Final Project - Draft Report

3D Graphics & Animation
Physics based Game

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July 2024

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I Introduction

Overview

In this part of the preliminary report I will try to explain and present the project concept and motivation for the project. It is stated in requirements that this “Introduction” part can be based on our project proposal video. However, that assignment had a certain extent of literature review and other requirements which overlap with later parts/sections (“Literature Review” and “Project Design”) of this report. In order to avoid repeating myself I will address those requirements in appropriate sections and in the “Introduction” section I will focus on my personal motivation and how the idea for this project was born. Another thing that is important to mention is that these sections were individual peer review assignments and are now merged (obliged to page-limit rule) into one document “Preliminary Report” which is why referencing/citation that existed for each individual section was moved to the end of this report.

P.S. In order to avoid self-plagiarism, I must mention that I have already developed an app/website for studying physics for my Agile Software Projects (ASP) assignment. Since the motivation (teaching/studying physics innovatively) behind these **different** projects is more or less the same, explanation for my motivation might correspond to a certain degree to the “motivation” I submitted for my ASP project.

3D Game for Physics learning

I would like to present to you my project idea for the “Physics based Game” which is a final project idea from the course/module “3D Graphics & Animation”. As a physics lover, student and also a tutor, I have encountered various situations that negatively affected the learning process. I will try to present key moments/situations that shaped the development of this idea and helped it “mature” in my mind. These moments can be observed from two different perspectives: me as a student and me as a tutor. That is also the way I would like to group and compile those experiences so that I can clearly present the trajectory of idea development in chronological order.

Firstly, I would like to present/list situations that I have experienced as a student and which made me think that lessons could be delivered in a better (more engaging) way.

Below is the summary/compilation of situations that I experienced as a student of physics:

- Dry Theory - Many times my classmates and I were overburdened with "endless" theory that lacked practical examples which would depicture/illustrate potential applications of those physics concepts
- Iterative approach - with different teachers I have experienced the opposite problem from the previous. Namely lessons were focused on solving countless worksheet problems without having proper theoretical background
- Laboratory focused - At first glance this one seems to be better since it focuses on interaction with real-life problems. However, failing to combine it with underlying theoretical background leaves students with superficial knowledge.
- Absence of systematicity - systematicity can be very important especially when it comes to teaching how ideas were developing through history and how they were intertwined and mutually conditioned. Absence of systematicity leaves the student without deeper insight.

Even as a student I was aware that it is impossible to make a perfect lesson that is suitable for every student. This was proven when I myself became the tutor, which allowed me to see things from the opposite/different angle. While I was a tutor I worked with K12 students individually and in small groups.

Below is the summary/compilation of situations that I experienced as a physics tutor:

- Unable to apply knowledge - many students were well-versed in reciting theory but lacked math knowledge and creativity to apply theory in practice
- Superficial knowledge - some students were able to solve only simple problems that required applying formulas by substituting values. This is due to lack of knowledge about underlying theory
- Incoherent knowledge - some students who were familiar with physics principles and were inclined towards natural sciences had "fragmented" knowledge because they lacked consistency in studying

Some of the above-mentioned issues were addressed in the project that I developed with my team for ASP but some of the issues were not solved in the best possible way. In the meantime I became aware of other problems and their potential solutions. Things started falling into place when I took courses related to Unity real time engine (3D Graphics and Animation, VR and Games Development) and started reading research about "Learning sciences". This is when the culmination of previous experiences led to an idea to develop a "Physics based Game" that will teach physics through gaming. In the next chapter of this report ("Literature Review") I will address my previous work and pieces of work that helped the idea for this game to form/conceive.

