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## Overview

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Did you know that when Victor Cruz catches a game winning touchdown, the prolate spheroid he's holding helped the quarterback to throw a perfect spiral? Wait, what? Well, the shape of a football is a prolate spheroid, and its gyroscopic effect reduces drag and helps the ball reach its intended receiver.

This is just one example of how football and science are connected through physics—the branch of science that deals with the physical world. You can learn all about prolate spheroids and many more fun football-to-science connections when you play the games included here.

To get started, print out a copy of the **Football Science Playbook** for each person who wants to play. The Playbook highlights key information about each science principle, as well as the football positions and actions that might utilize each principle. Keep the Playbook with you for easy reference as you play each game.

If you're ready to tackle the physics of football, challenge your family to a game of **Football Bingo, Flag Football** or **Football Concentration** and learn as you play!



**FOOTBALL SCIENCE PLAYBOOK**

Refer to the diagrams and principles here to play the games included in this guide.

Diagram	Offensive Action	Scientific Principle
	throwing a pass	<p><b>VECTORS</b></p> <p>A vector is a quantity with both magnitude and direction. Why does a <b>quarterback</b> need to understand vectors? In order to <b>make precise passes</b>, the quarterback (or any passer) needs to calculate where to throw the ball (direction), as well as how hard to throw the ball (magnitude). In other words, the passer needs to figure out the correct vector so that the ball connects with the receiver. The tricky part is that the receiver is also moving at a certain speed (magnitude) in a certain direction, creating his own vector.</p>
	throwing, kicking	<p><b>PROLATE SPHEROID</b></p> <p>A prolate spheroid is a 2D shape also called an ellipse. A football is a prolate spheroid.</p> <p>How does the shape of the football help <b>quarterbacks</b> and <b>kickers</b>? The shape of the football lets players put a spin or spiral on the ball when they throw it or kick it. This spin, or “gyroscopic effect”, reduces drag and helps to keep the ball on its intended path. The <b>ability to throw or kick a tight spiral</b> comes from the shape of the ball, and the fact that it will spin on its axis.</p>
	punting	<p><b>PROJECTILE MOTION</b></p> <p>Projectile Motion is the path a moving object follows through space over time. When a football (the object) is punted, it travels through the air following a path. Gravity slows the ball as it travels vertically to its peak and gravity accelerates its descent, until it hits the ground.</p> <p>How does a <b>punter</b> use projectile motion to help his team on a fourth down punt? The punter can control the angle of the kick, the rotation of the ball, and the speed the ball leaves his foot. These factors allow the punter to control the path or projectile motion of the ball. This allows the punter to <b>control how high, how far</b> and thereby <b>how much time the ball hangs in the air</b>. This allows his teammates to get downfield before the ball is caught by the opposing team. This makes it difficult for their opponents to catch and run the ball.</p>

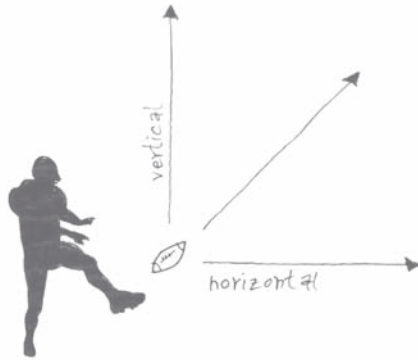
## FOOTBALL SCIENCE PLAYBOOK

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### Diagram

### Offensive Action

### Scientific Principle

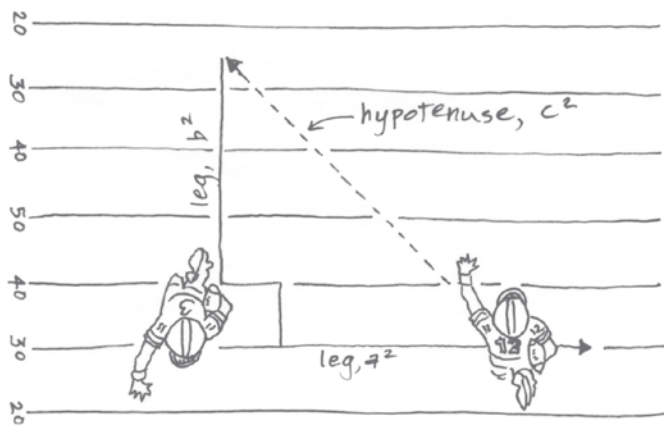


kicking

### NEWTON'S SECOND LAW OF MOTION

Newton's Second Law of Motion states that a force applied to an object, like a football, produces a proportional acceleration. In other words, if an object is accelerating, then there is a force on it.

