Exercise & Sports Biomechanics

Dr. Rajinikumar Palaniyappan
Centre of Excellence in Biomechanics Cum High Performance Centre for Sports
Department of Sport Biomechanics & Kinesiology
Tamil Nadu Physical Education & Sports University, Chennai (TN)

Week 05
Lecture 23
Projectile Motion

[Hello everyone! Welcome back to this course. Today, we are going to discuss the kinematics of projectile motion. In projectile motion, we discuss the projectile].

What do you mean by a projectile?

A projectile is a body in free fall. So here, the body, object, or any equipment which is suspended in the air is called a projectile. In other words, we call it a body in free fall. Whether it is equipment, an athlete, or any object which is suspended in the air is called a projectile. As a common word, we use the term body. So, body means it may be an athlete who is in the air, equipment, or any object which is suspended in the air. So, the body in free fall, the projectile, is affected only by gravity and air resistance. And here, you can see a high jumper jumping over the horizontal bar. The objective of the high jumper is to clear the maximum vertical distance. And here, one more example we have is pole vault.

The objective of the pole vaulter is to clear the maximum height. In the third picture, what you see here is a long jumper after the takeoff. She has a flight and landing; her body is airborne. Here, we see a horizontal projectile. As far as projectiles are concerned, we have two types based on the objective: one is a vertical projectile, and another is a horizontal projectile. The objective of the horizontal projectile is to have the maximum distance horizontally, and the objective of the vertical projectile is to clear the maximum vertical distance. And you can see the javelin thrower who is throwing the javelin. The javelin is a projectile with the objective of having the maximum horizontal distance.

And when we discuss projectiles, there is some terminology we need to understand. Say, for example, apex. **Apex** means the maximum height reached by a projectile. And **gravity**, the **gravitational acceleration** acting on the projectile's body, is constant throughout the flight. The acceleration is $-9.81 m/s^2$.

And when we analyze a projectile, the horizontal speed of the projectile remains constant throughout the trajectory.

What is trajectory?

Trajectory is nothing but the flight path of an object. So, the projectile is released at a particular speed, at an angle, at a particular height. So, these are the three factors that are very important when we analyze the projectile. Then the range, the difference between the initial and final, the release and landing, is called the range. So, we will see what the examples of projectiles in sports are. So first, we will see the horizontal projectiles. So, the horizontal projectiles examples are a long jumper after the takeoff, a triple jumper after the final takeoff, and even when an athlete is running, when he is airborne, he is a projectile, and the shot put which is released from the hands of the shot putter, as well as the javelin which is in flight, and the hammer which is in flight, and the discus which is in flight. So, these are all the examples of horizontal projectiles, but when it comes to vertical projectiles in sports, it is a high jumper, a pole vaulter, and apart from this, a hurdler after the takeoff, he has to clear the distance horizontally as well as vertically, so the objective of a hurdler is to clear the given vertical distance and maximal horizontal distance to keep the pace of the running. Here, we see some of the important metrics or variables with regard to projectile motion analysis. First one is at what speed it is being released, and how long it is in the air, that is the flight time, and the angle of projection, the height of projection, and then how high it reaches and how far it reaches, that is the vertical distance as well as the horizontal distance. So, these are all the important metrics that have to be taken into consideration when we analyze any projectile in sports. When we analyze the linear and angular motion, which are part of the general motion, so similarly we have horizontal and vertical components in a projectile motion, so the horizontal component is unaffected by gravity, so the initial velocity is always equivalent to the final velocity when the horizontal speed of a component in a projectile motion is concerned, whereas the vertical component of the projectile is affected by the gravitational acceleration, so the horizontal component and vertical component are independent of each other, and if you see here in the first picture So, a player is dropping the ball from a 1-meter height. So, the ball is affected by the gravitational acceleration. And in the second picture, a player is striking the ball at the same height, 1 meter. And here, the ball has both horizontal and vertical components.

Only the vertical component is affected by gravitational acceleration. Whereas, the horizontal component is unaffected. Whenever we analyze projectile motion, we have to take into consideration the horizontal as well as the vertical component of the projectile motion. So once again, I would like to reiterate that the horizontal component of projectile motion is unaffected by gravitational acceleration.

