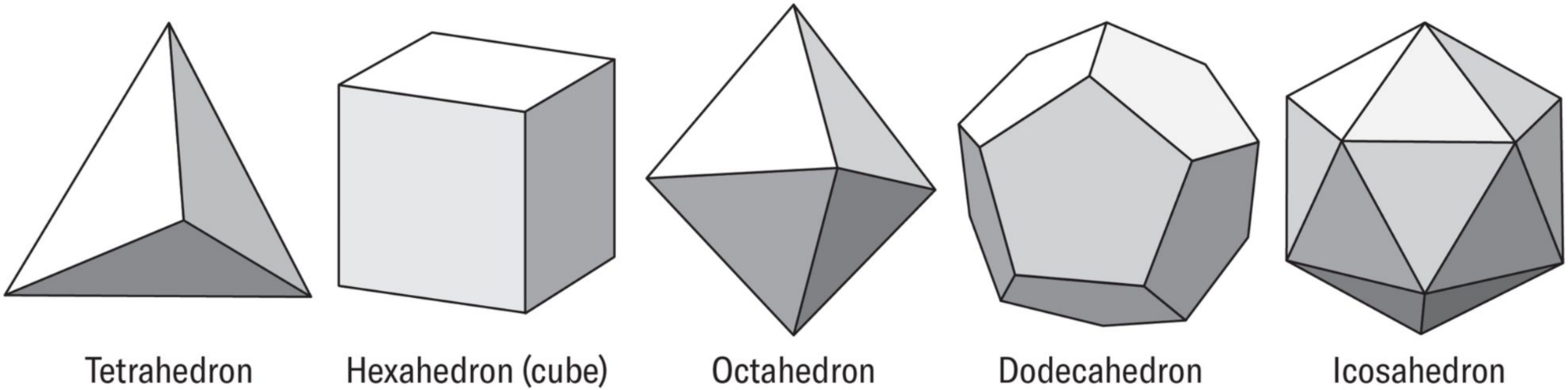
The Physics behind the Law of Football

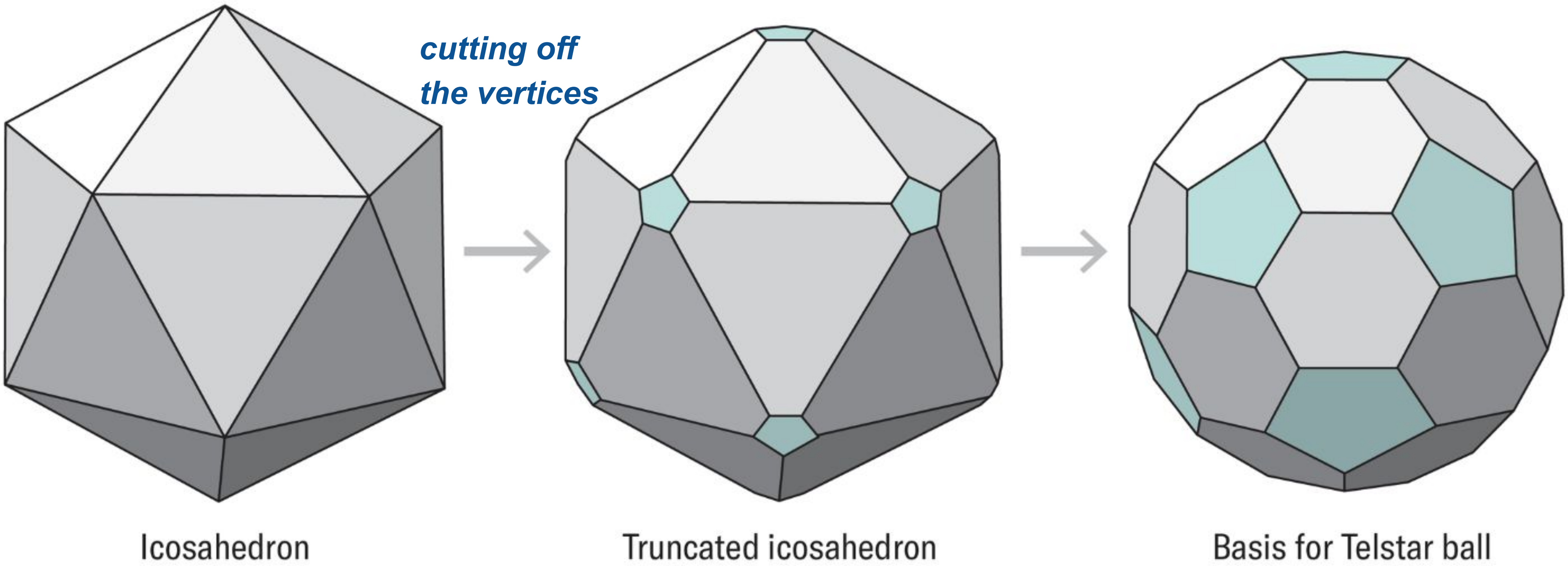
Thursday, 11 June 2026 will be the kick-off of the **(FIFA) World Cup 26** at the iconic Estadio Azteca Mexico City. Before each dramatic kickoff, artists and researchers spend years designing, testing and revising the **official match ball.**



