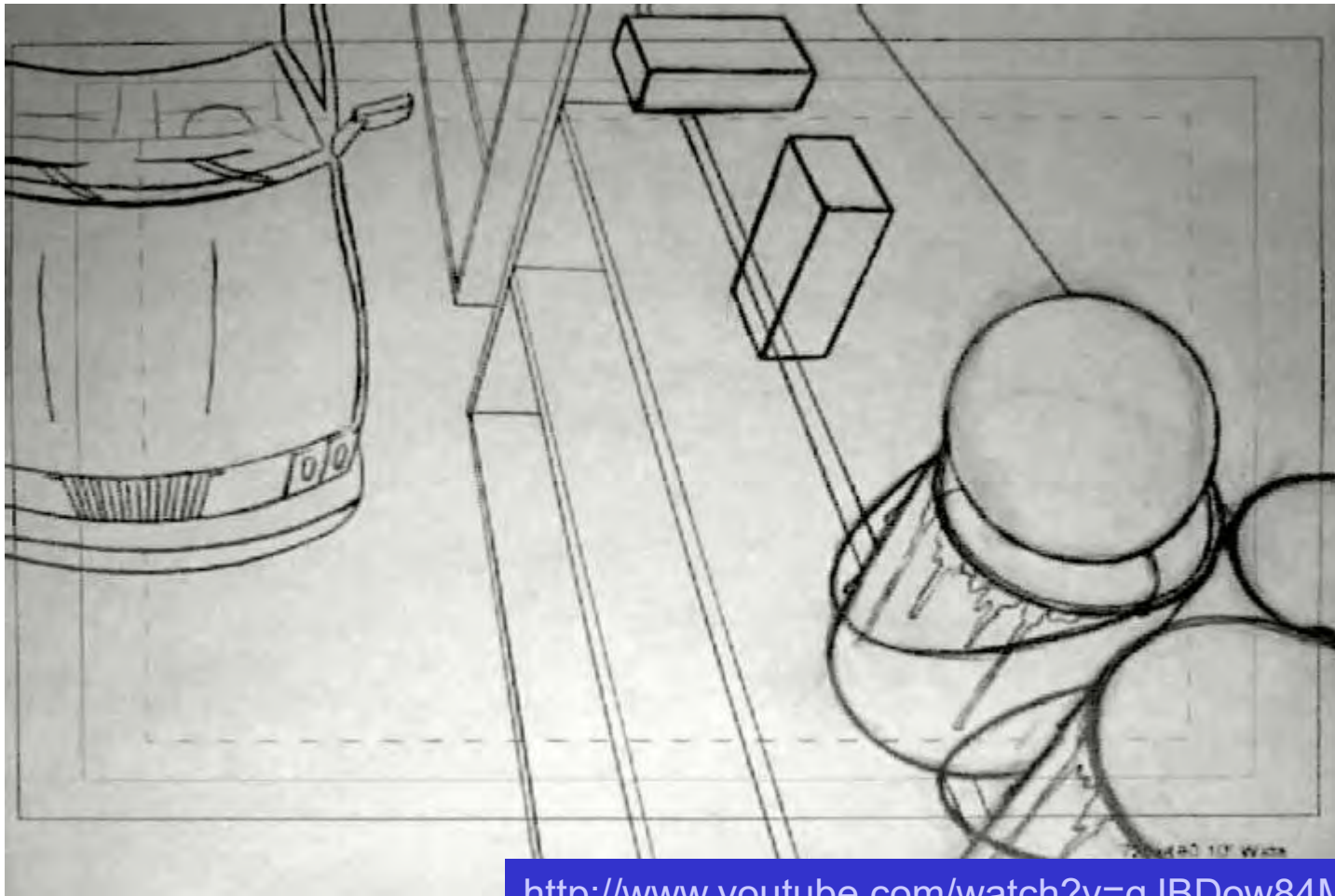


Spinning, Tumbling & Wobbling



National Science Foundation
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Brick Drop Pencil Test