II Literature Review

Introduction (Overview)

In this document I will present the literature review for my Final Project. As already mentioned in the “Introduction” document (Project proposal) I will develop a “Physics based Game” which is a project idea for the course “CM3045 3D Graphics and Animation”. My game will be a 3D platform game that teaches physical principles in a fun and entertaining way while providing appropriate background theory and formulas which can be applied in game in order to overcome the “puzzles”. In this way students can go through the game both intuitively and studiously, which should keep them engaged and focused for longer periods of time while learning spontaneously (without even thinking/realizing that they are studying).
Since this is a novel approach to studying physics (studying physics theory through gaming) and there are not many sources/research on this specific approach, my literature review will be mainly focused on other games that use/apply/utilize physics. Besides other games this literature review will also cover an application that I developed (for Agile Software Projects) for studying physics and also a research article about the needs of modern education. In the end I will show the table which will clearly present strengths/deficiencies and allow us to see what is the intersection for all positive and negative sides. This intersection will be the area on which my project/game will build upon.
Every piece of work has positive and negative sides depending on the angle (perspective) we are observing from. Therefore examples below will be observed and judged based on:

1) How engaging/entertaining this game is thanks to physics
2) Is it gratifying and if it is in what way/terms
3) How intuitive (easy to understand and pick up) physics concepts are
4) Understanding of the individual phenomena and retained knowledge

Based on how physics is utilized in games, we can divide games into several groups. Below are the groups, their representative and their reviews:

GTA - Grand Theft Auto

[1]Grand Theft Auto is one of the most famous and one of countless games that incorporate physics in order to make it more exciting and engaging but not necessarily to teach physics. That is why I chose it as a representative for this “group” of games.

- This game (type/group of games) showcases exceptional 3D open-world design with realistic graphics and utilizes almost every aspect of physics, which makes it a highly engaging and immersive experience.
- GTA relies solely on the player's natural (intuitive) comprehension of the world which means that it combines different/various physical principles just for the sake of achieving realism without any emphasis on teaching specific physical concepts.
- Even though it has a progression system in terms of missions, this game lacks clear learning objectives and structure, which is considered as one of its major drawbacks.
- The game is not practical/accessible for most students due to the high hardware requirements, paid license and the time-consuming nature of it.

Evaluation:

1) Relatively realistic implementation of physics in this game makes it engaging/entertaining because player can try/experiment with things/activities that would be dangerous to do in real life
2) This game offers only virtual (not real) gratification in the form of: accomplished missions, in-game cash, cosmetic items… Even though this type of gratification can be entertaining for some time, in the end the player can be left with a dull feeling (emptiness) and regret for wasted time. More importantly, it doesn't have any gratification for learning physics lessons since it doesn't teach physics at all.
3) When it comes to intuitiveness and easiness of picking up physical concepts, it can be considered easy for learning. There is no steep learning curve since it uses standard game controls and incorporates many aspects of everyday life (which people unconsciously understand even though they can't describe them formally/scientifically).
4) In terms of understanding individual phenomena and retaining knowledge GTA leaves the player with the same knowledge.

Human: Fall Flat

[2]Human: Fall Flat is a representative of a "group" of games that I would like to address and those are games that utilize concrete physical phenomena as one of the key components of the gameplay. This group could also be represented by "Tomb Raider" but it lacks multiplayer.

- This 3D platformer game features realistic levels which are filled with physics-based puzzles and obstacles that players should overcome in order to progress.
- In contrast to the previous group/type, this one is focused on specific physical phenomena, such as gravity, levers and pendulums, among others.
- This game boasts simple yet clear and understandable graphics, which allows the player to concentrate on the fundamental physical principles it teaches.
- A limitation/drawback of the game is that it is solely focused on phenomena without providing an explanation/theory for why and how they occur.
- Another limitation of the game is that some physical phenomena are overemphasized which results in an unrealistic representation of the behavior.
- Due to its simple graphics, the game does not require powerful and expensive hardware. This goes well with the license which is relatively cheap.

Evaluation:

1) Physics and specific principles of physics are the center of the gameplay which makes the player understand the principle in order to progress. This approach and somewhat augmented physics is very engaging and entertaining since it helps the player to spontaneously think about physics problems.
2) Even though this is all virtual, Human: Fall Flat lets the player to play with other people which allows the player to measure himself/herself against other people. It can offer great satisfaction if the player is quick witted and manages to think/conclude faster than other players.
3) Simple yet understandable graphics and emphasis on key components makes this game very intuitive and easy to pick up and play.
4) In certain situations augmented physics can be counterintuitive to some extent, which can lead to wrong perception/knowledge of physics.

Interactive Physics - Physics Lab

Another “group” of apps/games that I would like to address are those that are mainly focused on teaching physical principles and theory without any focusing on entertainment and engagement. For this “group” I chose the app [3]“Interactive Physics - Physics Lab”.

