

# PhysiCombat: A Projectile Motion Multiplayer Turn-Based Physics Game on Android

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## **Abstrak**

*Pelajaran sekolah bisa jadi tidak menarik dan bahkan membosankan, mata pelajaran seperti matematika, fisika, atau kimia termasuk dalam daftar mata kuliah tersebut dan salah satu topik yang sering kali sulit dipahami adalah topik gerak parabola. Gamifikasi dipandang sebagai salah satu konsep di mana pembelajaran bisa jauh lebih menarik. Dengan menggunakan Unity 3D, kami dapat mengembangkan gamifikasi dari pelajaran gerak parabola. Dengan mengubahnya menjadi mirip game Angry Bird, proses pembelajaran dialami dalam game turn-based ini menjadi menarik. Alih-alih menunjuk arah tembak, siswa diminta menghitung kecepatan dengan mengambil nilai yang ada seperti sudut dan jarak. Permainan dapat dimainkan sendiri, seperti dalam mode latihan, atau dua pemain seperti dalam mode versus atau bahkan dua kelompok yang sangat dapat diterapkan dalam satu kelas (contoh yaitu. Grup 1 vs Grup 2) dan karena menggunakan persamaan fisika nyata, aplikasi dapat untuk menunjukkan simulasi realistis dari jalur gerakan parabola tersebut.*

**Kata kunci**—gerak parabola, pedagogy, gamifikasi, Unity 3D, fisika

## **Abstract**

*School lessons can be uninteresting and even dull. Subjects like maths, physics or chemistry are on top of the list, and one topic that often hard to grasp is the projectile motion lesson. Gamification is seen as one of the concepts where learning can be much more engaging. Using Unity 3D, we were able to develop gamification of the projectile motion lesson. By transforming it into an Angry Birds look alike, the learning process is experienced in this turn-based game become much more enjoyable. Instead of pointing where to shoot, students are asked to calculate the velocity by taking the given value such as angle and distance. The game can be played alone, as in practice mode, or two players as in versus mode or even two groups which is very applicable in a class (i.e. Group 1 vs Group 2) and since it uses real physics equation, the application able to show a realistic simulation of the projectile motion path.*

**Keywords**—projectile motion, pedagogy, gamification, Unity 3D, physics

## 1. BACKGROUND

Nowadays technology advancement is moving very quickly, including its role in various fields including non-technology related, such as in agriculture, health as well as in education. A school is a place where teaching and learning activities are ongoing daily. It is undeniable that the quality of learning activities conducted at a school is one of the most critical factors that affect the quality of the school [1]. Therefore, often, inadequate or relatively ineffective learning tools and method can affect students' progress in grasping the lessons they are studying. Situation

described earlier can be seen by student learning results that often cannot reach the school's KKM (Minimal Criteria) that is set by the Indonesian Education Board [2].

Physics is one of those high school students' less favored subjects [3]. When we inquire about the reasons why high school students are having trouble studying physics, we will consider various kinds of explanations. Physics itself includes many sub-parts which students must learn. One of the important topics is the parabolic motion or often called parabolic projectile motion [4]. This motion is a two-dimensional motion with an object flung sideways into the air meant to resist surface friction. The parabolic motion is a mixture velocity on X-axis and on the Y-axis [5]. When students study this principle, they usually will not rely on a parabolic acceleration testing apparatus as it is rarely available at schools; instead, they would rely on printed images or video lesson. This may make the experience of learning very monotonous or simply dull [6].

Therefore, on this research, we aim to create a more user-friendly, if not more exciting, way to study through gamification of the concept. The application that we will create is a game that is based on all the physics attribute of parabolic motion that can be played by two students with turn-based mechanism. This method, hopefully, will turn the students to learn and practice using the formula in a more enjoyable approach.

## 2. LITERATURE REVIEW

This research is based on several physics concepts, and formulas as well may be related to previous research that similar to or existing application that is available for the public.

### 2.1 Physics Concepts and Formula

A parabolic motion of an object that is launched from one point to another point is based on the Velocity formula that is shown below in Figure 1.