Only the vertical component of projectile motion is affected by gravitational acceleration. So, if you see in both instances, whether the ball is dropped from a 1-meter height vertically or when a ball is struck by the player at a height of 1 meter horizontally, the flight time is the same for both projectiles. Let us see how the projectile trajectory changes with and without gravitational acceleration. So, if you see in this picture, the first Trajectory, which is diagonal and represented by the letter A, is unaffected because there is no gravitational acceleration acting on this projectile, and it has a diagonal vector, a diagonal trajectory. Whereas, if you see the letter B, the trajectory of this projectile is affected by gravitational influence, which is making a parabolic path. And you can see the change in the trajectory. So, hence, the vertical component of the projectile is affected by gravitational acceleration. And the horizontal component is unaffected. So, we come to know from this picture.

What are the factors that influence projectile trajectory?

The factors that affect projectile motion are the speed of release, angle of release, and relative height of release. These are the three important factors affecting the projectile trajectory or path of the trajectory. And apart from this, air resistance and the spin of the ball also play a role in changing the projectile trajectory.

But we consider these three mechanical factors—speed of release, angle of release, and relative height of release—as the major factors influencing the trajectory of the projectile. We will discuss further in detail the factors influencing projectile motion by neglecting air resistance or without the influence of air resistance. So, here in this picture, you can see the projectile thrown at different angles. So, different angles, right from 10 degrees, 30 degrees, 45 degrees, 60 degrees, to 80 degrees.

So, when we change the projectile's angle of release, the trajectory changes. And with regard to projectile motion, we can discuss the variables and the factors that influence the particular variable. Here, we take flight time as one of the variables. Flight time is nothing but how long an object or the body projectile is in the air. This is determined by two main factors: first, initial vertical velocity, and second, relative projection height. So, initial vertical velocity and relative projection height are the two factors that determine the flight time of a projectile.

Horizontal displacement:

So, how far an object travels is determined by the horizontal velocity of the projectile as well as the relative projection height. These are the two factors which determine the object's horizontal displacement. For example, if a long jumper wants to go a farther distance, if the body of the long jumper is a horizontal projectile, that is determined by the horizontal velocity and relative projection height.

Vertical displacement:

The vertical displacement of the object or a projectile is determined by the initial vertical velocity and relative projection height. These are the two factors which determine the vertical displacement of a projectile. And finally, if we want to see the trajectory which is influenced by the factors of initial speed, projection angle, and relative projection height. These are the three key factors which determine the trajectory of a projectile. The angle of projection and the effect of air resistance determine the shape of the projectile's trajectory. And when it comes to different projectiles, say for example, a release of a basketball or a release of the long jumper's body right from the takeoff board to the landing pit. So, these are all different projectiles with different heights of release.

Let us discuss in detail the factors which are affecting the projectile. So, here we are going to discuss the effect of the projection angle on the projectile trajectory. And here, if you see the picture, it is perfectly vertical, that is 90 degrees. So, the projectile trajectory is perfectly vertical, and this can be seen in a basketball match when a player retrieves the ball by jumping in the air from the basket.

And the second one is the **oblique trajectory**. If the release angle is from about 0 to 45 degrees, the projectile will follow an oblique trajectory. The speed of release always determines the length of the trajectory, but the projection angle determines the shape of the trajectory. And when the ball is released or when the object is released at either 0 to 45 degrees, it follows a parabolic trajectory.

A **parabola** is nothing but a symmetrical shape on the right and left sides, having a mirror image. And the third one is the **horizontal trajectory**. When the ball is released or when the body is released at zero degrees, it will have a horizontal trajectory, which resembles half of a parabola. And by seeing these three shapes of projectile trajectory, it is completely based on the projection angle. Because the projection angle determines the shape of the trajectory.

And we can have some examples in each trajectory. So, in a vertical trajectory, a high jumper who is making a high jump attempt from takeoff to landing, a pole vaulter, and a basketball player. In volleyball, a player who is in the front row trying to spike the ball or block the ball, you can find them following a complete vertical trajectory at a 90-degree angle. Second comes the oblique trajectory.

When we see the examples following the **oblique trajectory**, a football that is kicked by a player at a degree of 45 degrees or any degree from 0 to 45. It is following an oblique trajectory resembling a parabola and when it comes to the horizontal trajectory, the shot put is released by the shot putter at a zero-degree angle and it follows a horizontal trajectory. And similar is the case we are going to discuss. And these are all the examples for each trajectory.

Hence, we come to the conclusion that the projection angle determines the shape of the trajectory. So, now we are going to see the effect of projection speed on the projectile trajectory when the angle of release is kept constant. So, if you see in this picture, the angle of release at 45 degrees is kept constant and the release speed changes from 10 meters per second to 30 meters per second. So, obviously, it is known that the 10 meters per second speed has reduced the length of the trajectory. And if you see the 20 meters per second, it is more than the 10 meters per second speed trajectory.