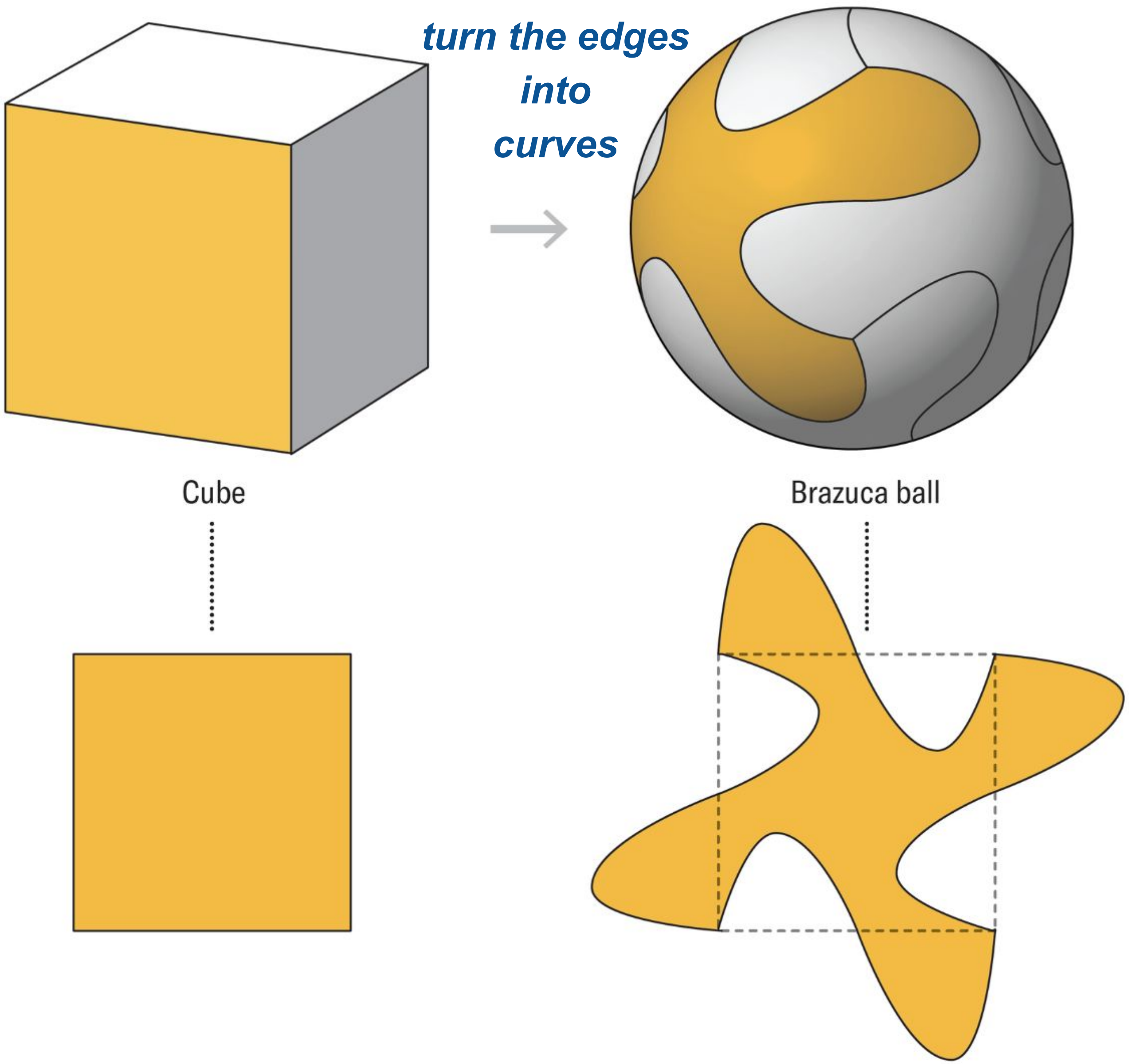
PLATONIC SOLIDS: convex, regular polyhedra with congruent regular polygon faces and the same number of faces meeting at each vertex

The Physics behind the Law of Football

The classic soccer ball, originally called the **Telstar ball** used in the official **FIFA World Cup match in 1970**. The stark black-and-white color scheme was meant to increase visibility on black-and-white TVs, which were still prevalent at the time.