How does Newton's Second Law help a **kicker** kick a field goal? An object with a mass will not accelerate unless it has a force applied to it. In kicking a field goal, **the force applied to the mass of a football is the kicker's foot.**

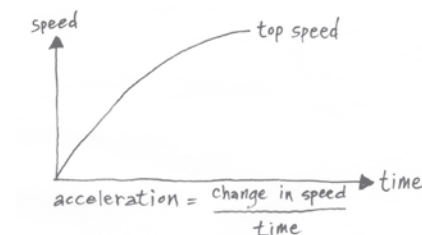


catching,  
running

### PYTHAGOREAN THEOREM

The pythagorean theorem is a relation, in geometry, among the three sides of a right triangle. In any right-angled triangle, the two sides or legs meet to create the right angle. The longer side, opposite the right angle, is called the hypotenuse. In a right-angled triangle: the square of the hypotenuse is equal to the sum of the squares of the other two sides.

Why might a **wide receiver** think about the pythagorean theorem when they want to avoid being tackled? When a wide receiver is about to catch a ball, he must think about his path to the goal line as well as the position of the defender who will try to stop him. In this example, the receiver can think of his path to the goal line and his path to the defender as the sides or legs of a right triangle. He also knows that the defender will be calculating his own "angle of pursuit", the angle he must run to catch the wide receiver. In this case **the longest leg of the triangle or the hypotenuse is also the defender's angle of pursuit.**



running

### KINEMATICS

Kinematics describes the motion of objects.

How does kinematics allow **running backs** to run faster than defenders? The kinematic concepts of **position, velocity and acceleration** can be used to describe how a running back moves. Running backs who understand how fast speed is changing and how to reach their top speed quickly will discover they can beat faster opponents and achieve **great speed to elude tacklers.**



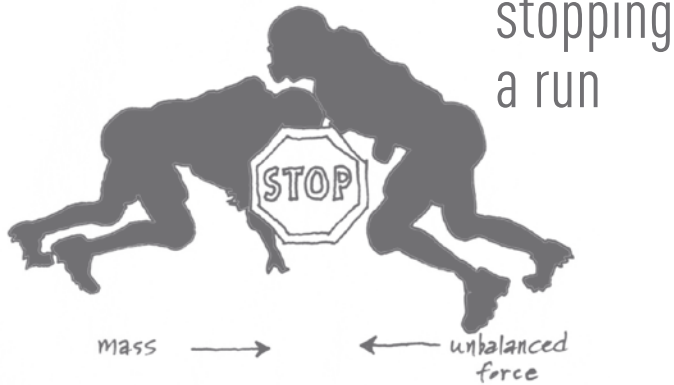
## FOOTBALL SCIENCE PLAYBOOK

Refer to the diagrams and principles here to play the games included in this guide.

