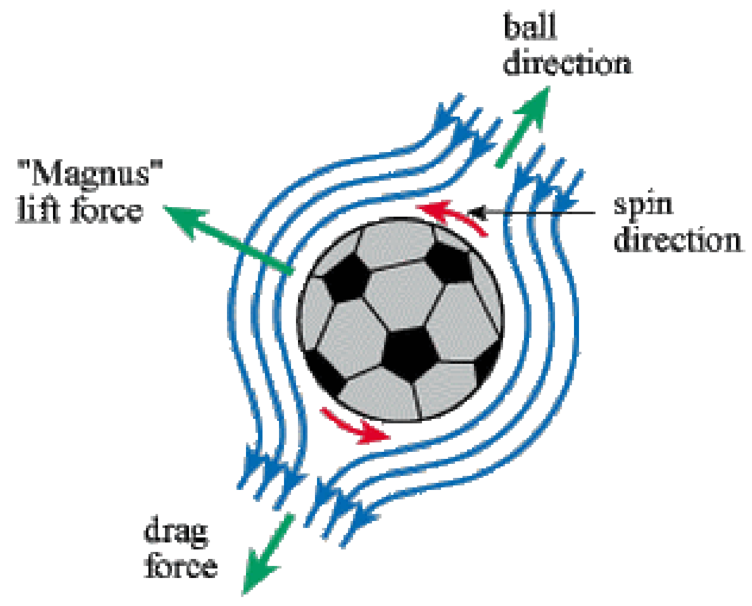
Magnus Effect

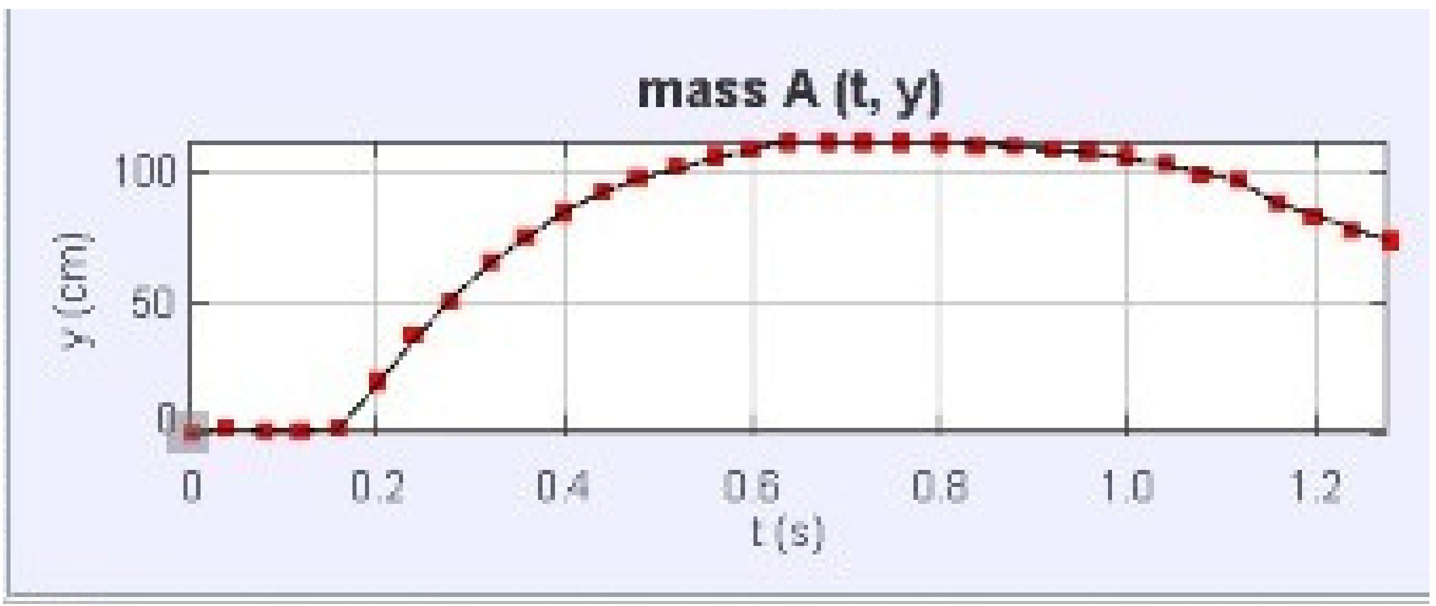
THE PHYSICS OF FOOTBALL

In 1997, Brazilian defender Roberto Carlos scored an astounding free kick against France. The shot was taken 35 meters from goal, and the ball followed a curved trajectory so magnificent that it seemed impossible, compelling physicists to study it. extensively. And it turns out that a phenomenon called the Magnus effect was at work.