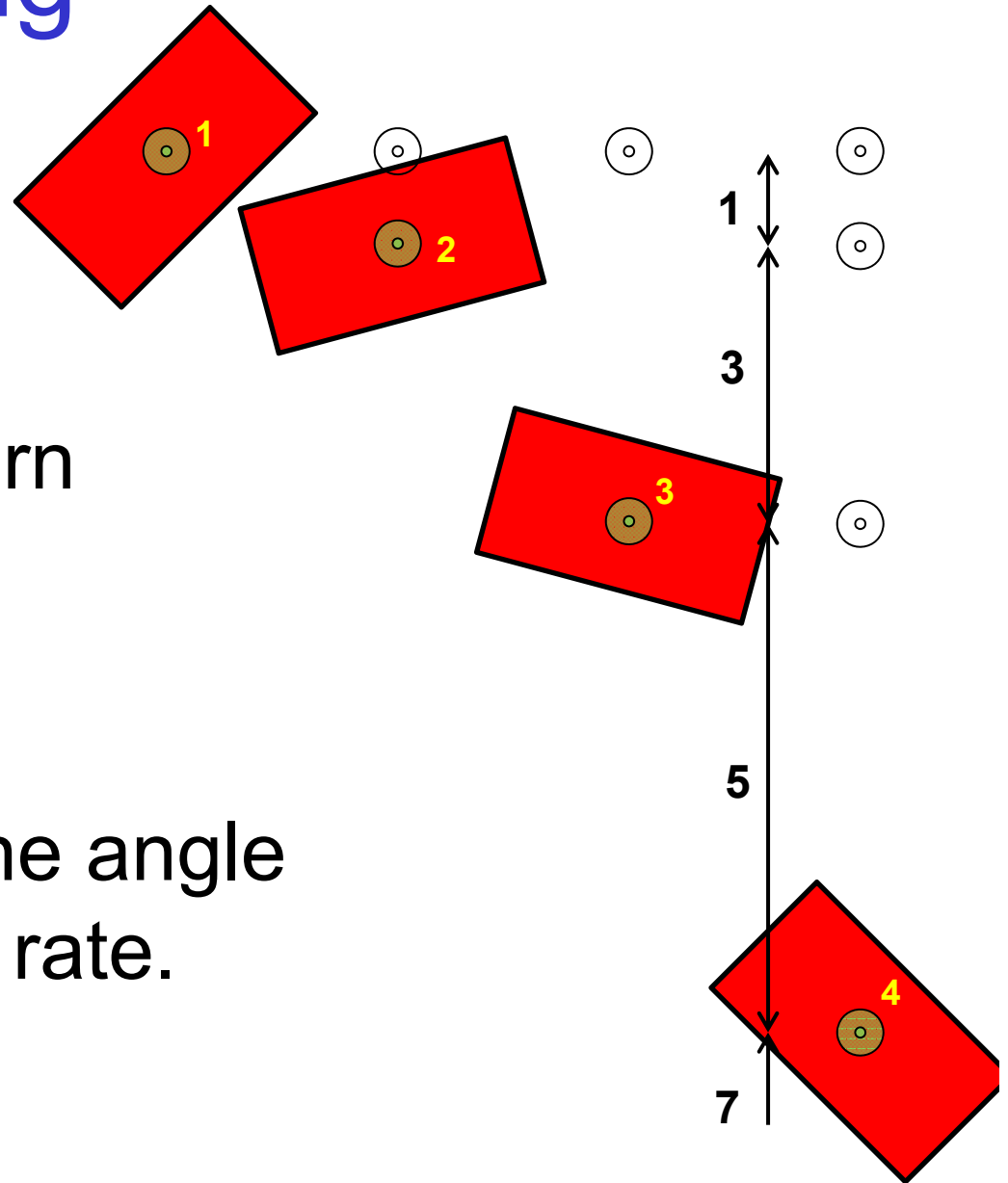


<http://www.youtube.com/watch?v=gJBDow84MLw>

Simple Spinning

A falling brick may turn by simple spinning around its center.

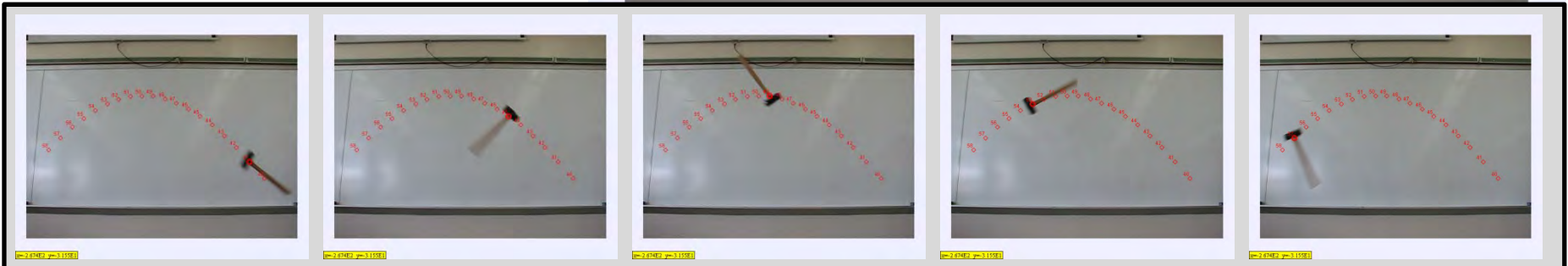
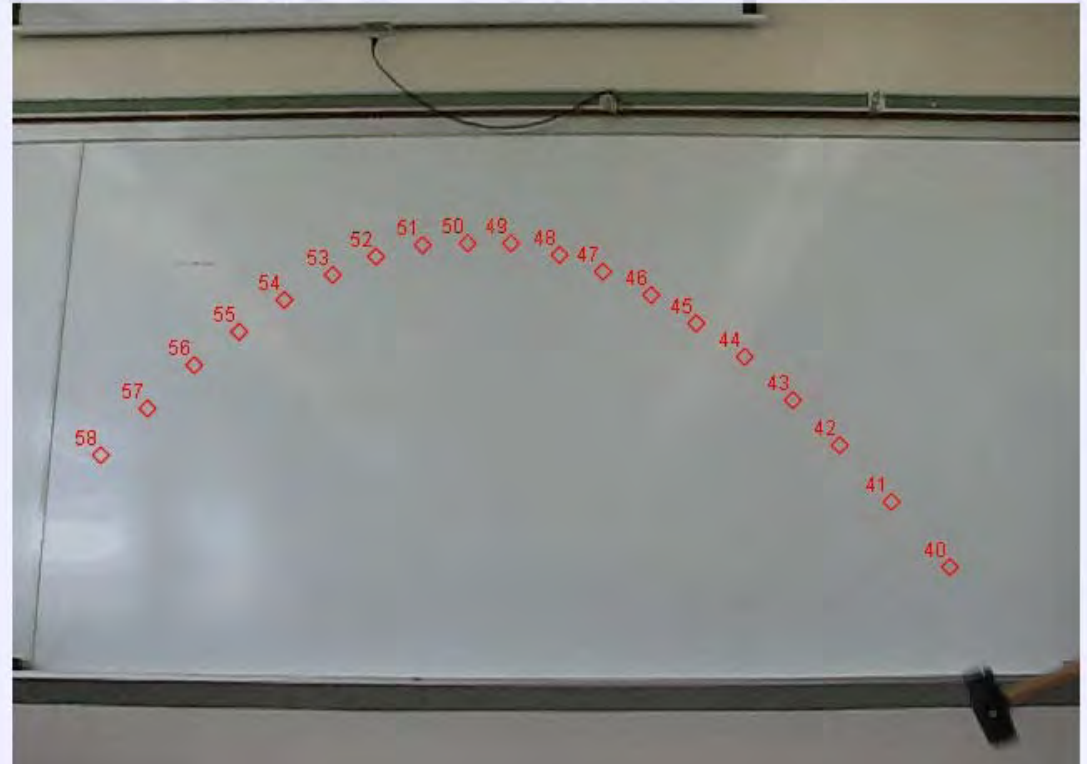
In simple spinning, the angle rotates at a constant rate.



