PHYSICS OF A SOCCER BALL TRAJECTORY

by Emily Erdman and Madelaine Holden

Although physics may seem esoteric at times, concepts are easily applied to everyday activities ranging from the reflection of light through a glass of water to the sound of an ambulance as it is coming towards you. One such activity, soccer, provides ample material for a physics-minded analysis. An important part of soccer is obviously the kicking of the soccer ball, and the consequent kinetic energy that results. This kinetic energy trades off with potential energy as the ball flies through the air, also checked by factors such as air resistance.

The path of the kicked soccer-ball follows a curved trajectory, as Tartaglia and Galileo found in the 16th and 17th centuries. But how is the ball itself pushed into this path? It is all based on energy, both potential and kinetic. As the player's foot accelerates into the ball, two laws come into effect: The conservation of energy and the conservation of angular momentum. If no energy was let off, the speed of the ball would be exactly twice that of the foot (due to the "bouncing" effect of the kick). The ball is struck as close to the leg's maximum velocity as possible – so really, the ball "bounces" off of the moving foot for a finite distance. The momentum of the foot goes into the ball, giving the ball a velocity as found by the equation below:

$$v_{ball} = v_0 \frac{1+e}{1+(m\ell^2/I)}$$

The ball has constant horizontal velocity and constant vertical acceleration. The horizontal velocity is 9.3 m/s, while the vertical acceleration is always the acceleration of gravity, around 9.8 m/s^2. The horizontal velocity was found by finding the average slope of the position vs. time graph of the ball's flight. A video clip of a soccer ball being kicked was the data used to create graphs and demonstrate the trajectory of a soccer ball.

EQUATIONS

Kinetic Energy – Energy of moving objects; it depends on an object's mass and velocity

$KE = 1/2\ mv^2$

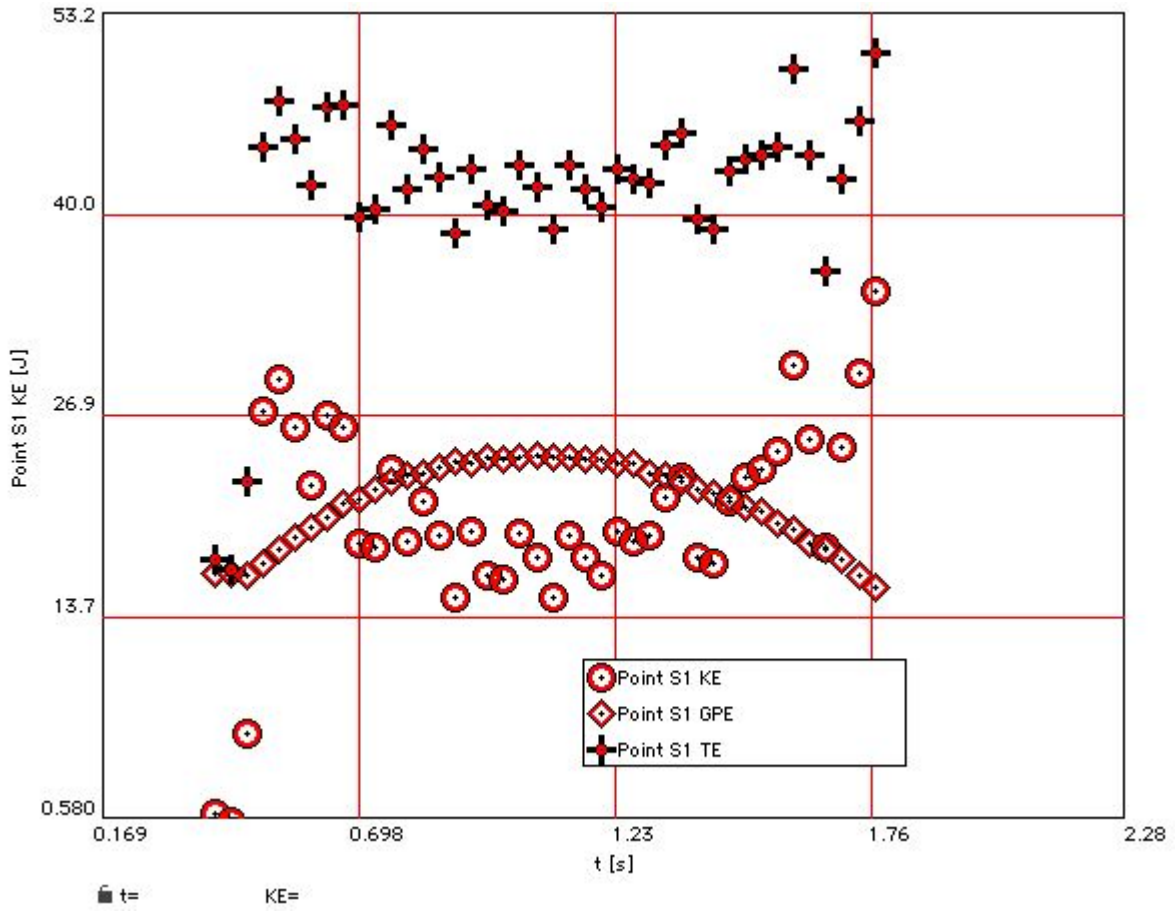
m = mass; v = velocity

Potential Energy – Energy stored in an object; depends on an object's position above Earth's surface
PE = mgh
m = mass; g = gravity; h = height

The Potential Energy at the top of the trajectory = Kinetic Energy at the bottom.
$1/2\ mv^2 = mgh$

The total energy of the system equals Kinetic + Potential.

Work – Transfer of energy through mechanical means; the term used to describe energy changes from Kinetic to Potential
Work = KE
When Work is negative, the KE decreases (i.e., the upward path of the soccer ball).
When Work is positive, the KE increases (i.e., the downward path of the soccer ball).



This graph represents the potential and kinetic energy vs time of a soccer ball during flight. The squares symbolize the potential energy, while the circles symbolize the kinetic energy. The plus signs symbolize the two energies added together.

The two shapes of the energies appear in different directions because potential energy is based on the stored energy and kinetic energy is based on the motions energy. They sort of 'trade off', as one increases, the other decreases. And when added, they should form a straight horizontal line.