And it is not that when you increase the release speed, it increases the length of the trajectory. That is why all the athletes who are trying to throw any object or implement try to increase the speed of release. Say, for example, the javelin thrower. So, the javelin thrower never throws a javelin in a standing position. He takes an approach run of about 30 to 36 meters and he generates the momentum to increase or to have a better speed of release so that the implement can go a longer distance.

Similar is the case with regard to the long jumper. So, the long jumper becomes a projectile after the takeoff. But before he takes off, he takes an approach run with a distance of 40 to 45 meters. So, he runs and generates momentum to increase the release velocity. So that he can jump a farther distance.

And the same is the case with regard to the shot put. If you see shot putters, they use different techniques to generate momentum. The purpose of creating momentum is to increase the release velocity, whether it is discus, shot put, or hammer throw. So, if you have seen in athletic competitions, there is a circle and a throwing sector. Within the circle, the shot putter stands and performs one of the techniques, either the glide technique or the rotation technique.

So, they move before the release of the shot put because they try to create momentum, which helps them to increase the release velocity. So, the increase in the release velocity obviously helps the shot putter to gain more distance so that the shot put can move a farther distance. The same is the case with regard to discus and hammer throw. Discus throwers and hammer throwers rotate; they go for rotation to increase the momentum so that they can have a better release velocity. So obviously, we come to know that the release speed determines the length of the trajectory. That is why the athletes, in different techniques, create momentum by having an approach run or increasing the speed before the delivery.

The **relative projection** height is another factor that affects the trajectory of the projectile. So, we can see the objects that are released at different heights, relative projection heights. First, we see a football being kicked from initial to final. If you see the initial height of release and the final landing height, the difference is zero. And second, the relative projection height is a positive one.

When it is positive, the difference between the release height and the landing height is different. So, when the release height is higher than the landing height, it has a positive relative projection height. So, a shot putter who is releasing the shot put from a height of 2 meters, and if you can see the difference, it is a positive 2 meters, it is a positive relative projection height. And at the same time, if you see any basketball player who is just closer to the basketball ring, and when he or she releases the ball, the release height is less than the landing height. Obviously, the relative projection height of the basketball under the basket is minus 1.5 meters.

So, we can see these three types of relative projection height when different implements are released in different sports. And with regard to release height, when there is a change in release height or relative projection height, the angle of projection also changes. And when the relative projection height is 0, and if you want to send any projectile or any body to a farther distance, a longer distance, the optimal release angle is 45 degrees. And if the relative projection height is positive, it should be less than 45 degrees, the angle of release is less than 45 degrees when the relative projection height is 2 meters.

And when the relative projection height is negative in value, that means minus 1.5 meters or a negative relative projection height. In other words, I would say when the landing height is higher than the releasing height, the angle of release is more than 45 degrees. That is why if you see any basketball player, they will release the ball at more than 45 degrees depending upon the distance from the ring to the player's releasing point. So, at the same time, if you see the shot putters, javelin throwers, or discus throwers, their relative projection height is higher and positive.

And when it is positive, it is less than 45 degrees. That is why the shot putters always release the shot put around 30 to 35 degrees. And the same is the case with regard to long jumpers. The long jumpers, when they take off, the take-off angle of the long jumpers is between 18 to 25 degrees. See, as we discussed earlier, when the releasing height is less than the landing height, obviously the projection angle will be higher.

So, the basketball release angle is an example. Another fine example is the high jumper because soon after the high jump takeoff, the high jumper lands on a mat which is higher than the takeoff height or releasing height. The same is the case with regard to the pole vaulter. The pole vaulter takes the takeoff by planting the pole, but he is landing on a mat which is higher than the releasing height. So, these are all the activities or sports where the releasing angle will be higher than 45 degrees.

And when analyzing projectile motion, we have an example where we can find out the horizontal and vertical components. A basketball is released with an initial speed of 8 meters per second, which is the resultant velocity or final speed, at an angle of 60 degrees. So the speed of release is 8 meters per second, and the angle of release is 60 degrees. As we have already discussed, any projectile will have two components: one is horizontal, and the other is vertical. Again, I want to reiterate that the vertical component is affected by gravitational acceleration, and the horizontal component is constant right from the inception to the landing. The problem states that we need to find the horizontal and vertical components of the ball's initial velocity using the trigonometric method. So we can find out the horizontal component and the vertical component.