Simple Spinning

Hammer
rotates with
uniform
spinning as it
flies through
the air.

<http://www.youtube.com/watch?v=0uCSq05CXKU>

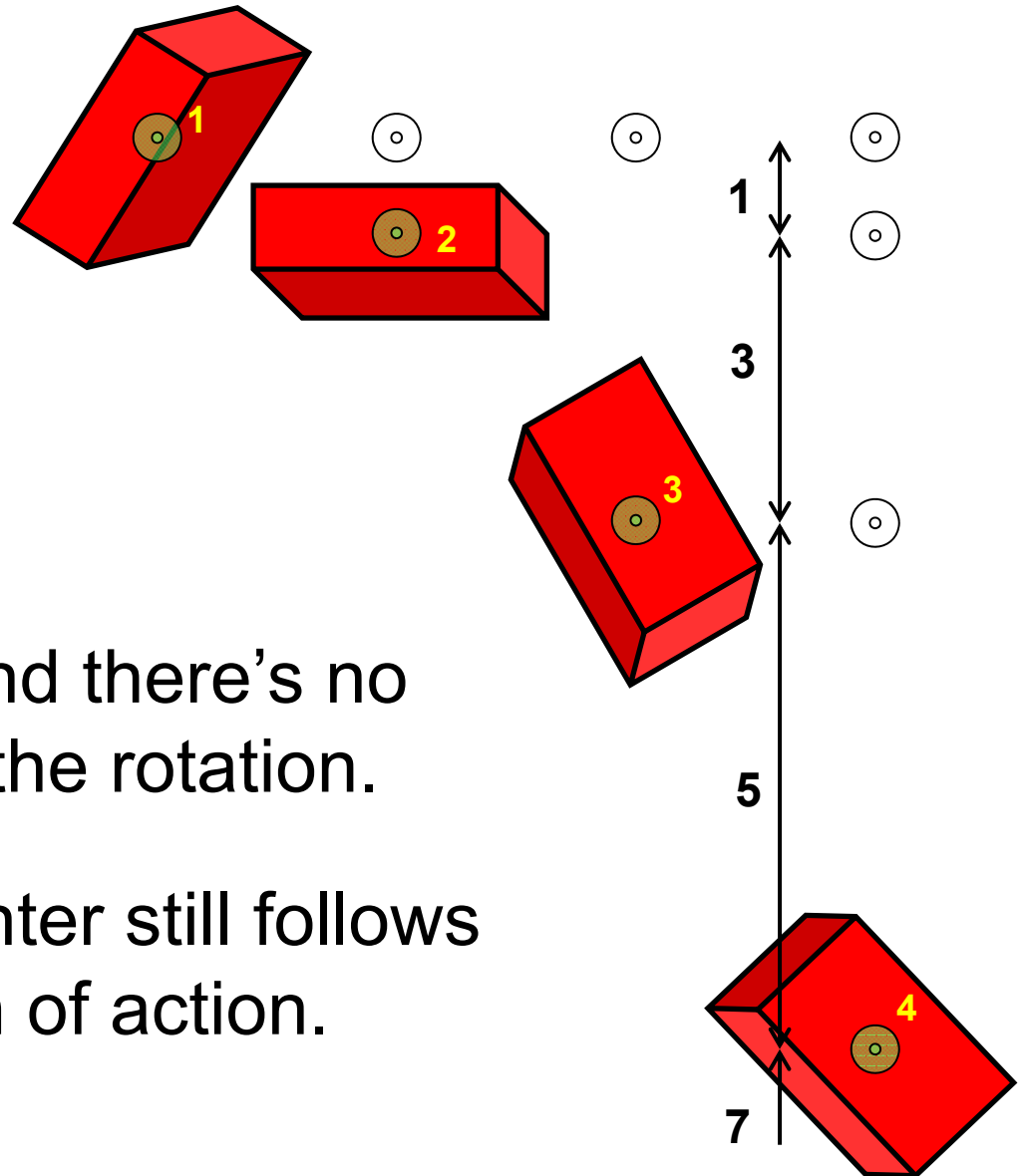


Tumbling

A falling brick may also turn by a more complicated tumbling motion.

Tumbling is *not cyclic* and there's no simple way to describe the rotation.