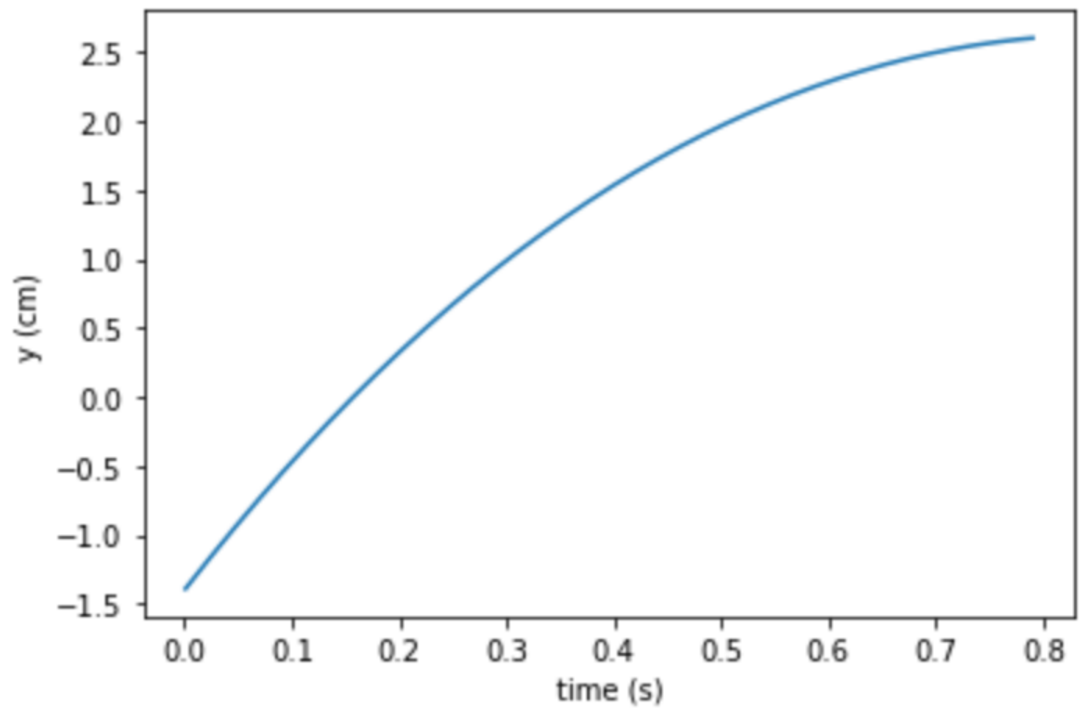
The Magnus Effect is a physical phenomenon whereby a spinning object creates a low-pressure zone on one side and a high-pressure zone on the other. In this case, the spin of the ball did the trick. The ball started on a straight trajectory, with air resistance on both sides slowing its movement. On one side, the airflow opposed the spin of the ball, reducing the air velocity and creating a high-pressure zone while on the other side, the airflow was in the same direction as the spin, increasing the air velocity and leading to a region of low pressure.
This difference in air pressure caused the ball to swerve towards the low-pressure zone towards the end of its path.