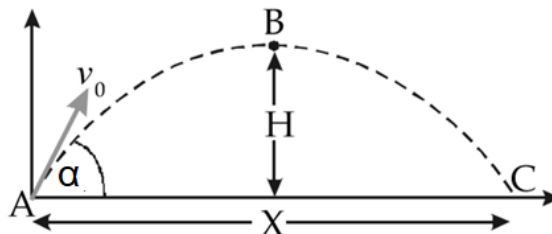


Figure 1 Parabolic Motion of Objects with the Highest Point and the Farthest Point [7]

The travel time to reach the furthest point (point C) is equal to twice the time needed to reach the highest point. The farthest distance reached by an object on the x-axis is shown on the following equation:

$$\begin{aligned} X &= v_0 \cos \alpha \left( \frac{v_0 \sin \alpha}{g} \right) \\ &= v_0^2 \left( \frac{\sin \alpha}{g} \right) \cos \alpha \quad (1) \end{aligned}$$

According to the trigonometric formula,  $2 \sin \alpha \cos \alpha = \sin 2\alpha$ , therefore the equation for the farthest distance that can be achieved by objects can be written as follows:

$$X = \frac{v_0^2 \sin 2\alpha}{g} \quad (2)$$

And from the equation we can get the formula to find  $V_0$ . This equation would be the base of the study where student would use to play the game.

$$\begin{aligned}
 v_0^2 \sin 2\alpha &= X \cdot g \\
 v_0^2 &= \frac{X \cdot g}{\sin 2\alpha} \\
 v_0 &= \sqrt{\frac{X \cdot g}{\sin 2\alpha}} \quad (3)
 \end{aligned}$$

Equation descriptions :

$V_x$  = Velocity on x-axis.

$V_y$  = velocity in y-axis.

$V_0$  = Initial Velocity.

$t$  = time.

$g$  = Earth gravitation pull (9,81 m/s).

$H$  = Maximum height of the item.

$X$  = distance where the item landed.

$\alpha$  = degree of the trajectory.

## 2.2 Related Studies and Existing App in Public Store

Several studies may have a similar goal or idea in teaching physics' parabolic or projectile motion lessons. While there are other studies related to this, but the following are researches that produce a media, app or product that is targeted for Indonesian's students as the audience in mind which is also what this research's app target users. We also cover list and review of similar existing application in Google's Play, an app store for Android.

### 2.2.1 Related Studies

Research by [8] is teaching students about projectile motion in the form of a mobile application as well. It offers video and static information about the theories and examples. While it is also a mobile application, yet the application merely giving static information and not much of interaction can be found. A similar approach is also done by [9] that is a mobile application as a platform. The application, however, offers much more interactive features. It offers a simulation model where user can input velocity and angle. On top of that, it also has an exercise page where user can have a quiz up to 5 questions. While it has the same goal as this research, it does not offers multi-user or group interaction like in turn-based game. There is also research done by [11] and [12] that is a video-based lesson which is also much less interactive.

This study also is a continuation of previous research where it uses Augmented Reality (AR) [12] with the different aim that is omitting the AR element but heavier emphasis on the game element which makes it more interactive and competitive. This app also gives random angle and allow players to move their canons, giving their opponent a much-complicated way to attack. While the game is turn-based however it can be played as first come first serve giving and an option for group versus another group to play.

### 2.2.2 Existing App in Public Store

Upon typing "projectile motion game" as the keywords, as shown in Figure 2, we have been shown several results [13]. Several applications are simulation-based such as "Projectile Motion for High School Physics" by Matthew Craig, "Projectile Motion Simulator with Air Friction" by AERDEMIR, or "Projectile Motion Simulator" by Yazan Apps. These simulations receive various kind of inputs and then 'simulate' it for the user can see the results.