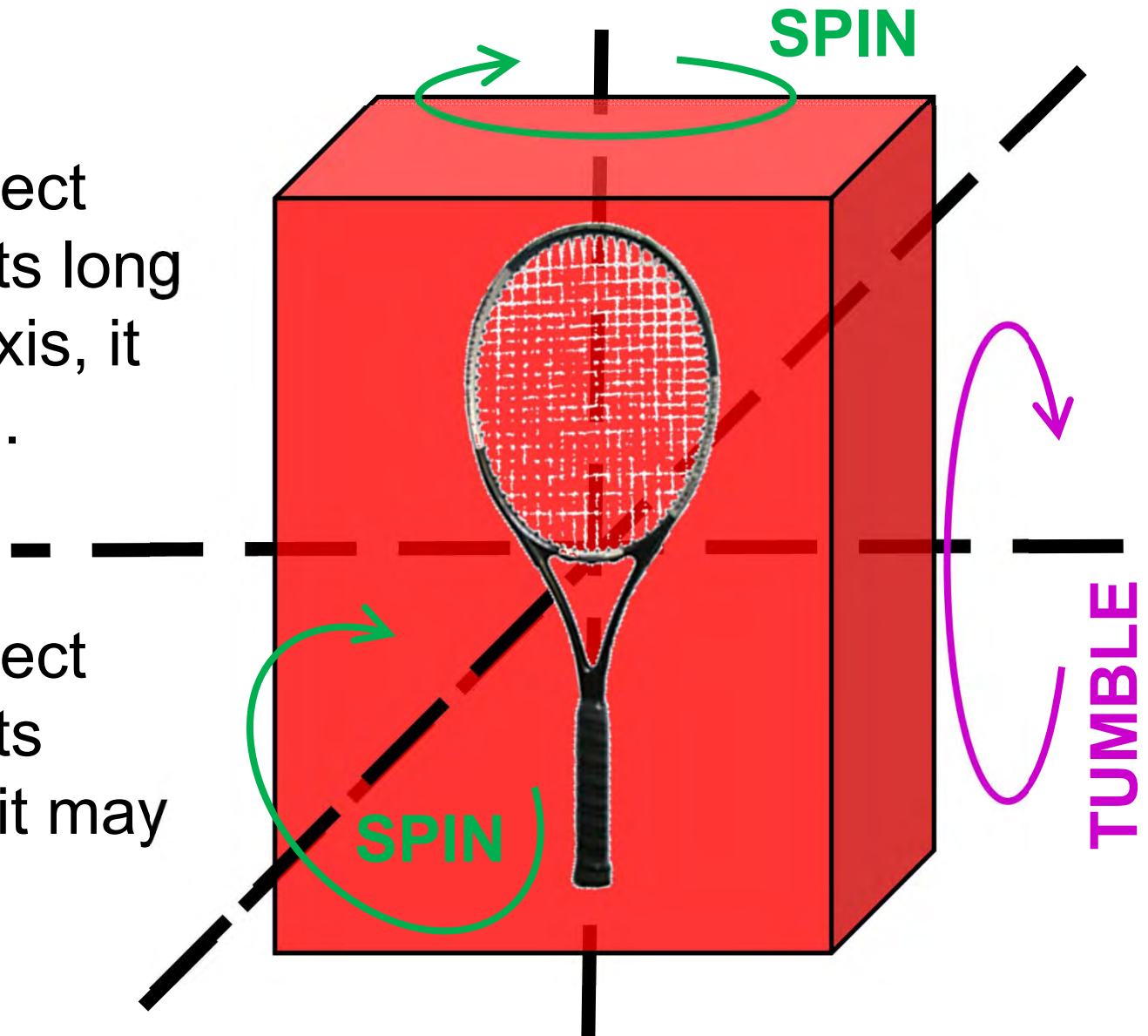
However, the brick's center still follows the same parabolic path of action.



Tennis Racket Theorem

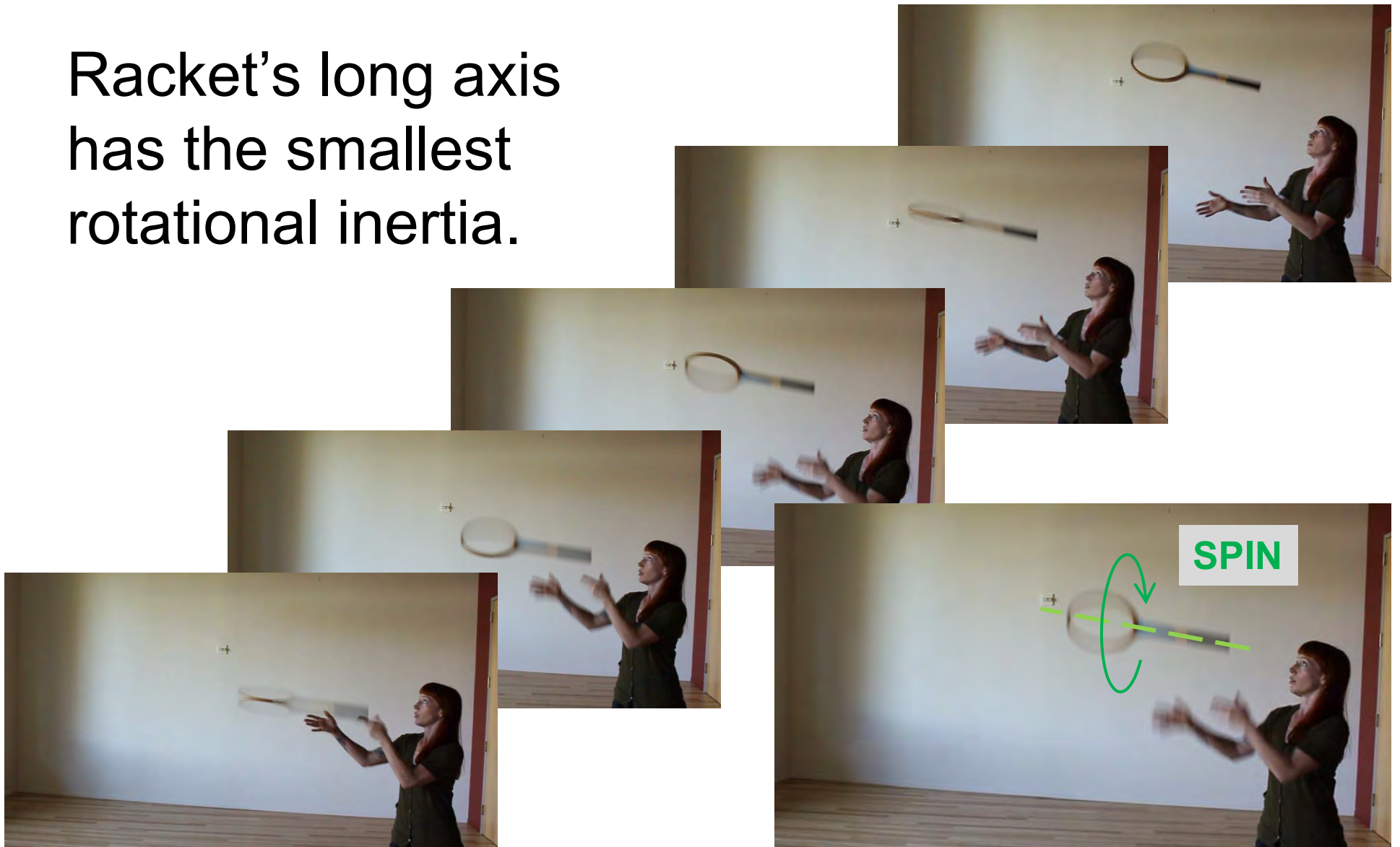
When an object turns about its long or its short axis, it tends to spin.