$$\vec{F}_{\text{Magnus}} = s\left(\vec{\omega} \times \vec{v}\right)$$



Tracker Data Analysis



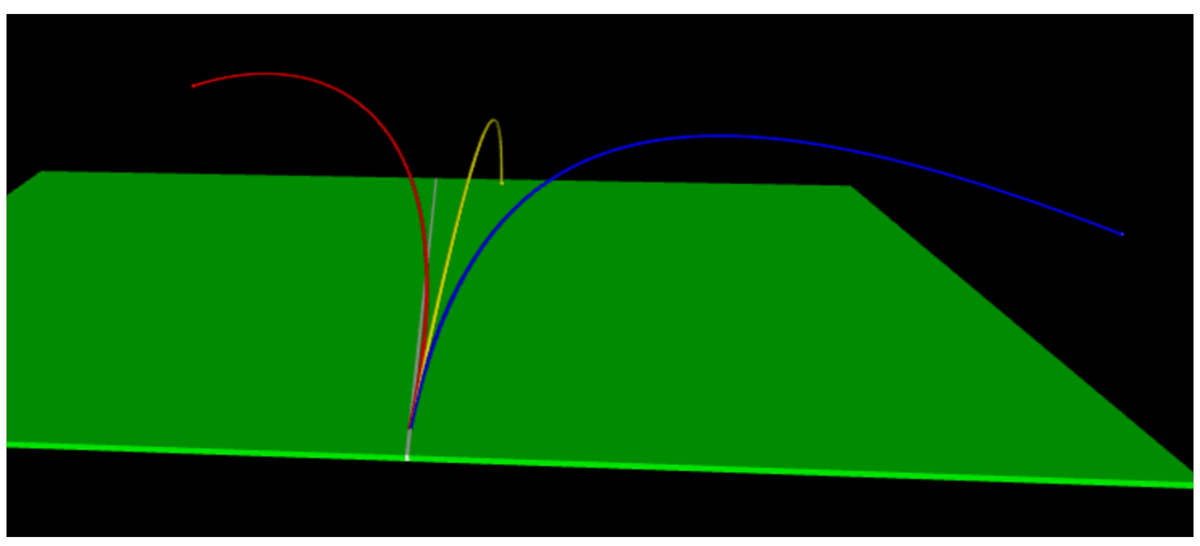
Python Simulation. Analysis

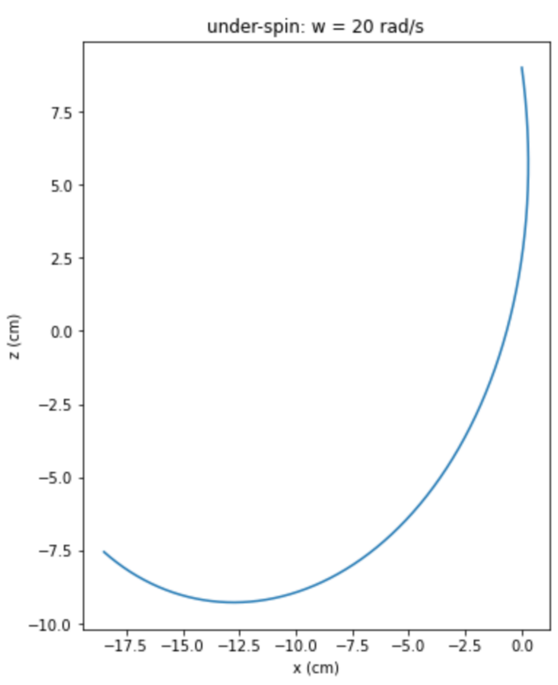
We used Tracker to analyse a free kick and then simulated the effect of the magnus force under identical conditions using Python.

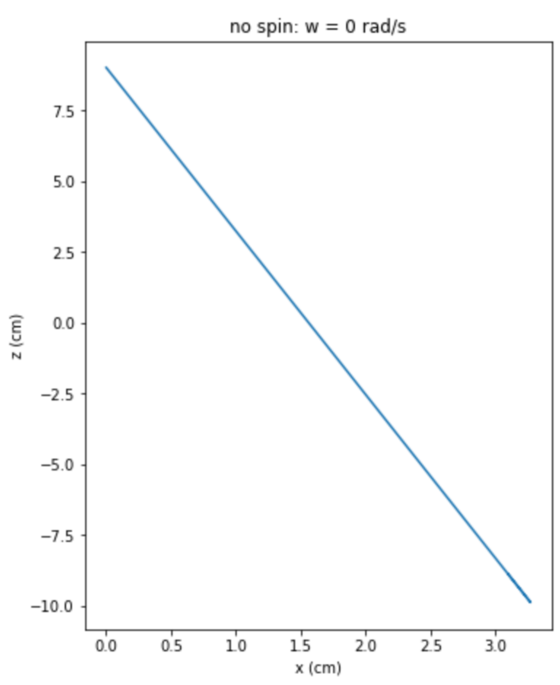
```
ball.v=ball.p/ball.m #calculate the velocity
F=ball.m*g-.5*rho*A*C*norm(ball.v)*mag(ball.v)**2+s*cross(ball.omega,ball.v) #calculate the force
ball.p=ball.p+F*dt #update the momentum
ball.pos=ball.pos+ball.p*dt/ball.m #update the position
t=t+dt #update the time
```

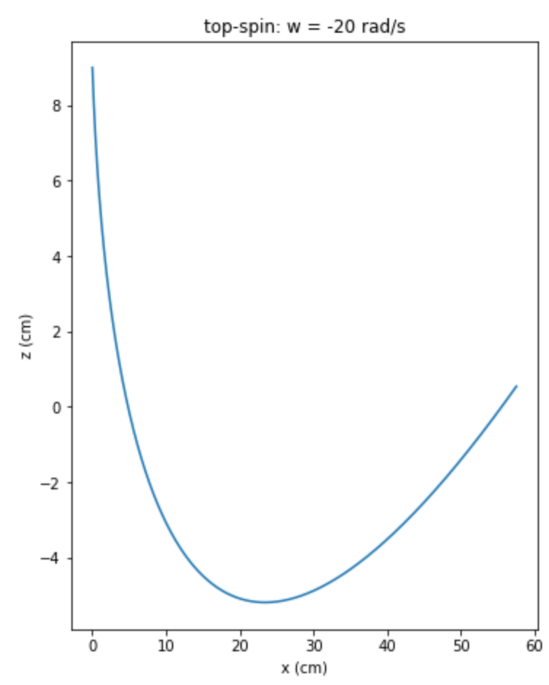
A snippet of the simulation code

We also simulated how the trajectories of the football would change if angular velocity was positive, zero and negative.









References: Sarafian, H., 2015. Impact of the Drag Force and the Magnus Effect on the Trajectory of a Baseball. World Journal of Mechanics, 05(04), pp.49-58.

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