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This article is from the In-Depth Report The Science of Pro Football

How Should You Launch a Ball to Achieve the Greatest Distance?

Physics gives a precise answer, at least in an ideal setting

November 9, 2010 |By The Editors

In the Projectile Motion episode of NBC Learn's "The Science of NFL Football," you see that punted footballs travel in an arc known to mathematicians as a parabola.

In any football game both teams square off against each other and against a shared opponent as well—gravity. Earth's gravitational pull makes long-range passing a challenge and pulls down even the hardest-struck punts and placekicks.

Because gravity is a constant, experienced quarterbacks and kickers can account for its effects to move the ball downfield as efficiently as possible. Like all projectiles, a football, once released, follows a path known in mathematical terms as a parabola—a symmetric arc that eventually returns the ball back to the ground. (In real life a projectile's flight is affected not only by gravity but by wind and drag from air resistance, so the parabola would not be perfect.)

Parabolas have been studied for millennia, and their properties are well understood. For any projectile under gravity's influence, the distance attained during its flight is equal to $\sin(2\theta)$ X v^2/g, where v is the projectile's initial speed, g is the acceleration toward Earth due to gravity and θ is the angle at which the projectile is launched.

That may look like a complicated equation, but a couple of the variables can be ignored. First, because the force of gravity is constant, g will be the same no matter how a punter kicks the ball. Second, for a punter trying to boot a ball as far as possible, you can assume that he is kicking as hard as he physically can, so v depends simply on how hard he can kick, not on any strategic decision for a given punt.

The only choice he has to make to maximize distance, then, is the angle at which he kicks the ball. You can see from the equation above that the distance traveled by the ball will be greatest when sin(2θ) is greatest. The sine function reaches its largest output value, 1, with an input angle of 90 degrees, so we can see that for the longest-range punts 2θ = 90 degrees and, therefore, θ = 45 degrees. A projectile, in other words, travels the farthest when it is launched at an angle of 45 degrees.

But what about trying to maximize a projectile's height to increase hang time? In a parabola the peak height attained by a projectile is equal to $(\sin(\theta))^2 \times v^2/2g$. Once again, we can ignore v and g, for the same reasons as above. (Anyone looking to loft a projectile as high as possible would simply launch it as fast as possible, and gravity is constant.)

So to send a projectile flying as high as it can go, you can see that you want to make $(\sin(\theta))^2$ as large as possible, which simply means making sin(θ) as large as possible. As mentioned above, the sine function reaches its biggest output value, 1, with an input angle of 90 degrees, so we can see that for a sky-high punt θ = 90. That means that the best way to launch a high-altitude projectile is to send it flying at a 90-degree angle to the ground—straight up.

Of course, a vertical punt doesn't help much with field position, so you're not likely to see a 90-degree punt on the football field anytime soon. Not on purpose, anyway.

The Editors. (2010). *How should you launch a ball to achieve the greatest distance?* Retrieved from http://www.scientificamerican.com/article/football-projectile-motion/?print=true

How Should You Launch a Ball to Achieve the Greatest Distance?

Text Dependent Questions

1. What effect does gravitational pull have on passes?

2. In line 8, the author refers to gravity as a constant. What does he mean by this statement?

3. What is a parabola?

4. Explain why parabola's of a football flight would not be perfect?

5. How can a punter ensure the football travels a large distance?

6. What affect does a punter's kick have on gravity?

7. Describe what a punter should do in order to increase hang time of the football?

8. Based on the information of the text, illustrate the path of a kick. Use terminology of the text to label your motion diagram.