### Diagram

### Defensive Action

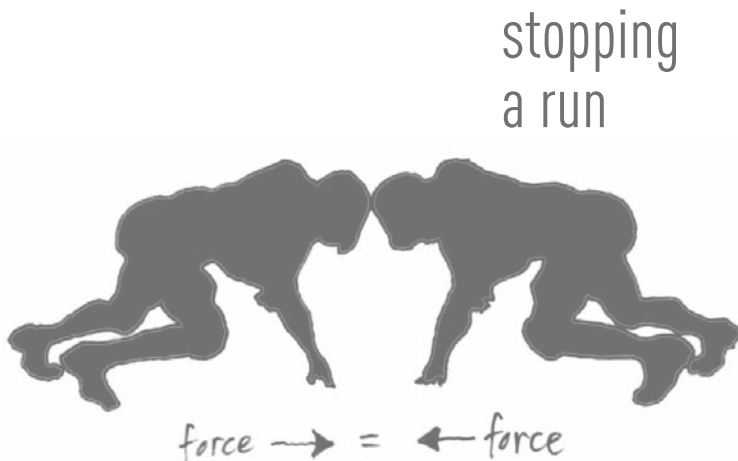
### Scientific Principle



### NEWTON'S FIRST LAW OF MOTION

Newton's First Law of Motion states that a mass, whether it is at rest or in motion, will want to continue to do what it is already doing, ie. rest or move, unless it is acted on by an unbalanced force.

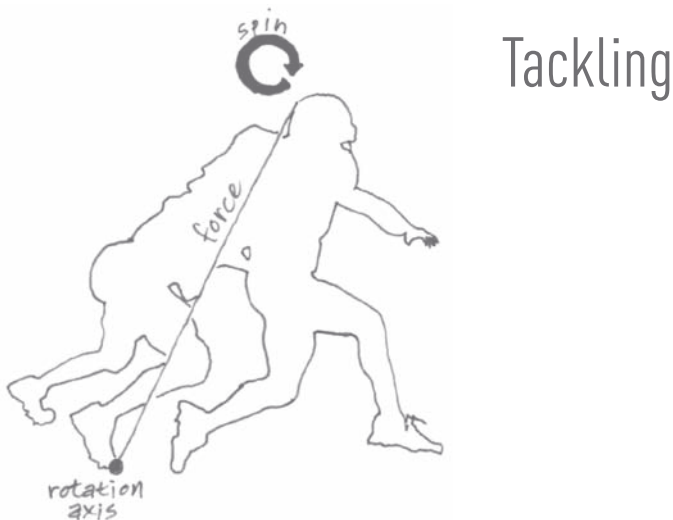
How does a **linebacker** use Newton's First Law to stop a runner? If a runner (the mass) is in motion, the mass will want to remain in motion unless an **unbalanced force** acts on it. An unbalanced force, such as a linebacker, must act on a runner to stop him.



### NEWTON'S THIRD LAW OF MOTION

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. So, if object A exerts a force on object B, object B will exert an equal and opposite force on object A.

Using Newton's Third Law of Motion, if a **safety** tackled a wide receiver, what reaction would you expect to see? When a safety (object A) exerts a force on a wide receiver (object B) to tackle him, the wide receiver (object B) will exert an equal and opposite reaction on the safety (object A). In the course of the tackle, **the players will exert an equal and opposite reaction on one another.**



### TORQUE

A torque causes another object to turn or rotate. Force must be applied to an object to create torque. Where the force is applied to the object determines whether or not there is torque, whether you can make the object spin.

How does torque allow a **defensive tackle** to make a tackle? Torque causes a player to spin. If you hit the player head on, there is no torque. **If the player is hit from the side, there is torque.** The player who stays the lowest will win the battle. If you can't get to the center of the mass, you can't make them spin.



## FOOTBALL SCIENCE PLAYBOOK

Refer to the diagrams and principles here to play the games included in this guide.

