

11.6 Backspin

WORKSHEET

The question

By pressing a finger down on it, a uniform spherical marble of radius a is made to slide along a horizontal table top with an initial linear velocity v_0 and an initial *backward* angular velocity ω_0 about the horizontal axis perpendicular to v_0 . The frictional force between the marble and the table is constant (independent of speed).

For what value of $v_0/(a\omega_0)$ does the marble

- (i) slide to a complete stop,
- (ii) come to a stop and then roll back towards its initial position with linear speed $v_0/7$?

Hints

Try the question on your own first. If you get stuck, read the hints *one at a time*, and go back to the question after each one. Hints marked *Pause and try* are the key steps.



Ask yourself The marble moves forwards at v and spins backwards at ω . How fast is the bottom point of the marble moving over the table? Which way does friction act?

STAGE 1 What friction does



Ask yourself Let the friction force be F , backwards. What does it do to v ? Its torque about the centre is Fa : does it increase or decrease the backspin?

STAGE 2 Stopping dead



Ask yourself For the marble to stop completely, v and ω must reach zero at the same moment. When does each reach zero?

STAGE 3 Coming back



Ask yourself If the backspin is larger, v reaches zero while ω is still positive. The bottom point is still sliding forwards, so friction still acts backwards. What happens next, and when does sliding stop?

Try this next

- 1 Topspin.** If the marble starts with forward spin ω_0 instead of backspin, find its final rolling speed. For what value of $v_0/(a\omega_0)$ does it speed up?
- 2 A snooker ball.** A ball struck centrally starts sliding at v_0 with no spin. Show that it ends up rolling at $\frac{5}{7}v_0$, and find the fraction of kinetic energy lost. (The kinetic energy of rolling is $\frac{1}{2}mV^2 + \frac{1}{2}I\omega^2$.)
- 3 A hoop.** Repeat the question for a thin hoop rolling in its own plane, with $I = ma^2$. What ratio $v_0/(a\omega_0)$ now makes it return at $\frac{v_0}{7}$?
- 4 The draw shot.** Where must a snooker cue strike the ball (at what height above the centre, in terms of a) for the ball to roll without sliding from the start? (*Hint:* take angular momentum about the contact point during the impulse.)

Further reading

- ▶ **David Morin**, *Introduction to Classical Mechanics* (Cambridge University Press), Chapter 8, on angular momentum and rolling with slipping.
- ▶ **Daniel Kleppner & Robert Kolenkow**, *An Introduction to Mechanics* (Cambridge University Press), the chapters on rigid body motion.
- ▶ **David Alciatore**, *The Illustrated Principles of Pool and Billiards* (Sterling). The physics of the game, with many diagrams.

The full guided solution, and what the question leads to at university, is in Section 11.6:
https://keithmcnulty.github.io/step_book_mcnulty/ch11/backspin.html