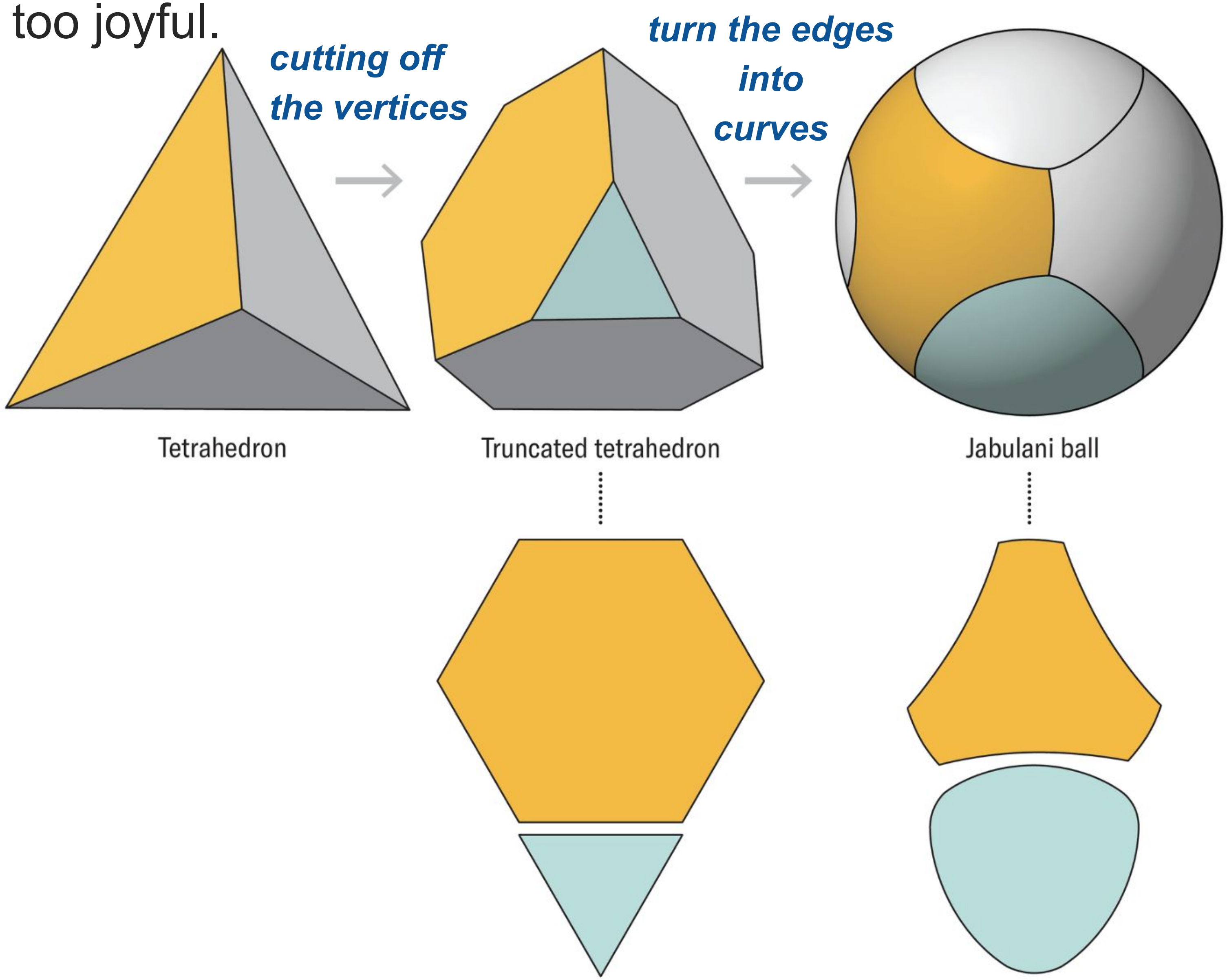


Brazuca ball 2014: a six-paneled ball based on a cube.