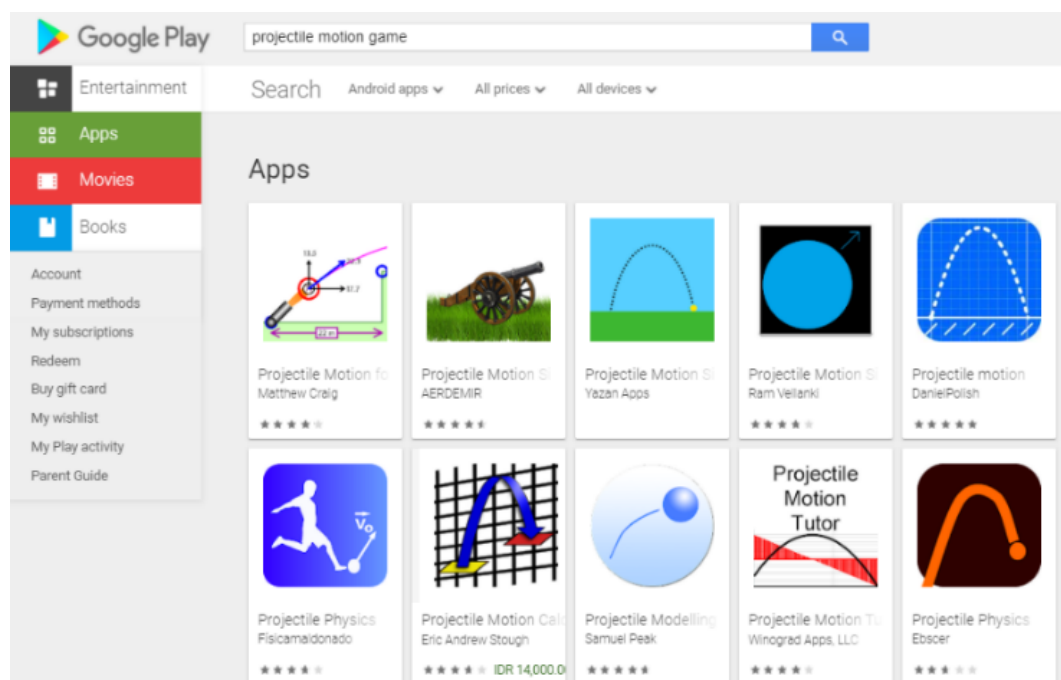


Figure 2 Google's Play search result for "Projectile Motion Game" keyword [13]

A different application is a calculator-based app. The app runs as a compact calculator where user can input various of variable and gives out trajectories, coordinates, times, flight speed and many more, such as "Projectile Motion Calculator" by Kids Code Pro and another one with the same title by Eric Andrew Stough.

All these applications are non-game based, thus giving our research application a different way and a much more interactive way of teaching or learning projectile motion.

### 3. RESEARCH METHOD

#### 3.1 Methodology

The study uses the approach of the Waterfall model, as this method has a very clear way of data gathering, preparation through execution. Scientists may also use this approach in rendering implementations such that the data obtained are more effective and of higher quality. Here are a few steps in the Waterfall model [14].

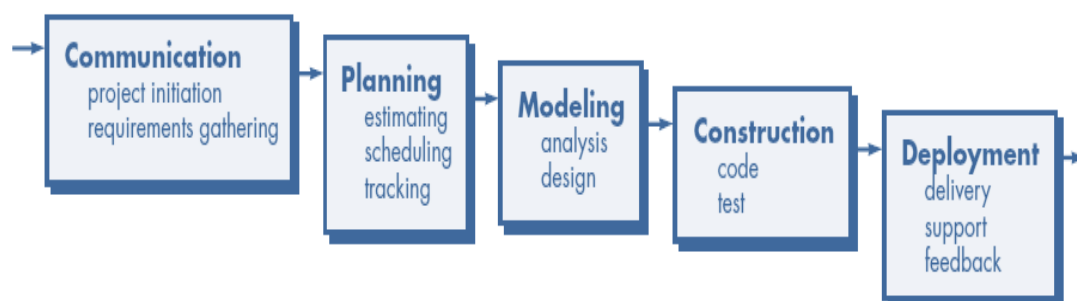


Figure 3 Modified Waterfall Model [14]

The following is the steps to be taken in the Modified Waterfall:

#### Communication (Project Initiation & Requirements Gathering):

Before starting the technical work, a conversation with the user is important in order to understand and attain the goal. The result of this interaction is project initialization, such as question analysis. The consequence of this correspondence is a configuration of the project, such as reviewing the difficulties found and gathering the necessary data, as well as helping to identify the program functions. At the same time, we may also take additional data from journals, posts and the internet.