We can resolve the problem in two ways. One is the graphical method. Another one is the trigonometric method. So in this chapter, we are going to use only the trigonometric method. So we can have a free body diagram of a basketball player who is going to release. So, this is the releasing velocity, which means 8 meters per second, but we want to have the split of horizontal velocity as well as the vertical velocity. The release velocity is 8 meters per second, but we do not know what the horizontal velocity and vertical velocity are when the ball is released at 60 degrees. In resolving a problem with regard to projectile motion, when we want to find out the horizontal component and the vertical component, the horizontal component magnitude is always equivalent to the initial velocity multiplied by the cosine of the projection angle. In this regard, the vertical component of the projectile motion is equivalent to the initial velocity multiplied by the sine of the projection angle. And if you see here, the horizontal velocity of the projectile is calculated based on the first component, which is the initial release velocity multiplied by the cosine of the releasing angle.

The cosine, because the releasing angle is 60 degrees, so the releasing angle of 60 degrees comes with cosine. The cosine value is 1/2. So, 1/2 can be converted into a fraction that is 0.5. So, 8 meters per second multiplied by 0.5 is equal to 4 meters per second.

V_h =(8m/s) (cos 60)

V_h =4m/s

So, we come to the conclusion that the horizontal velocity of the projectile is 4 meters per second.

Here, we are going to find out the **vertical velocity of the projectile**. So, the vertical velocity, as I already said, if you want to find out the vertical velocity, it is the product of the initial velocity multiplied by the sine of the projection angle.

V_v = (8m/s) (sin 60)

V_v = 6.9 m/s

And the projection angle is 60 degrees. The sine of 60° = $\sqrt{\frac{3}{2}}$, which has the fractional value of 0.866. When we multiply the initial velocity by the sine of 60 degrees at the value 0.866, it comes around 6.9 meters per second.

And here, we have found out that the horizontal velocity of the ball is 4 meters per second, and the vertical velocity of the ball is 6.9 meters per second. With these two values, we can use trigonometry by squaring the value of the horizontal velocity and squaring the value of the vertical velocity. Adding them and taking the square root value, you will get 8 meters per second, which is the resultant velocity. So, the trigonometric method is one of the methods we use to resolve any vectors. So, we are going to discuss the equations of constant acceleration. In other words, we call them the equations of projectile motion, which were formulated by the scientist Galileo 400 years back.

We are going to discuss some of the variables which we are going to measure and assess in equations of constant acceleration. So, here we have symbols as well as meanings and representations in equations.

SYMBOL	MEANING	REPRESENTING IN EQUATIONS
d	Displacement	Change in position
v	Velocity	Rate of change in position
a	Acceleration	Rate of change in velocity
t	Time	Time interval
v_1	Initial or first velocity	Velocity at time 1
v_2	Later or final velocity	Velocity at time 2
v_v	Vertical velocity	Vertical component of total velocity
v_h	Horizontal velocity	Horizontal component of total velocity

So, D represents displacement, which means how far an object has traveled, that is the change in position. V represents velocity, which is the rate of change of the position of the object. And A, obviously, everyone knows, represents acceleration, the rate of change of velocity.

And T represents time or the time interval. Further to these four basic components, D, V, A, T, displacement, velocity, acceleration, and time, we have initial velocity or first velocity, which is represented by V1, and V2 represents final velocity or later velocity, and Vv, which is vertical velocity, the vertical component of the total velocity. And Vh represents the horizontal velocity or the horizontal component of the total velocity. That is what we have already seen in the basketball summation, and the basketball was released at 8 meters per second at a 60-degree projection angle. So, in that calculation, we found out the vertical velocity of the ball as well as the horizontal velocity of the ball.

Here, we are going to further discuss the equations of constant acceleration with regard to the equations. So, the first three equations represent V2, which represents the final velocity. Final velocity can be found out by the equation $V_2 = V_1 + at$. The second equation is displacement. If you want to find out the displacement, $d = V_1t + \frac{1}{2}at^2$. Equation 3 is

$V_2^2 = V_1^2 + 2ad$. These are the main three equations written by the scientist Galileo. Here we are going to find out the horizontal component as well as the vertical component by having further equations derived from the initial three. If you see this graph, the vertical velocity keeps on changing, and the moment it reaches the apex, the vertical velocity of the projectile or object is zero, and the horizontal velocity is unaffected right from the inception of release to the end, and this is how you can see the graph.