The Physics behind the Law of Football

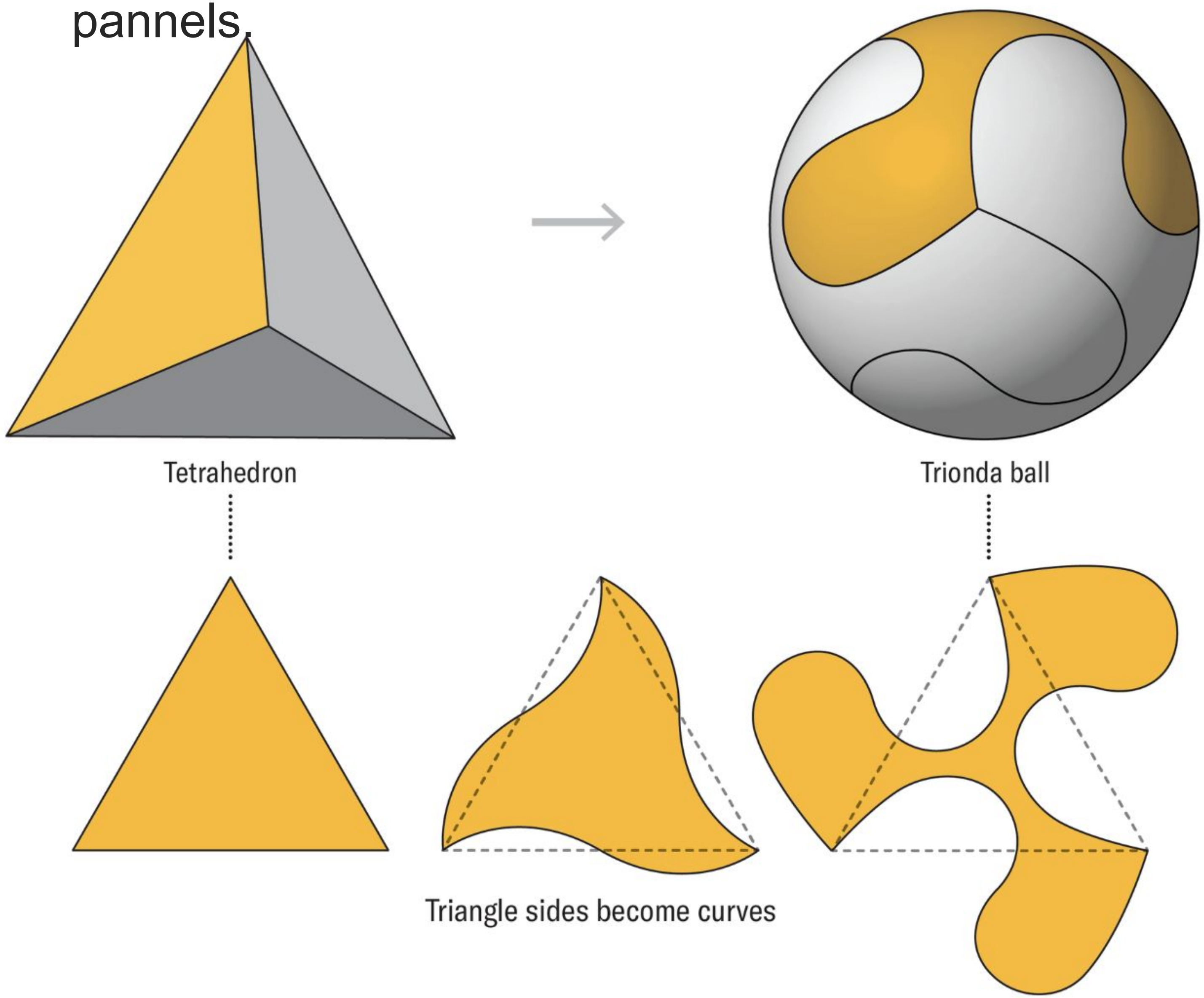
Jabulani ball 2010: whose name means “rejoice” in Zulu, might have been a bit too joyful.



Players complained it was unpredictable in the air and didn’t react the way they expected it to.

The Physics behind the Law of Football

The Trionda: The shape in the panels from extremely curving the edges of the pannels.



The rules for a football (soccer) ball are defined in Law 2:

- The ball must be spherical.
- Have a circumference between 68 and 70 cm.
- Weight between 410 and 450 grams at the start of the match.
- Pressure between 8.5 - 15.6 psi.
- It cannot bounce less than 50 cm or more than 65 cm on the first rebound when dropped from a height of 2 m.
- If a ball becomes defective during a match, play is stopped and it must be replaced.

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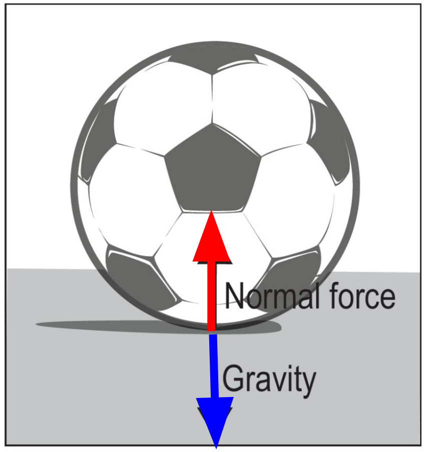
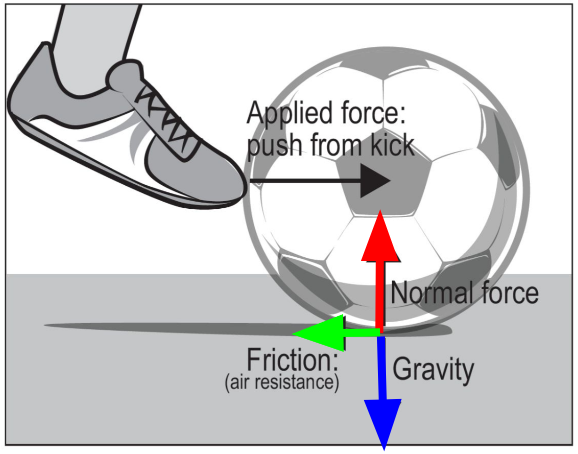
Newton's Laws of physics:

1st LAW : Inertia

An object at rest remains at rest, and an object in motion remains in motion at constant speed and in a straight line unless acted on by an unbalanced force. In terms of momentum, this means if the net force (F_{net}) is zero, then the momentum (p= m·v) is constant.