Diagram	Defensive Action	Scientific Principle
	<h3>Tackling</h3>	<h3>KINETIC ENERGY</h3> <p>Kinetic energy is the energy that refers to moving objects. A football or football player in motion are examples of objects that have kinetic energy.</p> <p>Can kinetic energy help a <b>linebacker</b> make a tackle? An object (linebacker) that is moving has kinetic energy and thereby the ability to do work (make a tackle). <b>Once the linebacker has kinetic energy he can apply force to an opposing player</b> over some distance. Momentum and kinetic energy are both produced during a tackle.</p>
	<h3>Stopping a QB sneak</h3>	<h3>INERTIA</h3> <p>Inertia is a part of Newton's First Law of Motion. It explains a mass's resistance to changes in its motion. Objects that have greater mass, have greater inertia.</p> <p>How does a <b>defensive tackle</b> use inertia to prevent a quarterback sneak? The quarterback sneak is a play that pits the interior offensive line against the interior defensive line. Both offense and defense hope that their line of players will create a massive wall, resistant to being moved. If the defensive tackles have the greater mass, they will be more difficult to move when they are at rest and more difficult to stop when they are in motion. <b>A 300 lb. tackle has a lot of inertia!</b></p>
	<h3>Tackling a receiver</h3>	<h3>MOMENTUM</h3> <p>Momentum is a part of Newton's Third Law of Motion and also relates to the mass of an object. If an object is at rest, it has zero momentum. A moving object, however, has momentum.</p> <p>How does a <b>cornerback</b> use momentum to stop a receiver? A wide receiver, running fast to catch a pass, will build up momentum. Double your speed and you double momentum. To change that receiver's momentum, a cornerback will need to apply a force to change the receiver's momentum. If the cornerback is running faster than the receiver, his <b>momentum will overcome the receiver's inertia.</b></p>



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## GAME #1: FOOTBALL CONCENTRATION

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### MATERIALS

One sheet of paper containing a list of the scientific principles found on the Football Science Playbook. One sheet of paper containing a list of the football actions that relate to each scientific principle.

### SET UP

Cut out the strips of paper on both pages. Then place the individual strips of paper face down on a flat surface.

### TO PLAY

Each player takes a turn flipping over two pieces of paper. The player reads the text on each piece and determines whether or not they've found a match between the football action and the scientific principle. Players should look at the Football Science Playbook if they need help making that decision. If there is no match, the player returns each paper to a face down position and the next player takes their turn. All players should be encouraged to try to remember the location of each piece of paper, on the flat surface, before they are flipped back over. When a player finds a match, they remove those two papers from the table and keep the match. When all the papers have been collected by individual players, the player with the most matches wins. Refer to the Football Science Playbook for instruction and guidance as you play.



Vectors

Prolate Spheroid

Projectile Motion

Newton's Second Law of Motion

Pythagorean Theorem

Kinematics

Newton's First Law of Motion

Newton's Third Law of Motion

Torque

Kinetic Energy

Inertia

Momentum





throwing a pass

throwing, kicking

punting

kicking

catching, running

running

stopping a run

stopping a run

tackling

tackling

stopping a QB sneak

tackling a receiver



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## GAME #2: FOOTBALL BINGO

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### MATERIALS

The Football Bingo Game consists of four different bingo game cards. The squares of each bingo card contain a scientific principle that is explained by the Football Science Playbook. There is also a sheet of paper containing strips of paper that list an excerpt, the basic idea, of each scientific principle. These strips of paper will be cut out and placed in a small bowl or paper bag. Players will also need markers such as pennies, buttons or checkers to cover the squares of their bingo game cards.

### SET UP

Cut out the strips of paper on each page. Fold them and place them in a small bag or bowl. Make sure each player has a Bingo Board, as well as something to cover up the spaces on the board, such as pennies, buttons, or checkers.

### TO PLAY

Each player takes a turn choosing a paper from the bag or bowl. After reading the text aloud, the player looks through The Football Science Playbook to see which scientific principle is the best match for that text. If the player's game board has a square with that principle, they cover the square while explaining how the scientific principle matched the paper they pulled from the bag. For example, if a player pulls the strip of paper that reads: "ability to throw or kick a tight spiral". The player would explain that they covered "Prolate Spheroid" on their game board because the shape of a football allows a player to throw a spiral. If there is no match, the next player takes their turn to reach into the bag or bowl.

The first player to cover one row on their bingo game card either horizontally, vertically, or diagonally is the winner.