#### Planning (Estimating, Scheduling, Tracking):

The next stage is the planning stage which covers the estimation of technical tasks to be performed, the risks that can occur, the resources needed to make the system, the work products to be produced, the scheduling of work to be carried out, and the tracking of the system development process.

#### Modelling (Analysis & Design):

This stage is the system architecture design and modelling stage, which focuses on the design of data structures, software models, user interfaces, and program algorithms. The goal is to understand better the overall picture of what is to be done.

#### Construction (Code & Test):

This construction stage is the method of converting a concept form into code that a computer can translate to. When the coding is complete, the program and even the code that was made can be checked. The goal is to recognize errors that can occur to be corrected later.

#### Deployment (Delivery, Support, Feedback):

The deployment phase is a customer-based deployment stage of the program, routine program servicing, software upgrade, product review, dan feedback-based software development so the system can continue to work and evolve according to its functions.

### *3.2 Conceptual Framework and Use Case Diagram*

The following are the Conceptual Diagram steps that are shown in Figure 4:

1. The application will start with at least two players unless the single-player want to practice by him or herself.
2. They can start the game, and the app will generate several variables with random values: the angle and the location of the cannons.
3. The user then has to input the velocity based on just those two given variables.
4. Once set, the application will calculate through its algorithm and will render the simulation by using a valid physics equation; thus, it is a realistic simulation.

5. The app then will update the score (or in this case the lives of the attacked players) if the projectile collided with the targeted cannon.
6. If the lives reach zero the game will be over.

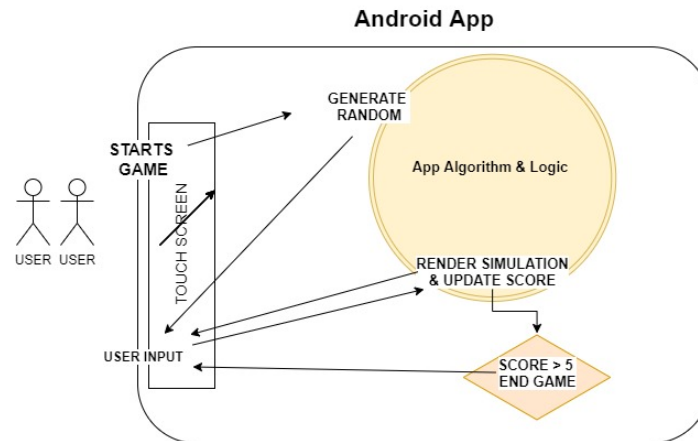


Figure 4 Conceptual Framework

As for the Class Diagram of the application, it has “Play”, “How to Play”, “Audio On/Off”, “Lesson”, “About” and “Exit” while inside “Play” user can access the “Launch Details” part.

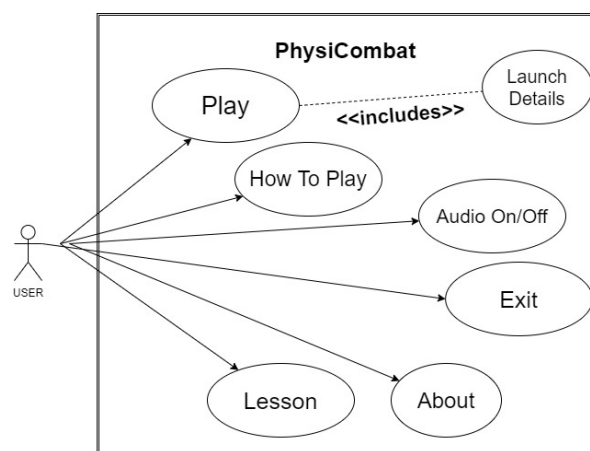


Figure 5 Class Diagram of the Application

### 3.3. Application Development

The research uses the Unity 3D engine, a well-known game development application, to create the application including the menu, logic and objects. There are actually two 3D objects that are the cannon and the wall. A field is a 2D object that is stretched. Scene of the Unity 3D can be seen in Figure 6 below.