When an object turns about its middle axis, it may tumble.



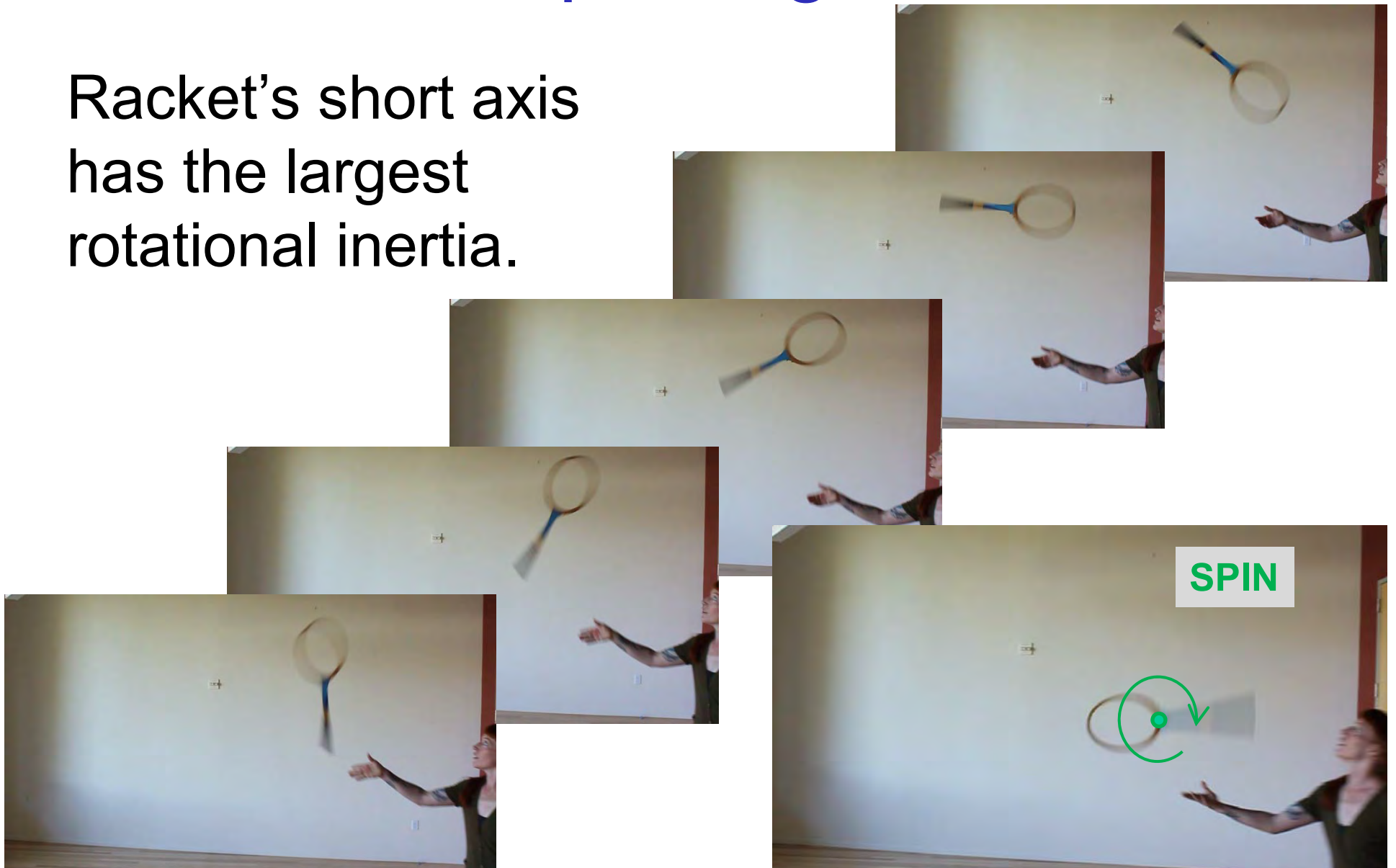
Long Axis Spinning

Racket's long axis
has the smallest
rotational inertia.



