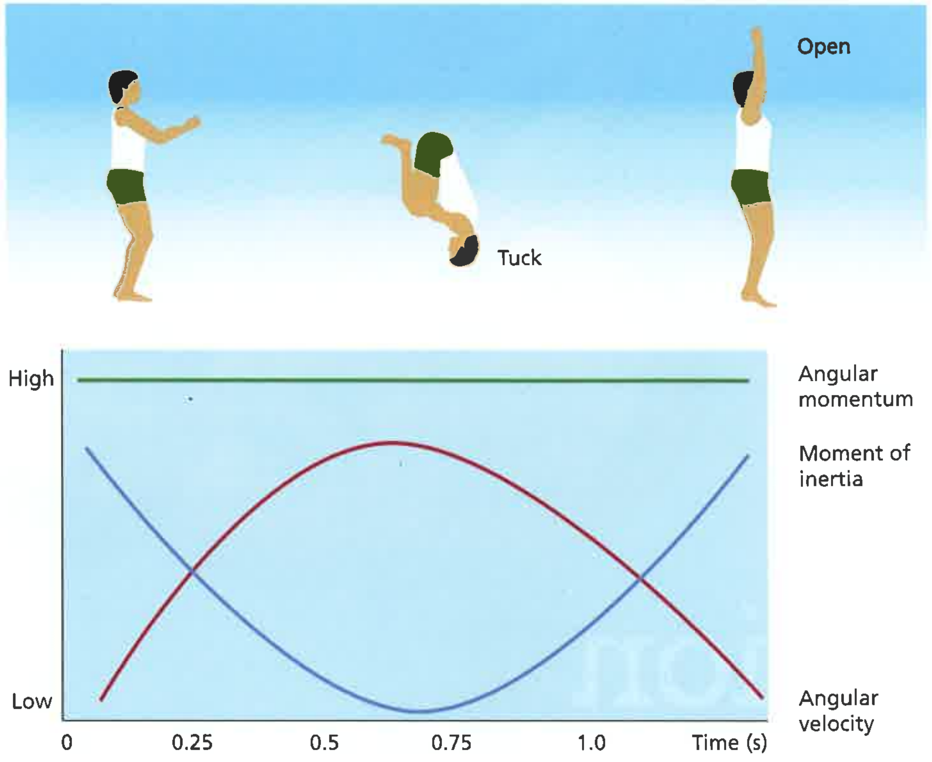

Figure 2 You need to go into your exam with a thorough understanding of this diagram

the midpoint of the back somersault when the body is tightly tucked and therefore possesses a low moment of inertia.

In an open somersault, as shown in Figure 3, the body parts are a large distance from the transverse axis and therefore the moment of inertia is high. When you compare this to Figure 2, you can see that at the start and end of the back somersault the body parts are a large distance from the axis and thus the moment of inertia is high.

Key exam points

- Moment of inertia refers to the distance of the body parts from the axis/mass of the body.
- Tucking up closer to the axis reduces moment of inertia.
- Opening out body parts and moving them away from the axis increases moment of inertia.

Angular velocity

In Figure 2 you will notice that as moment of inertia decreases, angular velocity increases (and vice versa). Angular velocity is the speed of rotation. When the body tucks up and moment of inertia decreases, the speed of rotation increases (and thus the angular velocity increases). Similarly, when the body opens up and the moment of inertia increases, the speed of rotation slows down (and thus the angular velocity decreases).

Although these concepts can be seen in Figure 2, they are also common in ice skating routines, when ice skaters have to adjust their rate of spin according to the move being performed. As a set of basic rules:

Figure 3 Open somersault

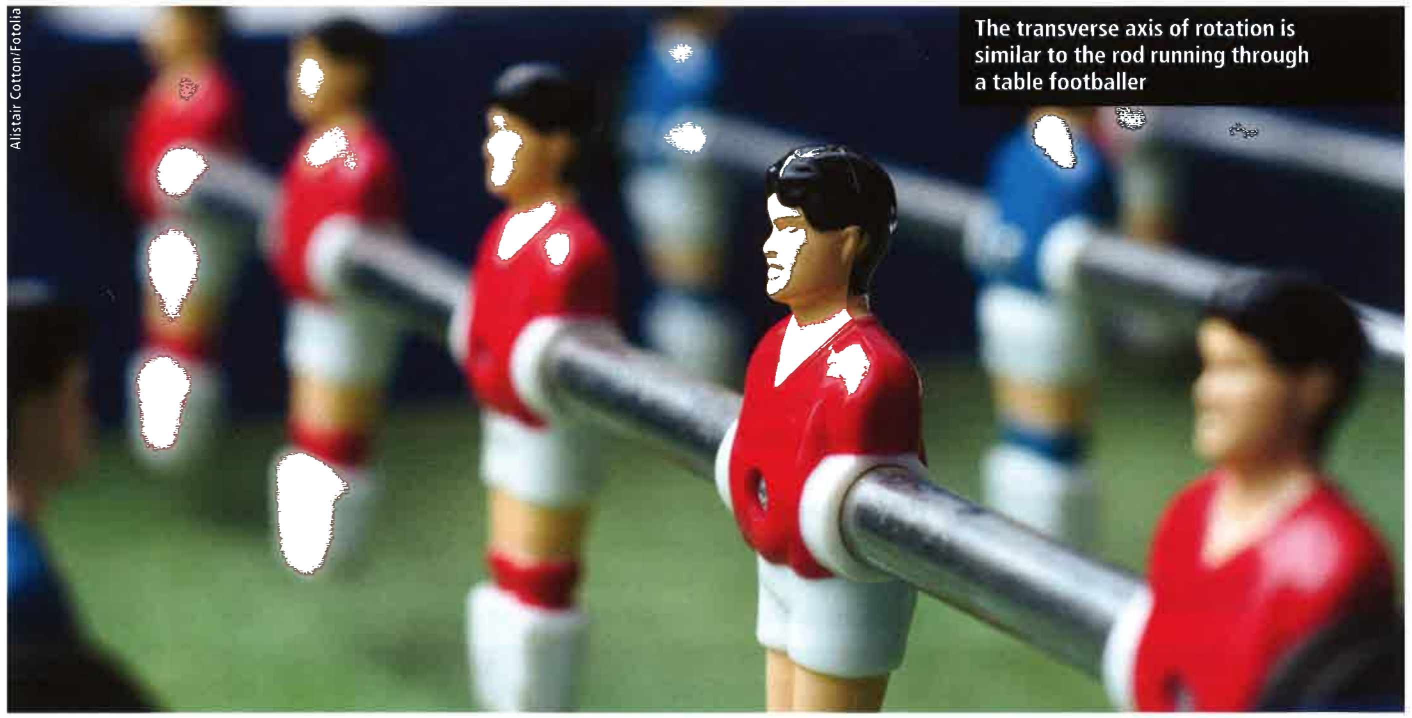

Figure 4 Kim Yuna performing a fast rotational spin

- If they adjust their body shape they will change their speed of rotation.
- If they want to speed up rotation they need to increase their angular velocity.
- This can be done by tucking up close to the axis of rotation.
- This is called decreasing their moment of inertia.
- If they need to slow down their rotational speed they open up their body parts away from the axis.
- This increases their moment of inertia and decreases their angular velocity.

Figure 4 shows 2013 World Figure Skating champion Kim Yuna performing a fast rotational spin. Her body parts are tucked in close to the longitudinal axis, thus reducing her moment of inertia and increasing her angular velocity.

Key exam points

- Angular velocity is the speed of rotation.
- It is directly affected by changes in body shape.
- A reduction in moment of inertia will increase angular velocity.
- An increase in moment of inertia will decrease angular velocity.
- Angular velocity and moment of inertia are inversely proportional.

Angular momentum

As you can see in Figure 2, angular momentum remains constant throughout a somersault rotation. In other words the quantity of rotation does not change. This is because angular momentum is the relationship between the other two lines. It can be expressed as:

moment of inertia × angular velocity

Key exam points

- During rotation angular momentum remains constant.
- Angular momentum = moment of inertia × angular velocity.

As exam questions regularly focus on how to change the rate of spin or to interpret Figure 2, it is important to mention all three biomechanical lines.

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