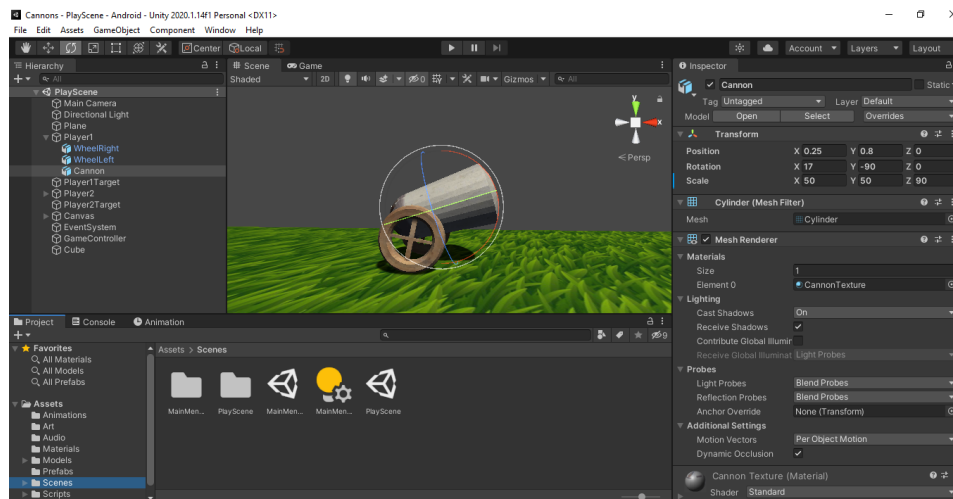


Figure 6 Application Development on Unity 3D Engine

#### 4. RESULT AND DISCUSSION

The application is build using Unity 3D version 2020.1.14f1 and currently available for Android-based smartphone only. The APK can be downloaded at <https://bit.ly/physicombat>. The design may still need to be updated, but the function and the current interface is very usable.

##### 4.1 Equation in Scripts

The program uses a real physics equation; therefore, it can give a realistic simulation. While the projectile motion equation is shown on equation (1), (2) and (3) yet for the actual program, we use a different equation that is provided by [15]. The equation as follows:

$$H = R \tan \alpha + \frac{1}{2} \times \frac{G.R^2}{v_0 x^2} \quad (4)$$

From equation (4) we can move the  $V_0 X$  to the left side, instead of the H.

$$\begin{aligned} \frac{1}{2} \times \frac{G.R^2}{v_0 x^2} &= H - R \tan \alpha \\ \frac{G.R^2}{v_0 x^2} &= 2(H - R \tan \alpha) \\ \frac{1}{v_0 x^2} &= \frac{2(H - R \tan \alpha)}{G.R^2} \\ v_0 x^2 &= \frac{G.R^2}{2(H - R \tan \alpha)} \\ v_0 x &= \sqrt{\frac{G.R^2}{2(H - R \tan \alpha)}} \quad (5) \end{aligned}$$

Once we got the  $V_0 X$  we can go ahead and find the  $V_0$ , which is the velocity. To do this, we use the equation  $V_0 X = V_0 \times \cos \alpha$ . Therefore  $V_0 = V_0 X / \cos \alpha$ . We can modify the equation (5) to accommodate this into:

$$v_0 = \frac{v_{0x}}{\cos \alpha} \quad (6)$$

This equation (6) will produce the same result if it is done with equation (3). However, students may use equation (3) as it is much simpler to do. As for the script, we use equation (6) since we use the script provided by [15]. Partial of the script is as follow:

```
// shorthands for the formula
float R = Vector3.Distance(projectileXZPos, targetXZPos);
float G = Physics.gravity.y;
float tanAlpha = Mathf.Tan(LaunchAngle * Mathf.Deg2Rad);
float H = TargetObjectTF.position.y - transform.position.y;

// calculate the local space components of the velocity
// required to land the projectile on the target object
float Vz = Mathf.Sqrt(G * R * R / (2.0f * (H - R * tanAlpha)));
float Vy = tanAlpha * Vz;
```