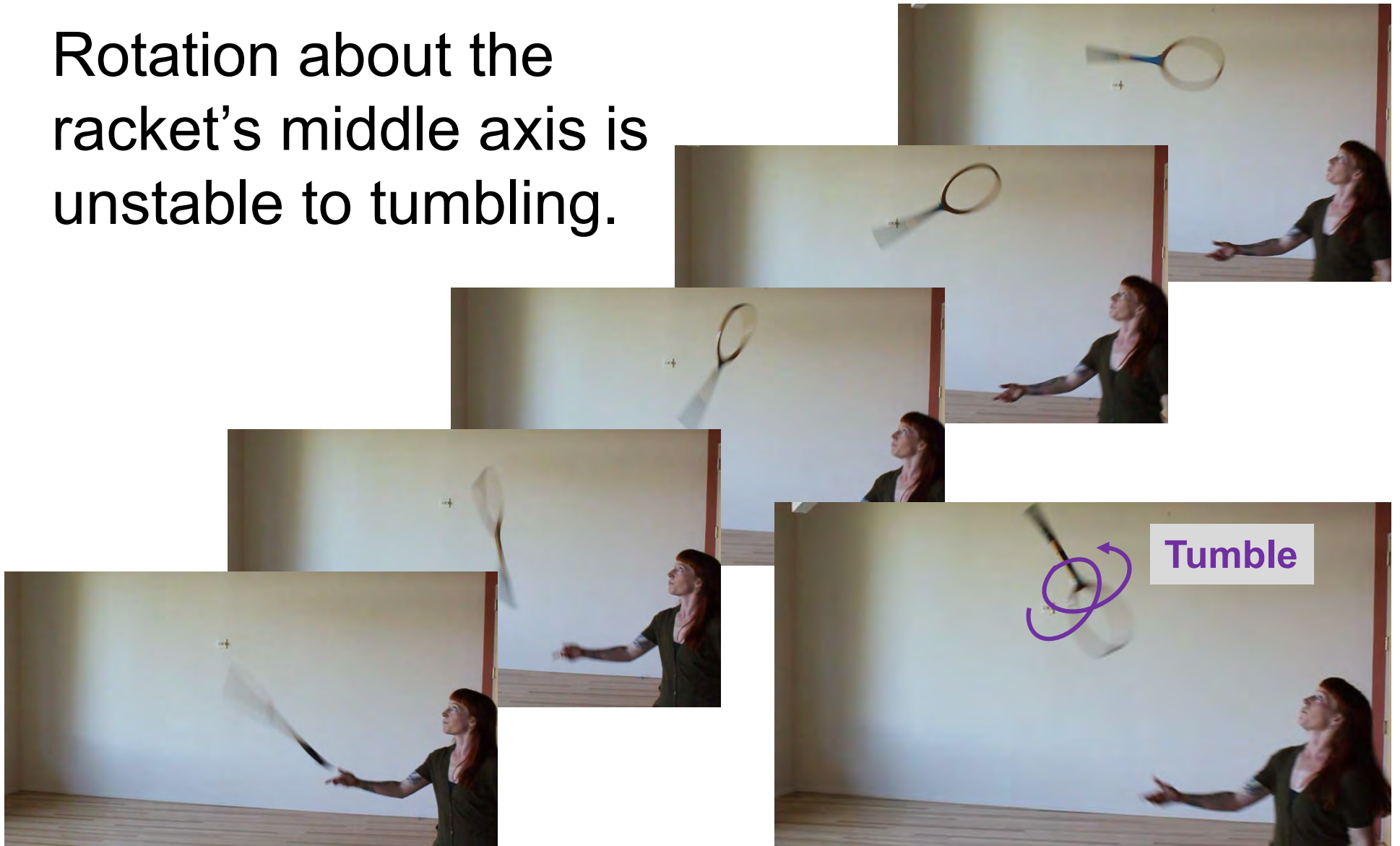
Short Axis Spinning

Racket's short axis
has the largest
rotational inertia.