The red component is the horizontal velocity of a projectile. The green component is the vertical velocity of the projectile. So, we clearly understand the fact that the vertical velocity or vertical component of the projectile is always affected by gravitational acceleration, whereas the horizontal component of the projectile is always constant, that is, equal to zero. We have already discussed the basic three equations for solving problems with regard to equations of constant acceleration or projectile motion. So, here in the blue chart, it says that the final velocity equals initial velocity plus acceleration times time.

So, when we solve the horizontal component of the projectile motion, we have already discussed that the horizontal component of the projectile motion is unaffected by gravitational acceleration. So, when the acceleration equals 0, then we have to remove all components that have acceleration. So, on the right side, if you remove all the acceleration components, then the equation comes as $V_2 = V1$, which is represented by 1H. So, 1H means the equation that represents finding out the horizontal component of a projectile and finding out the displacement of the horizontal component of a projectile, so it is $d = V_1t$, which is represented by equation 2H. When you want to find $V_2^2 = V_1^2$, which is represented by equation 3H, and here we have a problem.

So, an object is thrown into the air at an initial velocity of 18 meters per second, and the total flight time is 2 seconds. What is the displacement? So, if you want to find out the displacement, here we have two metrics: initial velocity as well as the time of flight. So, when we see all these three equations, we have two components which perfectly match with equation 2H and that is, $d=V_1t$. And so, this equation 2H is selected and the initial velocity, which is 18 meters per second, when it is multiplied by the time of flight, it is 36 meters. So, we come to the conclusion that if a ball is thrown at an initial velocity of 18 meters per second and the flight time is 2 seconds, the total displacement of the object is 36 meters. This is how we solve the horizontal component of projectile motion.

We have one more example to find out the horizontal component of projectile motion by using the same equation. So here, the displacement is equal to initial velocity multiplied by time. So that is what the 2H formula says. And here you can find a basketball player who is going to shoot the ball. And if you want to find out the distance of the throw, we have only two components: the metrics of the ball are given, which are the initial velocity of 4 meters per second and the time of flight of 2 seconds.

What is the displacement of the ball?

We use the formula: $d = V_1t$. The initial velocity is 4 meters per second. The time of flight is 2 seconds. So, the ball has a total displacement of 8 meters. The same applies to any basketball thrown from different distances if you want to find out the displacement. If you want to find out the displacement of any ball, like a handball thrown from one player to another. These are all the equations we can use to find out the displacement of the projectile.

Vertical component of projectile motion:

The vertical component of projectile motion always has a constant acceleration of -9.81m/s^2. Here, we see the already discussed three equations: $V_2 = V_1 + at$.

Displacement (d) = $V_1t + 1/2\ at^2$, and $V_2^2 = V_1^2 + 2ad$. Here, the initial velocity is 0. When is the initial velocity 0? When the projectile is dropped from a static position, the initial velocity is zero. And when the projectile reaches its apex, the final velocity will be zero.

These are the two occasions where the velocity will be zero. So, the first one is when the ball is dropped from a height. In this picture, a person is dropping the ball right from his hand, so the initial velocity is equal to zero. But when you want to find out the final velocity when the ball is released from the static position, we use a different formula. That is, final velocity is equal to acceleration multiplied by time, and the second component is that final velocity is equal to zero. When the final velocity is equal to 0, when the ball is released, when the ball reaches its apex, obviously the final velocity will be 0. So, first we will resolve when the initial velocity is equal to 0, what is the displacement of an object? And here, the time of flight of an object which is dropped from the static position is 3 seconds. And the final velocity of the ball is 29.43 metres per second. How is this found out? How have we found out the final velocity? That means, what is the acceleration? The acceleration of the vertical component is 9.81 metres per second. So, multiplied by the time of flight, 3 seconds. $V_2 = at$, $V_2 = 29.43$m/s

So, we arrive at the final velocity that is 29.4 metres per second. So, that is the final velocity of an object which is released from the static position.