- This application was my idea that was developed for Agile Software Projects. It was developed mostly in p5.js with the idea to graphically represent specific/concrete/”isolated” physical principles/phenomena and to simulate their lab examples.
- Users are allowed to control the experiment by entering numerical values as parameters for the equations which describe the phenomena.
- Each lab/simulation describes one specific principle/phenomena and provides adequate underlying theory and practice examples.
- This app can calculate missing values based on the given values, then it draws a graph that mathematically describes the experiment.
- It can run on any device that has a browser and internet connection.
- It lacks real interactivity which means that the user only needs to enter the values and after that loses “control” because the computer will take over from there and simulate everything based on those values.
- The question that arises is whether this is an entertaining experience. Unfortunately it is not fun to play like video games and therefore it is prone to distractions which can negatively affect the learning process.

Evaluation:

1) Unfortunately this app isn’t engaging/fun to play like video games and therefore it is prone to distractions and mind wandering.
2) Since it provides problems that need to be solved and all required tools (theory, formulas, calculator, graphs…) for solving problems, the user can easily test his/her knowledge and instantly get the results.
3) This app is not intuitive to pick up as video games per se, but it offers clear, concise and short step-by-step instructions.
4) Since this app is not focused on being entertaining, the user has to be self-driven and eager to study which can negatively affect the learning process. This is of course all on an individual basis and therefore retained knowledge can vary from user to user.

OPTIMISING LEARNING
IMPLICATIONS OF LEARNING SCIENCES RESEARCH

[5]This paper is a compilation and analysis of multiple papers which discuss deficiencies of traditional education, required changes and needs of modern education. I will try to condense all findings and address those that are relevant to this project.

This paper analyzes how industrial development and accompanying economical transformations have continually affected and keep affecting education (educational system) up until today. It is pointed out that the traditional model of education (referred to as “standard model”) has a specific structure meaning that it is standardized in a way that teaches progressively from “simple” to more “complicated” things. This model was not founded on scientific facts but simply on the belief that teachers should feed knowledge (scientific facts) to students and teach them procedures (step by step instructions) of applying those facts. Problem with this approach is that students “learn” scientific topics as independent “entities” without realizing how interconnected and intertwined all scientific topics are.

Digression:

This traditional method of procedurally executing tasks (learnt facts) reminds of a movie from 1936 “Modern Times” with Charlie Chaplin. In this movie Charlie Chaplin plays a factory worker who continuously repeats the same movement on a factory line. In certain moments these movements lead to his muscle memory initiating the same movement even when it is not needed which results in looking more like a robot than a human. This is a great example that shows how the needs of the industrial age affected modern day people. This also translates into the educational system of that time which perfectly reflected the procedural/methodical approach to executing tasks (learning/studying).

Since the global economy has shifted/is shifting from industrial to “innovation” economy driving forces of the economy have been changed. This means that resources accompanied by skilled workers are not sufficient anymore. New driving force that comes into the picture and serves as a catalyst for progress and development is “idea”. This research points out that creativity should be stimulated and cherished since it is the best incubator for innovative ideas that drive the modern economy. In order to stimulate creativity all resources at our disposal should be combined. This means that traditional scientific disciplines, modern tools, teachers and students should join forces in order to create a contemporary educational system that will suit the needs of each individual.

This paper/research talks about the needs of education in general and not about the physics (which is often called “mother of all sciences”), but I agree that education requires constant change/evolution and that the best thing that we can do is to try to use all tools that are available in order to create interdisciplinary solutions that will revolutionize education. That is why I intend to use all the tools at my disposal (physics, programming, mathematics, games…) in order to create a modern tool for teaching physics. This tool is envisioned as modular which means that it will be open for future upgrades/updates in order to accommodate constant and ongoing change. Detailed analysis/critique and decisions can be observed in the table below:

Comparison Table

	Utilization of Physics	*Purpose of Physics in the game*	*Learning objectives, structure,goals*	*Gratification and sense of achievement*	*Accessibility / Availability*
GTA	Mixes various aspects of physics	Simulating “realism” of the real world	No learning objectives in terms of physics	There are missions that are not physics related	Expensive but available on different platforms
Human: Fall Flat	Uses specific physics phenomena	Making the game more entertaining	Only intuitive understanding without underlying theory	No objective criteria, only comparison with other players	Relatively cheap and available on different platforms
Interactive Physics	Uses specific / individual physics phenomena	Teaching physics and potential applications	Learning step-by-step from easier to more complex	Solving concrete physics problems	Available on all platforms with a browser
Intersection / Decision	1 puzzle should use 1 physical principle or sensible combination of principles	Teaching physics and its applications in a fun and engaging way	To learn specific physics principles but also how they are intertwined with each other	Should have quantifiable/ measurable reward for solving concrete physics problem	Should be free and available on various platforms (Unity exports supported)

III Project Design

Overview

The game that I am making is a game for studying/learning physics in a fun and engaging way. Overall it is a 3D platformer with a modular design in mind where each level/puzzle is devoted to a certain physics concept/concepts. It will use standard keyboard controls for navigating through the world of physics. Details/specifics are already mentioned in the previous documents “Introduction - Project Concept” and “Literature Review” which will serve as a foundation for the overall/detailed design plan that is presented below.

Domain and Users

This game combines different genres with a singular purpose in mind and that is education in a fun and engaging way. Therefore it can not be classified and put in any of the well-established genres, but we can say that it belongs to the “educational-platformer” genre. As it was shown in “Literature Review”s research paper [5]“Optimising Learning - Implications of Learning Sciences Research” games and different forms of entertainment can be a great learning experience that can help students to “connect the dots” seamlessly.

This game is indeed for a wide audience. The reason for that is that learning has no age limit nor any other limits. It is meant for anyone who wants to learn about physics (theory and practice) but also for people who want to play just for fun since this game (physics concepts) can be picked up intuitively. Still I would like to mention a few categories that will be essential for the testing of this game. These categories were formed (“emerged”) based on the analysis that was shown in the “Literature Review” and the compilation table presented at the end of that document. They are listed below:

1) Pupils that encounter physics as a subject for the first time and have no previous “formal” knowledge of physics
2) Students of various ages that are familiar with basic physics concepts and have studied it in “traditional” way
3) Gifted students who attend specialized schools and attended various physics competitions
4) Physics teachers who teach by using “traditional” methods but are willing and open to test/experiment with something new and give their review/opinion
5) Teachers of gifted students who have experimented with various teaching methods and are willing to compare/review this game against other methods
6) Others (friends, family…), anyone who wants to give their input/opinion and therefore contribute the future development

Design and Structure of the Game

There are several components and key areas that I need to address here and therefore I have decided on the following structure of the presentation:

Feature List

There are many features that are envisioned for this project/game and I would like to present them in a concise and structured way. For detailed analysis and explanations about how the ideas for these features were conceived check the previous two documents “Introduction - Project Concept” and “Literature Review”.

The following is the summary of drawbacks/deficiencies that inspired features that will be presented/listed after:

- Some games that were analyzed lack clear learning structure and plan
- Certain apps don’t focus on specific phenomena/concepts and don’t answer questions “how” and “why” it happens.
- The app that addresses above mentioned issues is too focused on theory and fails to keep the student engaged/immersed which means that it is prone to distractions and mind-wandering
- Most of them lack gratification at the end of each lesson which could symbolize and indicate that lesson was learnt or mastered

My idea/goal is to address the issues that were mentioned by filling in the gaps with new features and to combine them with existing positive aspects of each game/app. This synergy will/should lead to an almost perfect learning experience through gaming. The following is the list of features that I intend to implement:

- Each level/puzzle will focus on certain topic and levels will progress in logical order (from kinematics to dynamic and statics and so on)
- If the player can’t figure out the puzzle intuitively there will be hints that offer detailed explanations and theory
- It is known that games are the biggest distraction, and that is why this game will keep the student away from other distractions. However in order to make the game more dynamic there will be a timer that gives extra points for each second left at the end of every level.
- Student/player will also be able to earn extra points for every hint that was not opened because he/she managed to figure out the puzzle without assistance.
- Scorelist and grading - at the end of each level student will be informed about the earned points. Based on this, student will be graded and informed if he/she needs to work on certain aspects.