If players have already played other downloadable football games and they already remember information about the scientific principles, there is no need to reference the Football Science Playbook for additional help.



make precise passes

ability to throw or kick a tight spiral

control how high, how far, how much time the ball hangs in the air

the force applied to the mass of a football is the kicker's foot

the longest leg of the triangle or the hypotenuse is  
also the defenders, "angle of pursuit"

position, velocity and acceleration, great speed to elude tacklers

unbalanced force a linebacker, can act on a runner, to stop him

the players will exert an equal and opposite reaction on one another

if the player is hit from the side, there is torque

once the linebacker has kinetic energy he can  
apply force to an opposing player

a 300 lb. tackle has a lot of inertia

momentum will overcome the receivers inertia

**FOOTBALL BINGO BOARD**

Torque	Pythagorean Theorem	Projectile Motion and Parabolas	Newton's First Law	Kinematics
Kinematics	Geometric Shapes	Newton's Third Law	Vectors	Newton's Second Law
Newton's First Law	Newton's Second Law		Kinematics	Pythagorean Theorem
Vectors	Torque	Newton's First Law	Newton's Second Law	Newton's Third Law
Newton's Third Law	Kinematics	Pythagorean Theorem	Torque	Vectors

**FOOTBALL BINGO BOARD**

Kinematics	Newton's First Law	Projectile Motion and Parabolas	Pythagorean Theorem	Torque
Newton's Second Law	Geometric Shapes	Kinematics	Vectors	Kinematics
Pythagorean Theorem	Torque		Newton's Third Law	Newton's First Law
Newton's Third Law	Newton's Second Law	Torque	Newton's Second Law	Vectors
Vectors	Kinematics	Pythagorean Theorem	Newton's First Law	Newton's Third Law

**FOOTBALL BINGO BOARD**

Newton's Third Law	Kinematics	Pythagorean Theorem	Torque	Vectors
Kinematics	Geometric Shapes	Newton's Second Law	Vectors	Newton's Third Law
Newton's First Law	Newton's Second Law		Torque	Pythagorean Theorem
Vectors	Kinematics	Newton's First Law	Newton's Second Law	Newton's Third Law
Torque	Pythagorean Theorem	Projectile Motion and Parabolas	Newton's First Law	Kinematics

**FOOTBALL BINGO BOARD**

Kinematics	Geometric Shapes	Newton's Third Law	Vectors	Newton's Second Law
Torque	Pythagorean Theorem	Projectile Motion and Parabolas	Newton's First Law	Kinematics
Kinematics	Vectors		Newton's First Law	Pythagorean Theorem
Newton's Second Law	Torque	Newton's First Law	Vectors	Newton's Third Law
Torque	Kinematics	Pythagorean Theorem	Newton's Third Law	Newton's Second Law

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## GAME #3: FLAG FOOTBALL

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### MATERIALS

One sheet of paper containing a list of the scientific principles found on the Football Science Playbook. These strips of paper will be cut out and placed in a small paper bag. You may want to make two copies so you have enough strips to pull out throughout the time you're watching the football game. There is also a separate sheet of paper containing four separate flags. Flags should be cut out using the dotted lines as guides.

### SET UP

Give each player a flag and a copy of the Football Science Playbook. Then, ask them to take their seats in front of the device where you will be viewing the football game. Cut out strips of paper that contain the science principles and place them in a bowl or paper bag.

### TO PLAY

Assemble a group of 4-6 friends or family members to watch at least one quarter of a football game together. Each player gets a flag. As the football game begins, the first player reaches into the bag, pulls out a strip of paper, and reads the scientific principle aloud. All players can refer to the Football Science Playbook to review the principle. Then, as soon as any player sees an example of that principle in the football game, they throw their flag. The first player to throw their flag explains where and how they saw the scientific principle displayed during the game. If they are incorrect, the second player who threw a flag can offer their explanation. If no other players threw a flag, play resumes, but players should be encouraged to continually review the Football Science Playbook to find the correct answer. One point is awarded for each correct flag thrown. The player with the most points at the end of a quarter, wins.



Vectors

Prolate Spheroid

Projectile Motion

Newton's Second Law of Motion

Pythagorean Theorem

Kinematics

Newton's First Law of Motion

Newton's Third Law of Motion

Torque

Kinetic Energy

Inertia

Momentum





cut on dotted line

