Robogals
Science Challenge

2020 Minor Challenge Set #1
STEM Field: Mechanical Engineering
Level: Senior
Challenge Name: Projectile Motion
Materials required:

- Football/Soccer ball/Anything you can kick a decent distance
- Stopwatch
- Tape measure or a football field
- Calculator
- Pencil and paper
- Willing friend

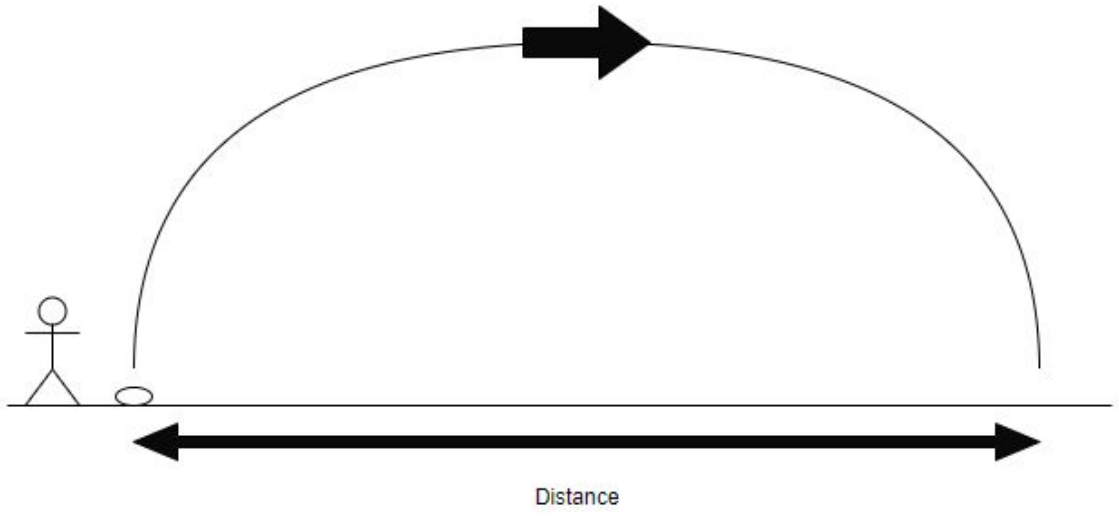
Introduction:

Ever wanted to know how high and how fast you can kick a football? Turns out, you can with some math! All you need to know is how far away from you the ball lands and how much time it spends in the air (the “hang time”). Combine these two simple measurements with a little bit of physics and you can start competing with your friends to see who can kick the highest or the fastest!

The math involved is studied in Year 11 & 12 Physics under Motion. In this experiment we’ll give you the necessary equations and guide you towards the final answer but if you take the time to think about the equations they’ll start to make sense.

Instructions:

1) Place your ball at a field where you can comfortably kick a ball without disturbing others.
2) Have your stopwatch ready so that when you give the ball a good kick, you can start the timer exactly when you kick the ball and stop the timer as soon as the ball hits the ground (first contact on the ground, not after the ball has finished bouncing).
3) Mark the two positions where you kicked the ball and where it landed.
4) Use a measuring tape to measure the distance between these positions.



Tips:

1) Here using your friend/mentor to handle the stopwatch can be useful so you can put all your attention into kicking the ball.
2) You can use your friend/mentor to mark one of the positions and an object like a water bottle as the other to easily measure the kicking distance.

Math:

1) Before we get started on the math make sure you have BOTH:
    a) Horizontal distance travelled (d)
    b) Time taken for ball to hit the ground (t)
2) Now for a bit of math. Divide the distance traveled (d, metres) by the amount of time (t, seconds). This tells you the ball's horizontal speed, x, in meters per second:

$$x = \frac{d}{t}$$

3) Calculate the ball's vertical speed, y, by multiplying half the hang time (t) by the acceleration due to gravity ($g = 9.8 m/s^2$):

$$y = \sqrt{\frac{g*t}{2} - x^2} = \sqrt{\frac{9.8*t}{2} - x^2}$$

5) Now it's time to combine the horizontal and vertical speeds to get the total speed, z. That's how fast you kicked the ball, in meters per second.

$$v = \sqrt{y^2 + x^2}$$

6) To calculate how high the ball went (h), take the vertical velocity squared and divide it by twice the gravitational acceleration:

$$h = \frac{y^2}{2*g} = \frac{y^2}{2*9.8}$$

7) You can also calculate the angle at which the ball left the ground (θ) by using a tiny bit of trigonometry (AND a calculator):

$$\theta = tan^{-1}(\frac{y}{x})$$

Extension: Freefall Motion

As an extension of the previous task, we will again look at a type of projectile motion this time much simpler. Simply drop an object (any object!) from a certain height and time how long it takes to fall to the ground. Make sure the object is *dropped and not pushed down or u*p, it changes the physics involved greatly!

1) Unknown height: Drop the object at any height but measure the time it takes to fall to the ground.

$$h = \frac{1}{2} * g * t^2 = \frac{1}{2} * 9.8 * t^2$$

2) Known height: Now repeat 1) except this time drop it at a height you've measured (for example 1 metre). Make sure you measure the time it takes to fall to the ground. Apply the formula below and see if there's any difference between the real height and the calculated height.

$$h = \frac{1}{2} * g * t^2 = \frac{1}{2} * 9.8 * t^2$$

3) Repeat 2) but with a different object. Do you get different height values for different objects? Which object got the closest to the actual height? What else could be at play that causes different objects to fall to the ground from the same height at different times?

Reflection Questions:

- What were the problems associated with the challenge? Are there any improvements you could suggest?
- What are the key concepts of science and engineering that relate to this challenge?

- According to your calculations how high did you kick the ball (h)? Is this a realistic number to how approximately high you actually kicked the ball? For example if your math gave you h = -20m there's definitely a mistake somewhere!
- Given all other numbers are the same, what angle (θ) do you think you should kick the ball at for the maximum horizontal distance. (Read up on the BBC Bitesize link referenced under Learn More! Resources for the answer!)
- These equations are simplified to give close but not completely accurate numbers. Think about the environment of how the kicked ball moves. What else is affecting it that we haven't considered in our equations?

Submission Guidelines:

- Submit a photo of the experiment setup. Include a short summary that addresses some of the Reflection Questions that also includes your calculations, scanned or typed out calculations are fine.
- In 2020 we have changed our submission guidelines compared to 2019. To submit fill out the form here: https://forms.gle/ChrCXLud97E4x3AT9

Learn More! Resources:

- The Physics Classroom - What is a Projectile https://www.physicsclassroom.com/class/vectors/Lesson-2/What-is-a-Projectile
- BBC Bitesize - Projectile Motion

https://www.bbc.com/bitesize/guides/zrsdmp3/revision/1

Sources:

Education.com. (2019). How to Find Maximum Height of a Projectile | Science project | Education.com. [online] Available at: https://www.education.com/science-fair/article/monday-night-football-tracking-trajectory/ [Accessed 18 Feb. 2019].