Forces acting on a soccer ball at rest



Forces acting on a soccer ball that is being kicked by a foot

2nd LAW : Force $F = m \cdot a$

The acceleration of an object depends on the mass of the object and the amount of force applied The rate of change of an object's momentum is directly proportional to the net force applied to it and in the same direction as the force.

$$F_{net} = \frac{\Delta p}{\Delta t}$$

3rd LAW : Action and Reaction

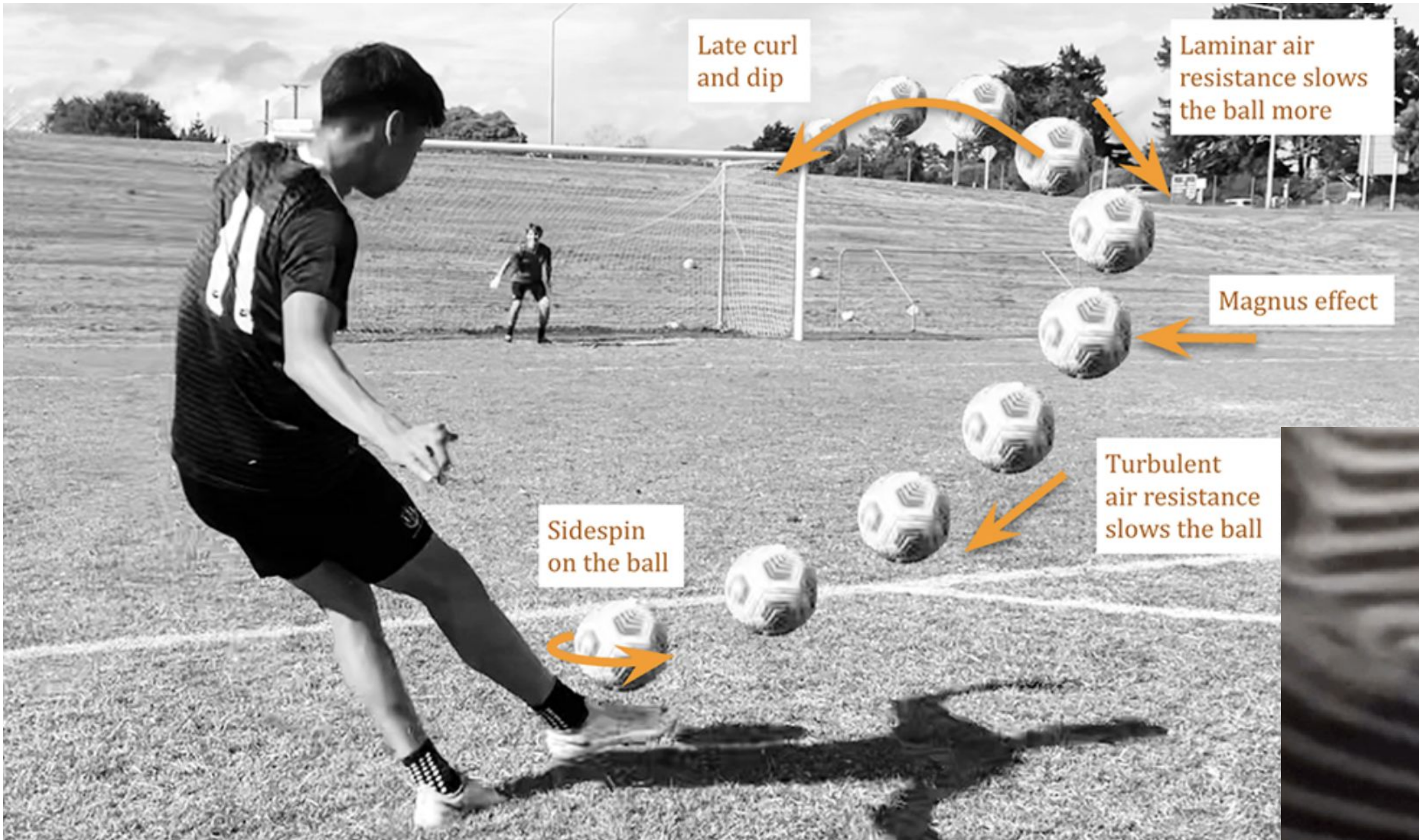
Whenever one object exerts a force on another object, the second object exerts an equal and opposite on the first.

