

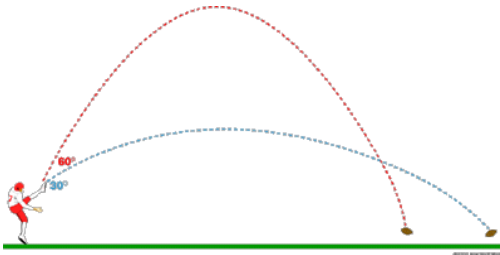
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How the Physics of Football Works

BY CRAIG FREUDENRICH, PH.D.

Throwing the Football



The angle of a kick helps determine how far it will travel.

When the football travels through the air, it always follows a curved, or **parabolic**, path because the movement of the ball in the vertical direction is influenced by the force of gravity. As the ball travels up, gravity slows it down until it stops briefly at its peak height; the ball then comes down, and gravity accelerates it until it hits the ground. This is the path of any object that is launched or thrown (football, arrow, ballistic missile) and is called **projectile motion**. To learn about projectile motion as it applies to football, let's examine a punt (Figure 1). When a punter kicks a football, he can control three factors:

- The velocity or speed at which the ball leaves his foot
- The angle of the kick
- The rotation of the football

The rotation of the ball -- spiral or end-over-end -- will influence how the ball slows down in flight, because the ball is affected by air drag. A spiraling kick will have less air drag, will not slow down as much and will be able to stay in the air longer and go farther than an end-over-end kick. The velocity of the ball and the angle of the kick are the major factors that determine:

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How long the ball will remain in the air (hang-time)

- How high the ball will go
- How far the ball will go

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When the ball leaves the punter's foot, it is moving with a given **velocity** (speed plus angle of direction) depending upon the **force** with which he kicks the ball. The ball moves in two directions, horizontally and vertically. Because the ball was launched at an angle, the velocity is divided into two pieces: a horizontal component and a vertical component. How fast the ball goes in the horizontal direction and how fast the ball goes in the vertical direction depend upon the angle of the kick. If the ball is kicked at a steep angle, then it will have more velocity in the vertical direction than in the horizontal direction -- the ball will go high, have a long hang-time, but travel a short distance. But if the ball is kicked at a shallow angle, it will have more velocity in the horizontal direction than in the vertical direction -- the ball will not go very high, will have a short hang-time, but will travel a far distance. The punter must decide on the best angle in view of his field position. These same factors influence a pass or field goal. However, a field goal kicker has a more difficult job because the ball often reaches its peak height before it reaches the uprights.

If you are not interested in the details of calculating the hang-time, peak height and range of a punt, [click here](#) to skip the following page.

TALKING PHYSICS

- **Acceleration** - Rate of change of velocity with respect to time (calculated by subtracting the starting velocity from the final velocity and dividing the difference by the time required to reach that final velocity)
- **Force** - influence on a body that causes it to change speed or direction
- **Velocity** - Speed and direction that an object travels (distance traveled divided by the elapsed amount of time)
- **Speed** - How quickly an object moves (distance traveled divided by the elapsed amount of time)

FOOTBALL BY THE NUMBERS

Since physics is a quantitative science, developing some units and measures is a good way to begin to understand the effects of physics on football. Consider these useful numbers and units developed by Dr. David Haase of [North Carolina State University](#):

- **Player at full speed** - ~22 miles per hour (9.8 m/s)
- **Linebacker** - ~220 pounds (98 kg)
- **Offensive lineman** - ~300 pounds (133 kg)



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