Figure 7 Partial script showing how the equation used in coding

Description of the variable is the following:  $R$ , like the equation, is to distance between the first position and the target position, this is acquired by using the “distance” properties of two positions: current and target.  $G$ , also similar to the equation, is the earth gravity in meter per second, taken from an existing variable. Since both objects have the same y-axis,  $H$  would always be 0.  $\tan \alpha$  would be the  $\tan \alpha$  part, and  $V_z$  is the  $V_{0X}$ .

#### 4.2. Menu Interface and Gameplay

Figure 8 is the Main Menu where user can choose “Lesson” where it shows about projectile motion and how to calculate the velocity by using the distance and angle. They can also choose “How To Play” where it shows how to play and win the game. The user also chooses “About” for the author information and “Sound On/Off” to turn on or off the sound and background music and “exit” to exit the application. Other than those users can choose “Start” to play the game.

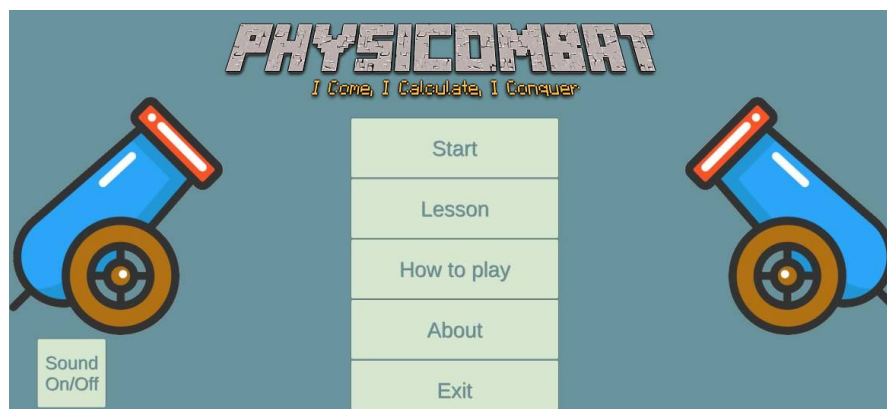


Figure 8 Main Menu

On Figure 9 we can see the in-game interface. There are two cannons for each session with 5 Lives each. The game also generates a random location for each cannons. The exact location is shown on the bottom left and bottom right of the screen. The number shown is how



far each cannon from the center. These pieces of information are where they will get the “R” or total horizontal distance in meter. While Player 1 always starts first, anyone can be Player 1 if they can calculate the first launch velocity.

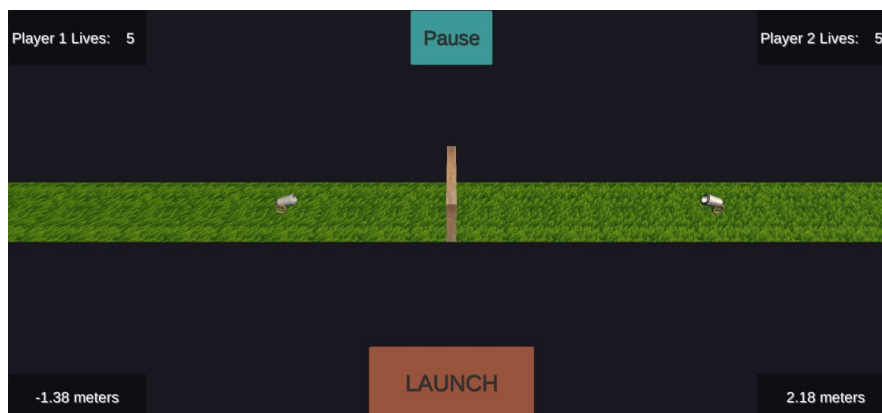


Figure 9 The match interface

On Figure 10 we can see the “Launch Details”. User will be given a random angle (to prevent them using the same angle over and over again), and after inspecting the distance, that is the location on both bottom corner user will have the distance. Then by using the equation (3) or (4) and (5) they can try to answer by putting the velocity. However, since the velocity is in km/h, they have to convert the result from the equation from m/s to km/h by multiplying it with 3.6.