Game Layout

Every game/app needs to be carefully designed and therefore a specific layout should be tailored to suit general needs and needs that are specific to that app/game only. Firstly I would like to address the general layout that is more or less the same for every game. The following is the overall design/structure of the game:

- Main Menu:
    - Play - consists of a sequence of simulations/puzzles/levels that are put in logical order (they will be addressed individually in next section)
    - Options:
        - Controls (this will allow certain customization in terms of key choice)
        - Sound:
            1) Ambient/Background sound
            2) Voice - used for instructions and in-game hints
            3) SFX - special effects for in-game actions
            4) General volume - used for overall control of all sounds
    - Exit - this one is self explanatory

I also need to address the specific layout for this game, which consists of unique puzzles/levels that are themed after correlating physics concepts/principles.
I will list levels that I am going to implement and stretch goals (italic) since the game will be modular and anyone can continue improving/upgrading the game.
The following is the list of levels/puzzles:

1) (Uniformly) Accelerated Linear/Circular Motion
2) Gravity and (Free) Fall
3) Fluid Dynamic
4) Bernoulli's Equation
5) Conservation of energy
6) Stretch goal - Coulomb's law, Momentum, Doppler effect

Technologies used

As recommended I will be using the Unity engine (version: 2019.4.16f1). As other real time engines it has many built-in functionalities/tools. However for certain features I will need some external tools/assets that can be created or imported.

- C# - writing scripts/components
- Physics formulas (custom algorithms) - when Unity's built-in engine lacks support
- Visual Studio Code (code editor)Visual Studio (IDE) - editing/debugging code
- Plastic/Github/Git - source code management and version control
- Blender&ProBuilder (Unity package) - to make models/assets and to supplement asset store
- External assets (asset store) - will be used in case that there is no appropriate alternative
- Post Processing - will be used to achieve more polished look/appearance

In case that the above mentioned tools are not sufficient, alternatives will be used and they will be addressed in future reports ("Draft Report" and "Final Report").

Evaluation Strategy

When it comes to video games it is very important for them to be tested early and if possible with real players. That is why I intend to start testing the game early which can be seen in the work plan. This will help me to spot bugs and to get valuable input in case that I missed something. However since this game is of educational character it is more important to test its results and findings in terms of conveying knowledge to users/players.

This user testing will be done by asking each user/user group (mentioned above) appropriate/relevant questions. Questions will be given in a form of a tailored questionnaire on Google Forms and results will be compiled, analyzed and presented in the Final Report.

The following is the list of questions that will be asked as part of user testing:

1) What aspects of the game did you find the most/least enjoyable?
2) Would you rate this game as easy to pick up and play?
3) Did you find the User Interface easy to navigate?
4) Are you satisfied with the available level of customization (if not what is missing)?
5) Is the game dynamic,engaging and fun to play?
6) Were you able to anticipate/intuitively guess physics concepts without using hints?
7) Were hints and background theory helpful enough to “solve” the puzzles?
8) When does the kinetic/potential energy have the highest value?
9) Would you include/add this game/tool into your “regular” teaching methods?
10) How can your students potentially benefit from using/playing this game?
11) How can gifted students potentially benefit from using/playing this game?

Disclaimer: Due to the word limit for each section, all questions are listed together, but they will be carefully selected and tailored for each user group.

Work Plan

The plan is slightly adjusted to accommodate the needs of delays due to technical issues(2 weeks)

Week 1	Week 2	Week 3	Week 4	Week 5
Setting up version control and pushing existing prototype	Implementing “(Uniformly) Accelerated Linear/Circular Motion” puzzles	Implementing “Gravity and (Free) Fall” puzzles/levels	Dealing with the backlog and potential bugs from previous level prototypes	Implementing “Fluid Dynamics” puzzle/level
Topic 8 Check list	Finding/creating appropriate assets	Testing prototype from the previous week	“Draft Report” and “Topic 9 Check list”	Finding/creating missing assets