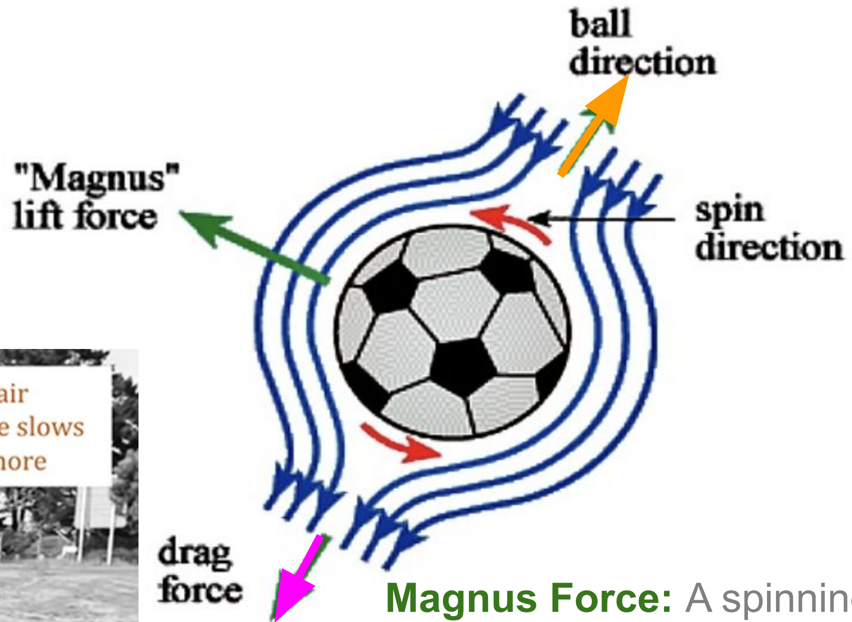
$$F_{12} = -F_{21}$$

The Physics behind the Law of Football

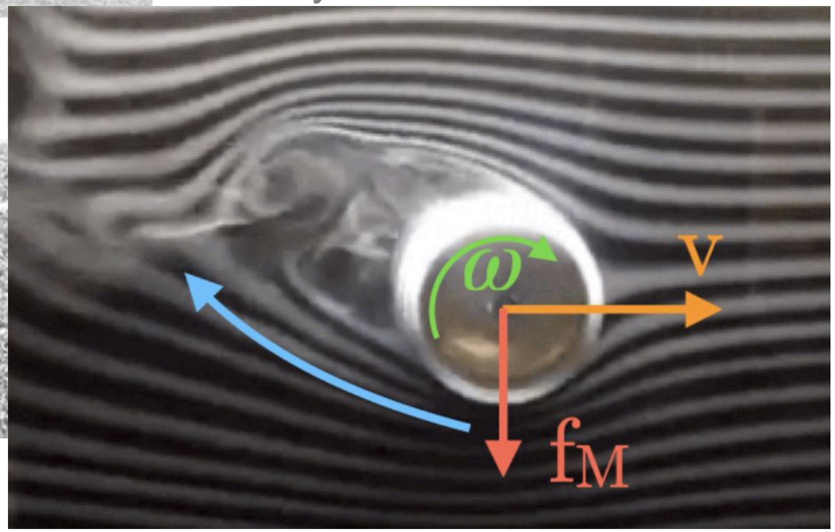
It's all in the physics …

Drag Force: Drag occurs when the soccer ball is kicked and it travels through the air pushing through while the air pushes back, thus slowing the soccer ball down according to aerodynamics. Drag is the reason that soccer ball doesn't travel in a perfect parabola.





Magnus Force: A spinning ball causes Magnus effect, which is responsible for curving the trajectory sideways.