The user also has the option to move their cannon by putting a value in “move”, it can be from -10 to 10 that is 10 units to left side up to 10 units to the right side. The move will be made after launching. The moving ability gives the player some dynamics so that the distance will not be the same on each turn. The user then can launch the cannonballs once ready, and it will be the other player turn after that.

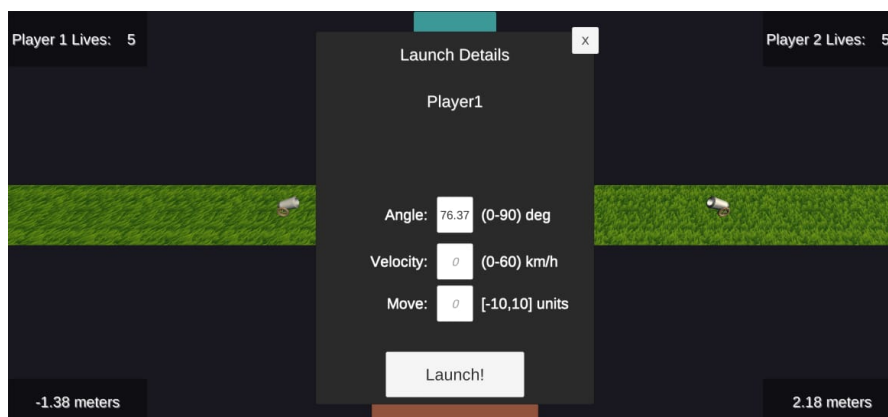


Figure 10 Launch Details

If the cannonball collided with the opponent's cannon, then their lives will be deducted by one. Whoever able to hit their opponent five times first will be declared the winner. Figure 11 show how the projectile launch and the game over a scene showing Player 2 won the game.