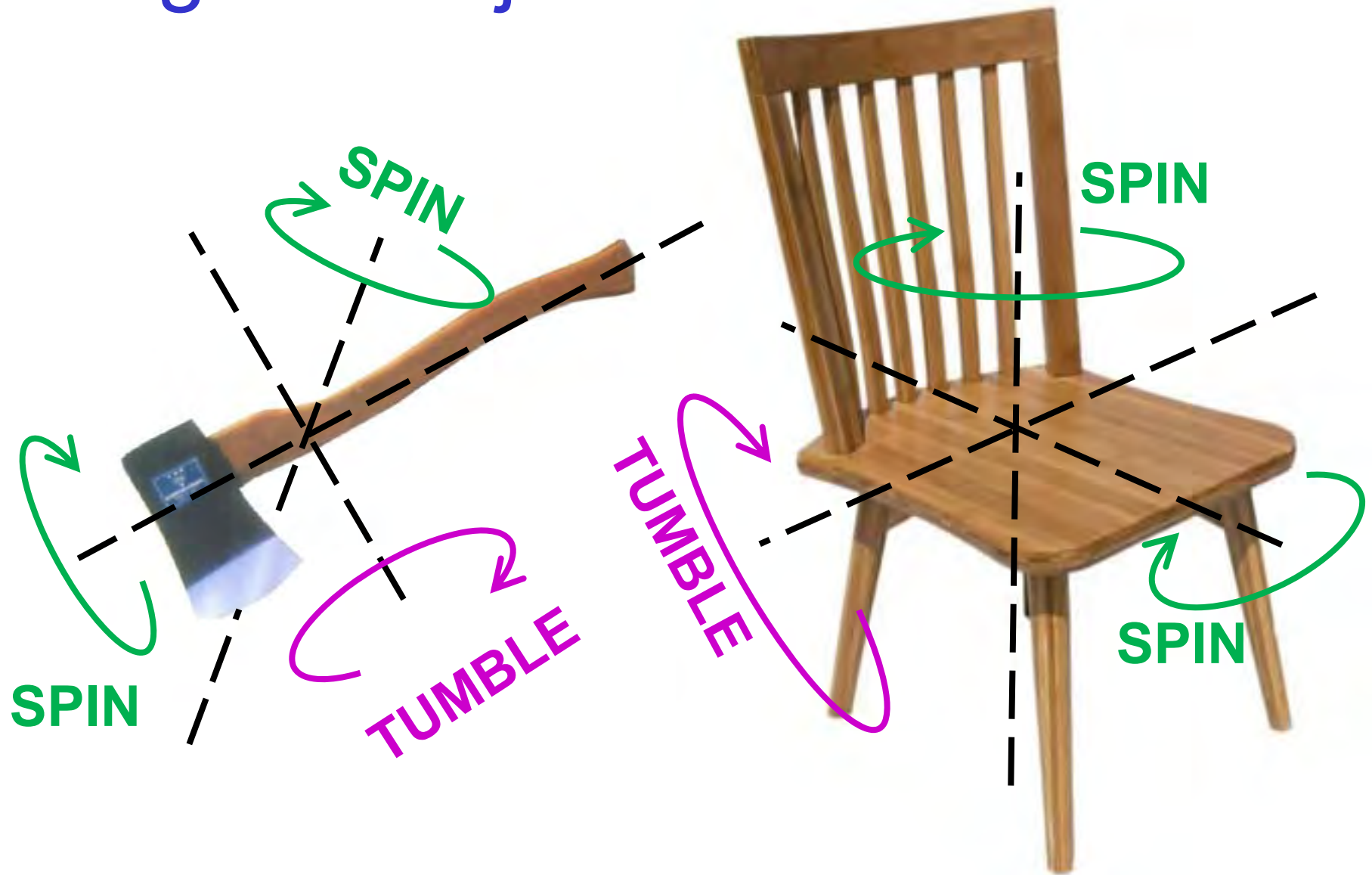


Middle Axis Tumbling

Rotation about the racket's middle axis is unstable to tumbling.



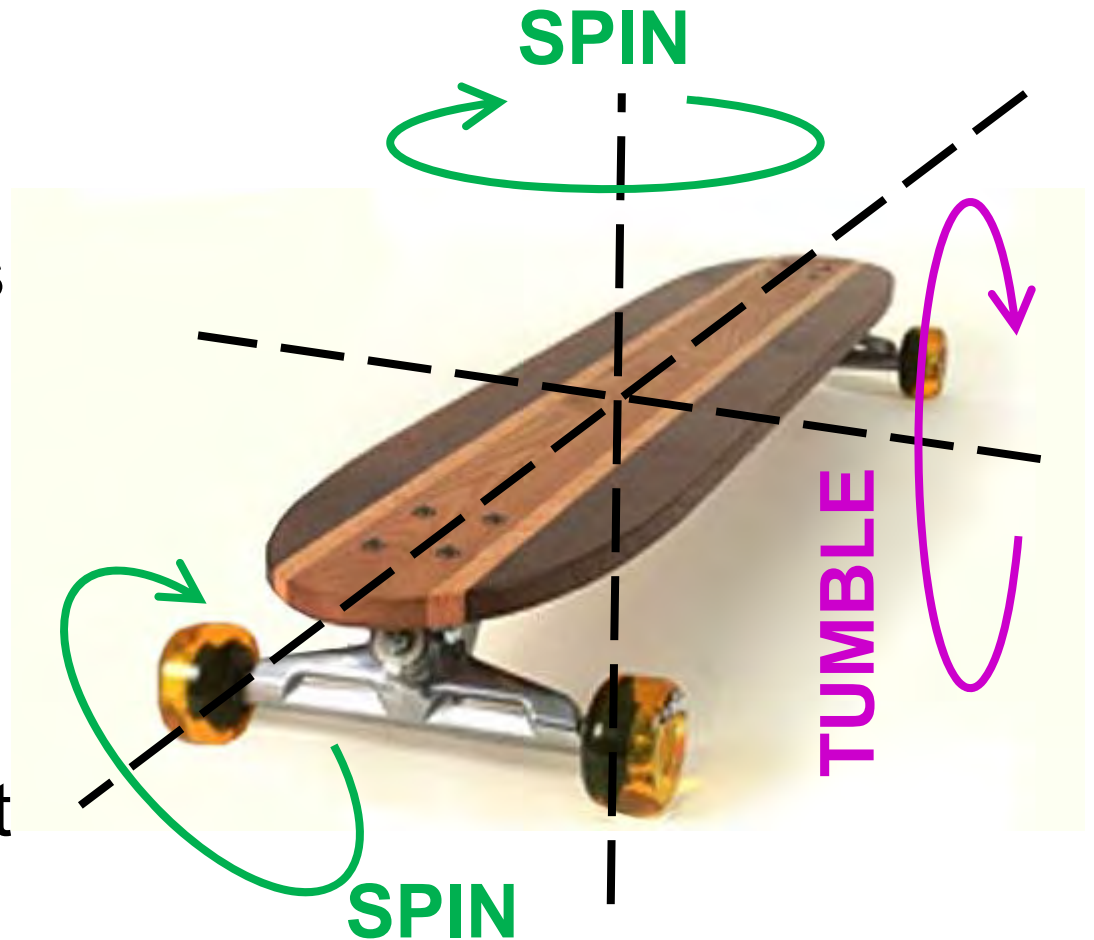
Irregular Objects



Skateboard Tricks

Possible to do skateboard tricks where the board spins on its short axis or its long axis.