The importance of texture and seams …

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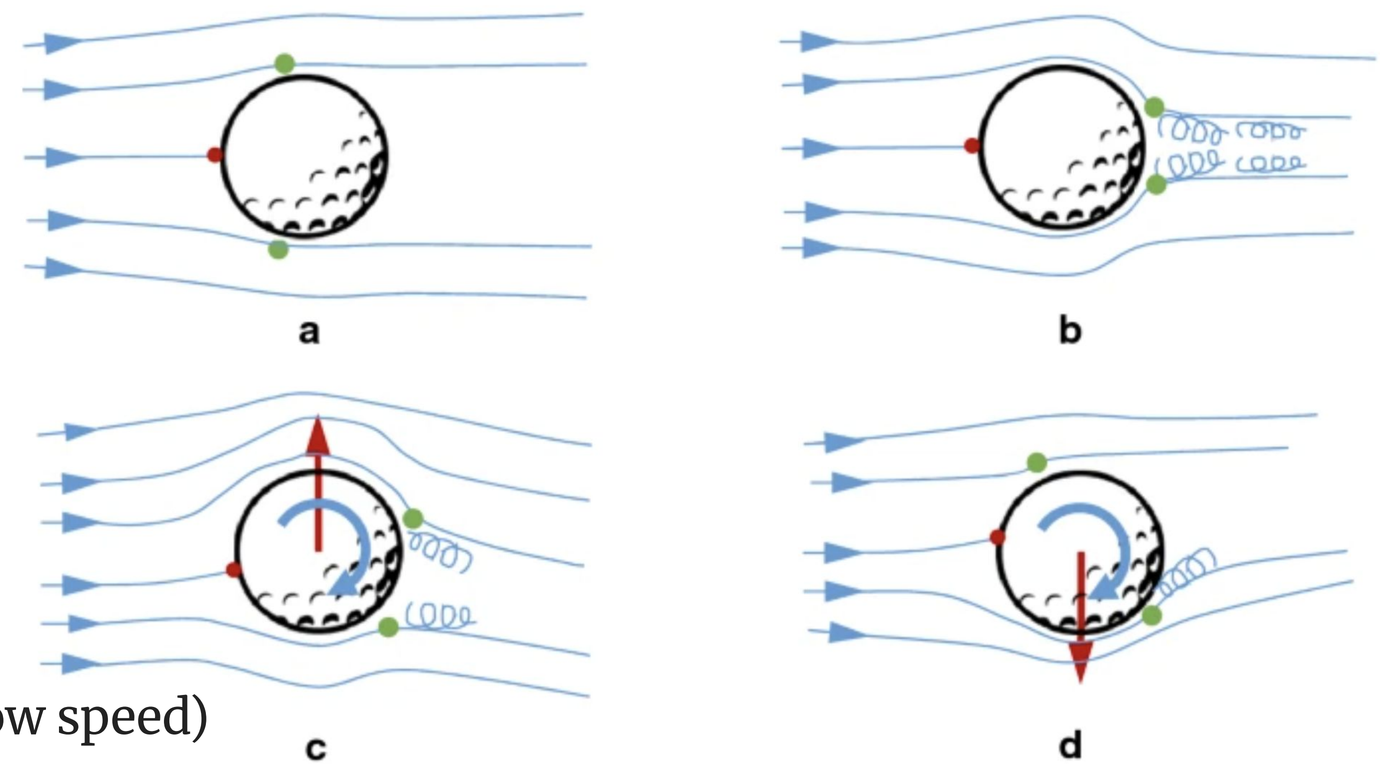


a Laminar boundary layer (slow speed)

b Turbulence boundary layer (high speed)

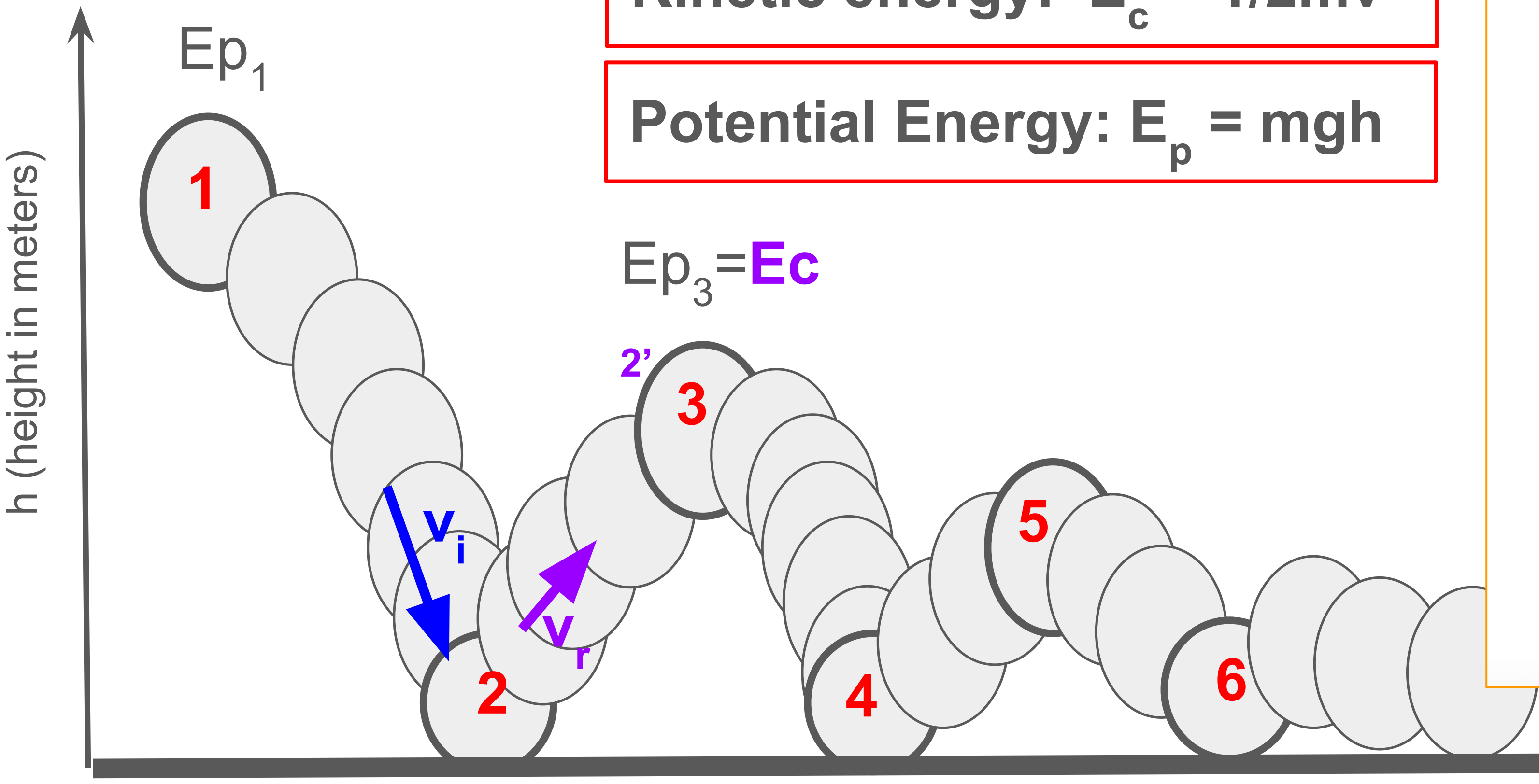
c Magnus effect (ball with rough surface or containing seams rotating → both sides generate turbulent air flow)

