

Peddalling equations

JUST AS IT TAKES A WHILE TO LEARN TO RIDE A BICYCLE, IT TOOK SCIENTISTS 120 YEARS to establish conclusively, with equations*, what gives a push bike its stability, says **Roger Highfield**

Since the bicycle's invention some time in the 1860s, mathematicians have tried to sum up bike riding with equations based on Newton's laws of motion.

One of the first attempts dates back to pioneering work in 1897 by French mathematician Emmanuel Carvallo. In 1899, the Cambridge undergraduate Francis Whipple had a go, using equations that had more general applicability (though were slightly wrong).

Recently, in the journal *Proceedings of the Royal Society*, a conclusive mathematical account of bike riding was described in a dense 28-page paper by Professor Andy Ruina of Cornell University, Jim Papadopoulos of Green Bay, Wisconsin, Jaap Meijaard of Nottingham University, and Prof Arend Schwab of Delft University of Technology, the Netherlands.

It was once thought that the stability is because the wheels act like gyroscopes to keep the bike upright.

But the secret is that there "is no one secret", says Prof Ruina. As many as 17 different parameters are crucial, from the radius and mass of the wheels to the position of the centre of the mass of the bicycle, to the angle of the steering axis.

"That is why it has taken 120 years to get it right. We have not found anything simpler," Prof Ruina, co-author of *Linearised dynamics equations for the balance and steer of a bicycle*, told *The Daily Telegraph*.

The team showed that Carvallo and Whipple were on the right track, though the credit for cracking the problem goes to German engineer E.

Dohring, who published his meticulous study in 1955.

This recent "definitive review" underlines bicycles' amazing ability to balance themselves. "You can give a bike a push and it will go 50 metres without falling. Even if it is knocked sideways, it will pop up again," says Prof Ruina.

As for how people are able to ride and steer a bike, "that is a much more subtle question," he admits. Prof Schwab is now working on incorporating the effects of the rider on the bike.

Chris Boardman, the Olympic gold-medal winning cyclist, who was in London recently to promote Tour de France, said he was surprised to learn it took so long to mathematically describe cycling.

"The scientists can come back to me if they come up with a formula for how not to fall off, but perhaps that will take another 100 years."

*Eg, cycling: $Mq+vClq+[gKo+v2K2]q=f$ (the mathematical way to ride a bike). **E**

- *The Daily Telegraph*