Almost impossible to spin the board along its middle axis without tumbling.



Wobbling

A symmetric object, like a football, may wobble as it spins.



electron9.phys.utk.edu

The ratio of wobbles per spinning turn depends on the objects shape, for example:

Football: About 3 wobbles each 5 spin turns.

Disk or Plate: About 2 wobbles for each spin turn.

Wobbling Football



Wobbling Plate

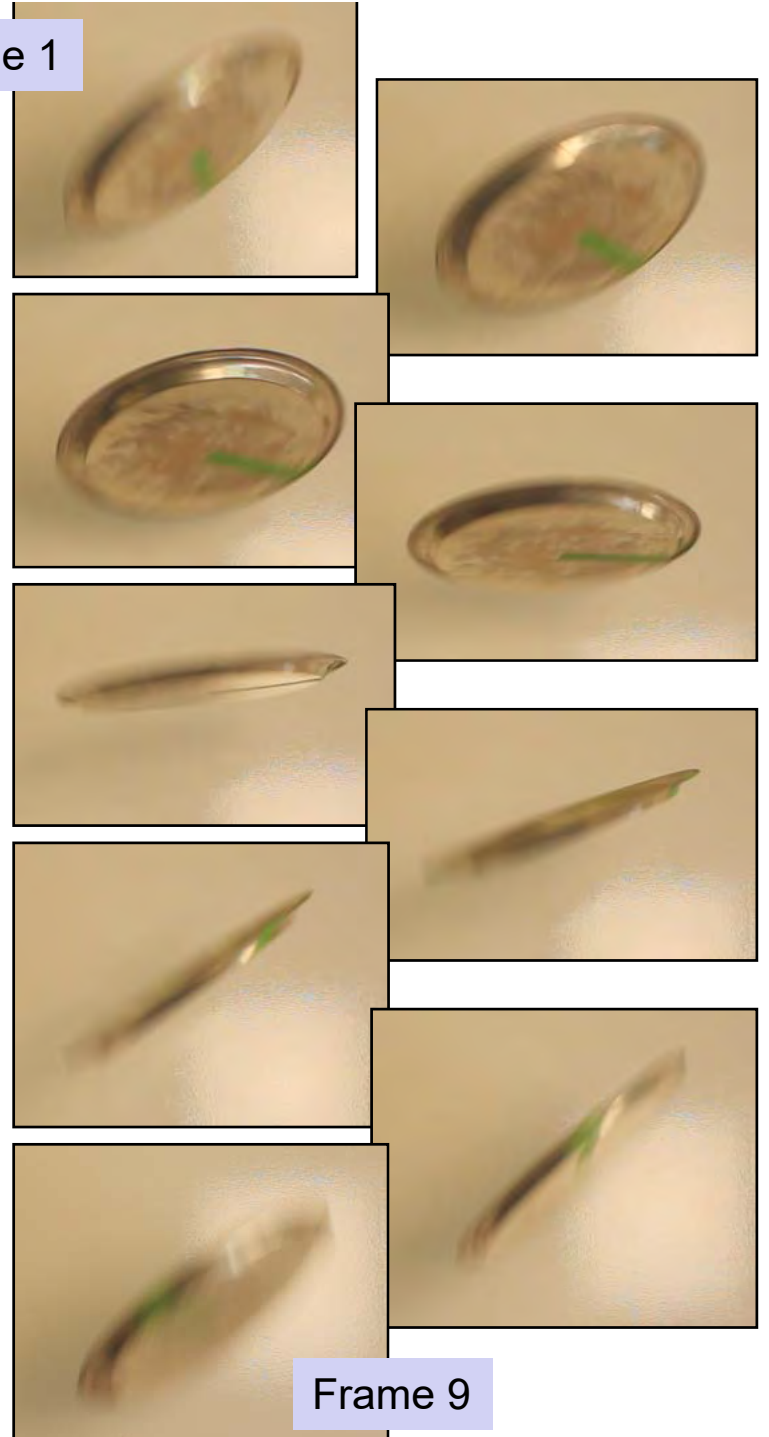


Wobbling Plate

The plate spins for a half-turn in eight frames (watch the green stripe).

During this time it does one full wobble (sides tilting up and down), returning to its original tilt angle.

Frame 1



Frame 9

Spinning & Wobbling Frequencies

Objects can spin faster or slower but then the wobble frequency has to be consistent with the spinning frequency.

Increasing the spinning frequency increases the wobble frequency by the same proportion.



Wobble radius does not affect the frequency.

Summary

- An object thrown in the air may spin or tumble depending on its shape and axis of rotation.
- By the Tennis Racket Theorem, spinning occurs when the rotation axis is along the object's long axis or its short axis.
- Tumbling is the irregular turning motion that occurs if the middle axis is the axis of rotation.
- Symmetric objects, such as disks, don't have a middle axis so they don't tumble. However, they can wobble as they spin.
- Spin and wobble frequencies are linked and their ratio depends on the shape of the object.