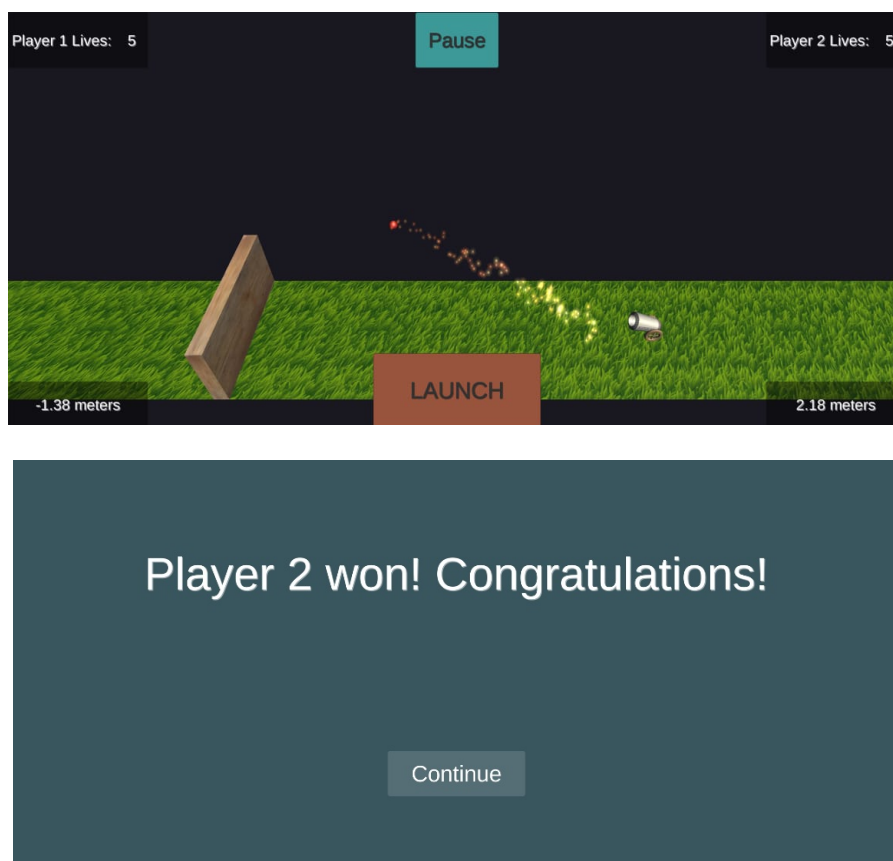


Figure 11 Launch Animation and End of Match

Users can also pause the game and choose the “Lesson” or “How to Play” menu or go back to “Main Menu” on a panel that appeared when it being paused as seen on Figure 12 below.

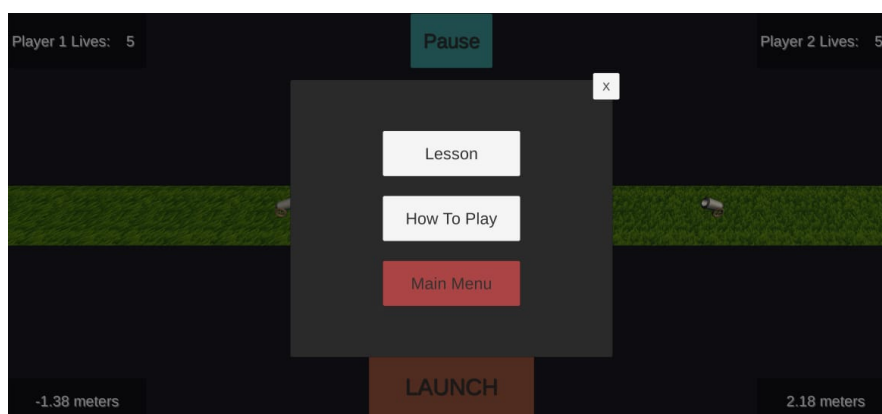


Figure 12 Pause Menu

#### 4.3 Testing

Testing is conducted to try all the function of the application. Unfortunately, we are unable to test the app on school due to the COVID-19 pandemic that causes all middle and highschool nearby closed. However, we have tested all the features and make sure that all

features are function properly and bug-free. Below are the features and results of each test conducted.

Table 1 Features Testing

No	Features/buttons	Description	Output
1	Start Menu	To enter the match screen	OK
2	Lesson, How to Play and About Menus	To display the “lesson”, “how to play” and “about” information	OK
3	Audio On/Off	To turn on or turn off the music and sound effect	OK
4	Inputting via the Launch Details Panel	To input the velocity and move units before launching the cannonball. The input has to be within the limit described in the panel	OK, warnings are displayed if the input is not within the limit
5	Launching and Logic Test	First is to calculate the force for the cannonball to simulate the projectile motion correctly secondly is to reduce 1 life of the opponent if it collides with the opponent’s cannon.	OK
6	Pause Button	Display how to play and exit to the main menu	OK
7	Exit Match and Exit Game	Exit the match or/and then exit the game	OK
8	Game Over Scene	Display and end game if any of the player lives reach 0.	OK

## 5. CONCLUSION & FUTURE WORKS

With a real physics equation implemented within the program, the game able to simulate a realistic simulation and while learning the relation between angle, velocity and point distance, students have the chance to play the game which might give them a sense of fun instead of the burden of studying. While such statement still needs to be proved on another research, this application has shown all the game elements that are shown in a turn-based projectile launcher game similar to the Angry Birds game, a game concept that is proven popular for youngsters.

In the future, we would like to take this to several classes in high school and have them try it and evaluate it. We also would add several attributes such as wind and different height (currently H is always 0) which might give more challenges to students in playing the game.

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