And we have another formula for the vertical component of projectile motion that is represented by the letter 2V. So, if you want to find out the displacement of an object, we have half a t squared, that is half acceleration multiplied by time squared, and the same if you want to find out the displacement of this object. Initially, in the first problem, we use the formula final velocity is equal to a t, acceleration multiplied by time, to find out the final velocity. But here, in the second problem, we want to find out the displacement of an object. So, for the displacement of an object, we have half a t squared. So, we have the time as well as we know the acceleration. And if we substitute the acceleration multiplied by the time squared, we get 44.15 meters as the displacement. So, using these two equations, the first equation helps us to find out the final velocity, and the second equation, that is 2V, helps to find out the displacement of the vertical component of projectile motion. The third one is $V_2 = 2ad$, and when the ball is dropped from a height, we have we can find out the displacement, 44.15 meters, and the final velocity is 29.43 meters per second.

And if you want to find out the $V_2^2 = 2 \times 9.81 \times 44.15$. Here, we have one more example to find out the vertical displacement of a projectile. So, we have these equations. Here comes the question: a ball is hit with an initial velocity of 15 meters per second, and the total ceiling height is 10 meters. So, the question is whether the ball will contact the ceiling or not. So, you would like to find out the displacement. When we want to find out the displacement, we go for this equation: $V_2^2 = V_1^2 + 2ad$. So, since the final velocity is equal to 0, initial velocity squared plus 2 a d is the equation which we are going to use.

We know two metrics. One is initial velocity. Another one is acceleration. So, initial velocity is 15 meters per second, which is put into the formula. So, that is 15 meters per second squared plus 2 into acceleration. We know the value of acceleration, which is minus 9.81 meters per second squared, and the unknown value is displacement. But when we put these equations and when you multiply the acceleration by the value 2, it is 19.62 meters per second squared multiplied by the displacement, which is equal to the initial velocity squared, that is 225 meters squared per second squared. When we substitute this, we divide the value that is 225 by 19.62, and we get the displacement of 11.47 meters, which means the ball can reach a height of 11.4 meters.

$V_2^2 = V_1^2 + 2ad$

$0 = V_1^2 + 2ad$

$0 = (15m/s^2) + (2)(-9.81m/s^2)\ d$

$(19.62\ m/s^2)\ d = 225\ m^2 / s^2$

$d = 11.47m$

So, the ceiling height is only 10 meters; obviously, we can answer the question that the ball will surely hit the ceiling at this velocity when the ball is released at 15 meters per second.

[Then, to finally wrap up,]

The Equations of Constant Acceleration

These equations may be used to relate linear kinematic quantities whenever acceleration (a) is a constant, unchanging value:

$$v_2 = v_1 + at \quad (1)$$

$$d = v_1 t + (\tfrac{1}{2})at^2 \quad (2)$$

$$v_2^2 = v_1^2 + 2ad \quad (3)$$

Special Case Applications of the Equations of Constant Acceleration

For the horizontal component of projectile motion, with $a = 0$:

$$d_h = v_h t \quad (2H)$$

For the vertical component of projectile motion, with $v_1 = 0$, as when the projectile is dropped from a static position:

$$v_2 = at \quad (1V)$$

$$d = (\tfrac{1}{2})at^2 \quad (2V)$$

$$v_2^2 = 2ad \quad (3V)$$

For the vertical component of projectile motion, with $v_2 = 0$, as when the projectile is at its apex:

$$0 = v_1 + at \quad (1A)$$

$$0 = v_1^2 + 2ad \quad (2A)$$

We have the equations of constant acceleration. So, first, we come up with the basic first three equations, and followed by, as we have already discussed, when you want to find out the horizontal component of a projectile with an acceleration of zero, we use the formula that is displacement is equal to horizontal velocity multiplied by time. And we use the further formula when you want to find out the vertical component of the projectile. So, what do you want to find out from this? When the vertical component of the projectile, the initial velocity is zero, we use these formulas, which are 1V, 2V, and 3V.

Depending on the given metrics, we can select any one of these equations. Furthermore, the third component is when the final velocity equals zero. That is what we saw in the last equation, which was the last question. So, when a ball is hit at 15 meters per second, will it hit the ceiling of a floor or the ceiling of a building? That is how we resolve and use this equation when the final velocity equals zero.

To sum it up, the equations of constant acceleration or projectile motion. Projectile motion is affected by factors such as speed of release, height of release, and angle of release. When it comes to the height of release, we always consider the relative height of release. So, whether it is positive, negative, or parabolic, that is zero. Finally, the equations of constant acceleration can be used to find the components of the horizontal and vertical components of projectile motion, as well as the displacement and flight time.

These are all the metrics we can determine. The horizontal acceleration of any projectile is always zero. The vertical acceleration of any projectile is minus 9.81 meters per second squared.

[Thank you, and I will meet you in the next video].