Week 6	Week 7	Week 8	Week 9	Week 10
Implementing “Bernoulli's Equation” puzzle/level	Dealing with the backlog and potential bugs from previous level prototypes	Implementing “Conservation of energy” puzzle/level	Implementing: main menu, options and unifying levels.	Reserved for polishing the project and dealing with any potential backlog
“Topic 10 checklist”, Testing prototypes	Start working on “Final Report” and user testing	Working on report, polishing assets, user testing	Final Exam, Working on report	Finalizing user testing and submitting “Final Report”

IV Implementation

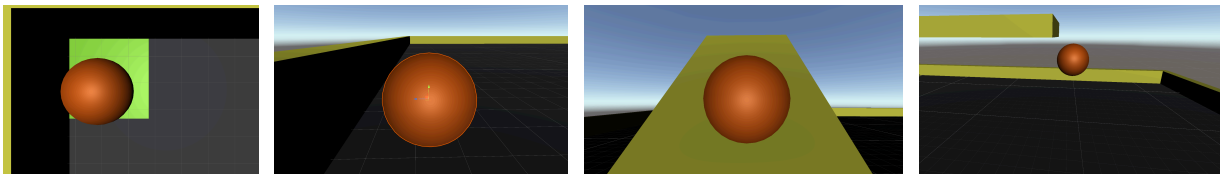
I would like to give you a presentation of my prototype for the Final Project “Physics based Game” called “Interactive Physics”. Inspiration and evolution of the idea for this project was already explained in previous chapters of this “Draft Report” but here I would like to present to you the first prototype for this project.

Namely this game is envisioned with a somewhat peculiar layout. This means that each level or puzzle represents a specific or concrete physics principle/phenomena or, in some cases, logical/sensible combinations of principles. Requirement for this assignment is to show the implementation of one of the most important features that are used in the project. However, since each level represents specific physics phenomena it is difficult to say which are the most important. Therefore, I will focus on describing what I have implemented so far. In order to solve this I have decided to implement several “semi-functional’ levels which include several physics principles (one principle per level) and showcase them one after another. Each of these levels is envisioned as sort of a sandbox or in other words an isolated experience. This means that each phenomena/level is a standalone experience which adds modularity to the project. This property is beneficial for several reasons. First of all, modularity is always considered to be a good practice in software engineering. Secondly, from physics perspective it allows student/player to focus on certain/desired physics principle and gradually progress towards more complex phenomena. Lastly, it opens the door for countless modifications/tweaks and prospective upgrades/updates. I believe that this way of presentation is a good choice since the final version of the game will consist of multiple “sandboxes” and principles shown in this prototype along with some other principles will also be assigned to individual “sandboxes”. I would also like to point out that inspiration for this “sandbox” experience came from the assignment “Interactive Physics Scene” in the course “3D Graphics and Animation”. That is why I used that assignment as a foundation layer for this prototype.

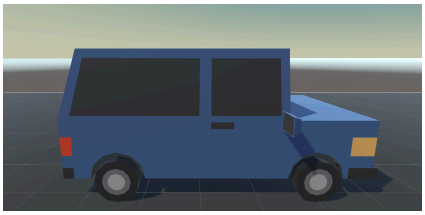
As it could be seen in the video that was submitted for “Project Proposal”, and in the screenshots below, the player takes the role of a physical body (material point) ,represented by a sphere (Unity’s 3D object), which is a common model in physics. Player can navigate the ball in four directions (up/forward, down/backward, left, right) by using standard keyboard controls (arrow keys or WASD keys). Besides the ball/sphere model, I am currently experimenting with an alternative model which would be a car. Reason for that is that it would make the experience more immersive (that can be achieved with a thoughtful implementation of cameras). However, for the sake of focusing on specific phenomena and for the sake of providing the same experience with both models (ball and car) I intend to keep a spherical collider and rigid body on the car model. In that way the car will add to the overall immersiveness but keep the properties of the ideal physical body (material point). At the beginning the ball has specified constant velocity that allows it to move uniformly. With that velocity the player can overcome most of the challenges/obstacles but in case that he/she needs/wants to go faster/slower the player should press the SPACE/CTRL key. Each press of these keys will increment/decrement the speed for a fixed value. Besides velocity and acceleration manipulation, the player can

manipulate/control other properties (mass, density, volume, coefficient of friction…). Each property manipulation is available on corresponding/appropriate level (e.g coefficient of friction is available in level about accelerated motion). In this prototype player can experience several phenomena (e.g uniform linear motion, acceleration, non-linear motion, seesaw, gravity…). Each level/sandbox has a starting and finishing position. Goal is to reach the finishing position by solving the puzzle which requires the correct implementation of the physics phenomena. Reaching the finish line of each level opens/unlocks the door for the next puzzle/sandbox. Level progression goes as follows (more will be added in the final version):

