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A2_1 Association Football on Mars

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Abstract
We assess the difficulties related to the game of association football when played on Mars. It is found that the different conditions would alter the game, but it would be possible to retain the game in a familiar but slightly changed form.

Introduction
Throughout history mankind has played sporting games for character building, training and simply for pleasure. It has also been argued that sport plays a part in oiling the social structures of humanity. Association football, hereafter simply referred to as football, is the world's largest sport by television viewers [1]. Therefore, if mankind's goal is to leave planet Earth, how will 'the beautiful game' be affected by the differing physics involved in these situations? This paper looks primarily at Mars, but the same techniques could be applied to a range of situations. Mars was chosen for its similarities with Earth as well as its differences. No doubt new sports may well replace or evolve from old sports, but with football being such a globally recognised activity it seems reasonable to assess what difficulties would be encountered in the Martian environment.

Martian Conditions
It is necessary to first assess the conditions found on Mars that may affect football. It is possible to separate the problem in to two separate halves; the first half consisting of difficulties arising due to physics of the game; the other arising due to the limitations of the human body. These difficulties can overlap and it is prudent to concentrate on those affecting the physics of the game and its essential differences from the game played on Earth. The mass of Mars is $6.4191 \times 10^{23} kg$ [2] which leads to a value of an acceleration due to gravity, g, at the surface of 3.711ms^{-2}. This is a substantial difference for a sport heavily based on the trajectory of spherical masses. An additional factor to consider when discussing ball trajectory is the temperature and pressure which can work together to create a different environment for the ball's flight. The surface temperature of Mars ranges from between -186K to 293K with the mean temperature being 210K [2]. The surface pressure on Mars is approximately 0.636kPa [2], significantly less than that of Earth. The most significant impact this will have is upon ball drag during trajectory.
An arising concern would also be the quality of light available to play the game. On Earth the daylight levels are typically on the order of 10000 lux [3] on an average day. On Mars these levels are approximately halved. This light is diffuse rather than direct. The English Football Association recommend at least 500 lux direct lighting [4]. This means that on a normal Martian day adequate light levels would be available, although floodlighting might be recommended. However during a Martian dust storm the light levels can be reduced to about 50 lux [5]. The dust storm itself may raise other issues such as a fog effect, although Martian dust storms are dissimilar to Earth storms and generate no winds as such. If adequate lighting were provided, such a storm should be no more of a problem to the game itself than a thunderstorm on Earth which would rarely result in a match being suspended.

Ball Trajectories
The largest impact on the physics of football may be the differing trajectories of the ball under lower gravity and pressure conditions. A term for drag is included for comparison between Earth and Mars and is shown below, although on Mars the drag term is minimal.

$$F_D = \frac{\rho C_D A \mathbf{v}^2}{2} \qquad (1)$$

where ρ is the density of the atmosphere, C_D is the drag coefficient, A is the area projected to the direction of travel and v is the velocity of the ball [6]. In turn we know the acceleration experienced during flight of a ball subjected to a force, or being kicked. In the x and y directions respectively this is,

$$a_x = -\frac{F_{D_x}}{m} \qquad a_y = -g - \frac{F_{D_y}}{m} \qquad (2)$$

where a_x is the acceleration in the$x$ direction, F_{D_x} is the drag force in the x direction, m is the mass of the ball and similarly for y [6]. Due to F_D being dependent on v^2 it is difficult to solve this problem exactly and we turn to numerical methods. Using the expressions for the accelerations and Newton's equations it is possible to estimate the velocity at a moment within a short time interval.

$$v_x + \Delta v_x = v_x + a_x \Delta t \qquad v_y + \Delta v_y = v_y + a_y \Delta t \quad (3)$$

where v_x is x-component of velocity, Δv_x is the change in the x-component of velocity, Δt is the short time interval and similarly for the y-components [6]. From this estimate we can also estimate the change in the distance in the x and y components of distance and it is then natural to complete the calculation by adding the distance calculated during the time period to the distance calculated in the previous time interval in an iterative process.

$$x + \Delta x = x + v_x \Delta t + \frac{1}{2} a_x (\Delta t)^2 \quad (4)$$

$$y + \Delta y = y + v_y \Delta t + \frac{1}{2} a_y (\Delta t)^2 \quad (5)$$

Having this knowledge it is then trivial to produce an estimate for both Earth and Mars by altering the starting conditions and using this numerical solution to observe the difference between the two trajectories. One such estimate is seen in Fig. 1 where a ball was kicked at a 30 degree angle at 30ms^{-1}. As can be seen the Earth ball quickly descends while the Martian ball goes high and further with reduced gravity and lack of air resistance. This roughly factor of four increase in the distance raises important issues about the game that would have to be address to retain the game in a form at least similar to that played on Earth.

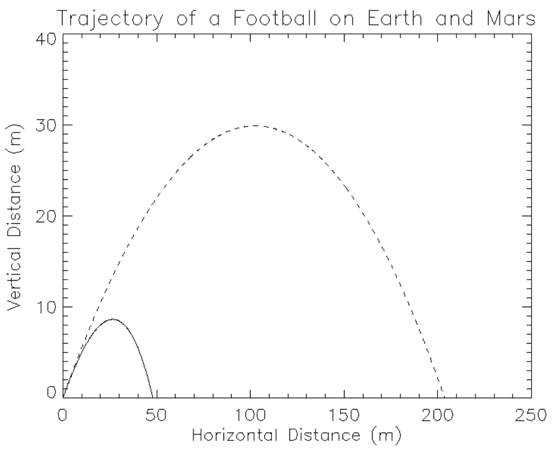

Fig. 1: A plot of height vs. distance for footballs kicked on Earth (solid line) and Mars (dashed line). A = 0.0375m^2 , $C_D = 0.25$, $m = 0.424$, ρ_{Earth} =1.2kg m^3 , ρ_{Mars} =0.02m^3

The lack of air resistance also is of concern to the Magnus force that arises due to balls that are in spin [7]. Spinning balls were not modeled in the simulation above, however the Magnus force can play a large part in the nature of the game, particularly in reference to so-called 'bending' of the ball by adding spin. The reputation of some football players arises purely due to their expertise at utilising the Magnus force to their and their team's benefit. However, with little air resistance to be encountered on Mars, the Magnus force is not manifested and the skill involved would not be necessary.

Discussion

To resolve the issue of larger trajectories a number of solutions are presented. Firstly, the players simply have to reduce the force which they apply to the ball or that it is made much more difficult to apply force to the ball. A criticism of this is that it may reduce the speed of the game but would resemble football as it is known on Earth. Another solution is to increase the size of the pitch to accommodate such large distances, while movement speed across the surface should be quicker, this may in itself slow the game down and would certainly make it a difficult sport to spectate. Either solution would undoubtedly require different athletic skills and whether Earth footballing skills are transferable to Mars is an interesting question. While the trajectory problem is solvable, the inability to 'bend' the ball due to a lack of air resistance would seem to decrease the skill involved in football. All problems, apart from the trajectory of the ball due to decreased gravity, could be solved by playing the game in a habitat arena, however one of the largest draws to the game of football is its ability to be played anywhere.

Conclusion

The difficulties faced in considering the physics of football on the Martian surface seem to be resolvable albeit leaving football in a different but still familiar form. Football should be able to make the transition to Mars relatively easily.

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