d Reverse Magnus effect (smooth surface ball rotating → one side the air flow is turbulent and the other side “glides” staying laminar)

Restitution coefficient (ε) = v_i / v_r is a measure of the elasticity and capacity of conservation of Mechanic energy of a bouncing ball. It is also important to control, so the ball's ***behavior is predictable***.

Kinetic energy: $E_c = 1/2mv^2$

Potential Energy: $E_p = mgh$



$Ec_2 = Ep_1$ $\quad$ $Ec_{2'} + Q_2$

$$\frac{Ep_3}{Ep_1} = \frac{Ec_r}{Ec_i}$$

$$\frac{m \cdot g \cdot h_3}{m \cdot g \cdot h_1} = \frac{1/2 \cdot m \cdot v_r^2}{1/2 \cdot m \cdot v_i^2}$$

$$\frac{h_1}{h_3} = \frac{v_r^2}{v_i^2}$$

$$\sqrt{\frac{h_1}{h_3}} = \frac{v_r}{v_i} = \varepsilon$$

Hasson, E. R. (2025, 25 de juliol). *The surprising math and physics behind the 2026 World Cup soccer ball: Here's how the new tetrahedron-based design for the "Trionda" soccer ball may affect next year's big game. Scientific American*. https://www.scientificamerican.com/article/the-surprising-math-and-physics-behind-the-2026-trionda-world-cup-soccer-ball/

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The answer has to do with “drag” —the force of air particles pushing back on the ball as it flies through space. Typically, the faster a ball moves, the more drag it experiences, which can slow it down and change its trajectory. But each ball also has a “critical speed” past which the drag on the ball decreases significantly. The smoother a ball is, the higher the critical speed barrier becomes. This is why the surfaces of golf balls have dimples: They lower the critical speed and help the balls move faster through the air. These effects mean that rounder and smoother isn’t always better—and may explain the Jabulani’s unpredictable behavior. The minimization of drag is likely why the Trionda ball has divots in its surface and offers another reason for its meandering seams. Ball designers use a combination of surface texture, seam length and seam depth to achieve just the right amount of “ roughness” so that players are comfortable with the ball when they step onto the field.

Ball designers use a combination of surface texture, seam length and seam depth to achieve just the right amount of “ roughness” so that players are comfortable with the ball when they step onto the field. While the amount of roughness is important, the placement of seams and surface texture can also affect a ball’s reliability in the air.

When a ball spins quickly through the air, the placement of ts rough elements matters less; the ball moves as if these features are evenly distributed. But if the ball is pitched or kicked in a way that minimizes spin, its rougher areas will feel different amounts of drag than smoother sides, causing it to move unpredictably.

Symmetry is one concern experts have about the Trionda ball; because it is based on a tetrahedron, it has fewer symmetries than, for example, the classic Telstar ball. Whereas the Telstar ball looks precisely the same in 60 possible positions, the Trionda ball only has 12 rotational symmetries.