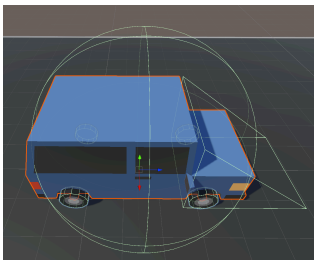
1) Uniform Linear Motion
2) Uniformly Accelerated Motion
3) Uniformly Accelerated Motion (with friction)
4) Circular Motion with corresponding forces (centrifugal and centripetal)



Pictures (1-4) - Ball model performing different physics phenomena



Picture 5 - Car (model from Unity)



Picture 6 - Spherical Collider for a car

When it comes to implementation, the game opens with the “Main Menu” screen which consists of basic options: tutorial, play, settings and exit. Tutorial and settings sections are still in development but have some working features (e.g. toggles and slider for controlling the light and volume of placeholder music). I used Unity UI (uGUI) for developing the Main Menu and in-game menu (floating screens). In game floating screens have no interactivity at the moment and they are there as placeholders. These screens will be used for tracking score, displaying the timer, showing hints and explaining physics phenomena if necessary. After the player chooses the “play” option in the Main Menu the first level appears and the game begins with the level progression that is described above.

Picture 7 - Main Menu Picture 8 - Settings Picture 9 - Resetting scene

I have also used Unity's input system that communicates with scripts that are controlling the ball. Control is achieved with appropriate manipulations/transformations of the Vector3 system. These manipulations are achieved by applying appropriate formulas for each physics principle. In the final version I intend to implement some of the following: fluid dynamics, Bernoulli's equation or Dopler's effect. This will require careful implementation of more "complex" algorithms/equations in order to convey the logic behind these principles but without delving deep into particle based fluid simulation.

Obviously this is a low fidelity prototype but I still wanted to test it in terms of user experience. I have tested it with my parents that have no experience with gaming but have a "decent" level of physics knowledge (father is a mechanical engineer). Since they are familiar with ARROW keys (from using Office and a browser) they picked it up relatively easily. They intuitively guessed what will happen with the elements that are exhibited in the prototype. In the end they suggested that I should create a nice environment that will be more appealing to a wider audience and they also suggested that levels should be thematically designed. Meaning that each puzzle shouldn't only be focused on the principle but also it should address the background story (inventor/scientist who invented/discovered the principle and how it was discovered).

This can be achieved with careful design in mind but I decided to leave it as a stretch goal and I will implement it only if the time allows.

As I have already mentioned this is a low fidelity prototype and it requires redesign, both audio and visual.

In terms of visuals I intend to implement assets of higher quality and more appealing design. This means that the experience will be enriched with appropriate particle effects, animations and thoughtful camera play/manipulation. Also I will upgrade the user interface so that it has a main menu and all sub-menus. In-game there will be a button that the user can click if he/she wants to use a hint. Besides this button there will be a clear interface that will show formulas/theory and also a score counter with a timer.

Last but not the least I need to work on audio which was not implemented in this prototype since I am still experimenting with ball and car models and how they interact with the environment. Therefore, it didn't make much sense to invest a lot of time into audio design for the features that might not end-up in the final version. As addressed in previous sections of this report audio will consist of ambient music, voice instructions and special effects.

V Evaluation

When it comes to evaluation I should first clarify some things that are specific for this project template and by extension to my project idea. Since this project uses the template “Physics based Game” from the course “3D Graphics and Animation” and I have envisioned it as an entertainment/educational genre I intend to do both technical testing and user testing. This approach is important for two reasons. Firstly, it will help me to gauge how effective it is when it comes to its main purpose (education through entertainment).Secondly, it will allow me to test whether it is technically sound, which can be challenging since my target audience uses a wide range of devices with different technical capabilities. Therefore, technical testing won’t be strictly done by me but it will also be closely intertwined with user testing by seamlessly incorporating related questions into forms which are provided for user feedback. Below I will explain both technical and user testing, how they are done, at what stages of development and to what group of users are different aspects of these tests related to.

Technical Testing

As mentioned above this aspect of testing consists of two parts:

i) **Testing that I do by myself**.

- As I stated before, each level of this game is devoted to a certain physics principle and therefore envisioned as an “independent” sandbox that is a part of a greater whole. This means that each level can be considered as an independent unit that can be added or removed from the game at any time. This is why I intend to test each level independently as a separate unit in order to test the modular aspect of my game. At the time of writing each level is a “bundle” of game objects that are sensibly organized together. However, as I approach the end of development I intend to test whether putting each level as a separate scene is more appropriate in terms of achieving modularity (important for possible future updates/upgrades). These findings will be included in my Final Report.

- Another important aspect of technical testing that I need to address is system requirements. I can’t expect all of the users (who participate in testing) to be tech-savvy therefore I have prepared several generations of devices (desktop PCs and Android phones), that range from decade old to the last generation devices. However, users will have the optional question that allows them to write the specifications (screen resolution, gpu/cpu or phone model) of a device they are using and how well the game runs (min/max and average fps). This testing will be compiled together with the feedback gathered in the questionnaire (explained in section below) and presented in my Final Report.

ii) **Testing that is incorporated into the user questionnaire**. This part will consist of two types of questions.

- First type are questions that can answered on a 1-5 scale (disagree, partially disagree, neither agree nor disagree, partially agree, agree) and those are:
    1. Game runs smoothly without sudden crashes.
    2. Game and UI scale appropriately (looks proportional and symmetrical on my screen/aspect ratio)
    3. Audio is synchronized with in-game actions/events.

- Second type are optional and open questions:
    1. State your screen resolution, gpu/cpu or phone model, RAM, OS.
    2. List minimum, maximum and average FPS.
    3. If you feel that something requires a more detailed explanation feel free to write any observations, feedback or comments that you deem important.

User Testing

The main target user groups were already mentioned in this report in the section "Domain and Users," and it is obvious that the majority of users are students and teachers. However, once the development phase of the Final Project started this semester, schools went on summer vacation. Therefore, my testing with these two groups has been somewhat limited up until this stage of development, and I have focused more on the other groups of users. As summer vacation is coming to an end, I intend to test it with students and teachers more extensively before my final iteration, which should give me enough time to analyze and compile findings and include them in my Final Report.

Earlier in this report, in the section "Evaluation Strategy," I compiled a list of questions that will be given to users in the form of a questionnaire. For each user group, I tailored a questionnaire suitable for that group. This was achieved by carefully choosing the appropriate questions from the list, adding some new questions, and including technical questions (mentioned in the section above).
For the sake of clarity, each questionnaire consists of: ***general questions*** *+* ***group specific questions*** *+* ***technical questions****.*

Firstly, I will list **general questions** (answered on a 1-5 scale) that each user group will get:

1. Game is dynamic, engaging and enjoyable to play.
2. Game is easy to pick up and play.
3. User interface is easy to navigate.
4. I was able to anticipate/intuitively guess physics concepts without using hints.
5. Hints and background theory were sufficient enough to "solve" the puzzles.
6. I would like to play this game again and explore future updates/topics.
7. Game looks visually appealing.

Lastly, I will present the questionnaires for each user group (**group specific questions**) below:

- *Pupils that encounter physics as a subject for the first time and have no previous "formal" knowledge of physics*
    1. Game makes physics more interesting than I had imagined.
    2. Game makes me confident/excited about starting my physics journey.
- *Students of various ages that are familiar with basic physics concepts and have studied it in "traditional" way*
    1. Game makes it more interesting than studying from books.
    2. Game is more interesting than traditional lab exercises/experiments.
- *Gifted students who attend specialized schools and attended various physics competitions*
    1. Game is more engaging than traditional learning methods (books and labs).
    2. Game enables me to experiment/explore in a risk-free environment unlike traditional labs.
    3. I am curious to explore/expand the game by "exploiting" its modular design.
- *Physics teachers who teach by using "traditional" methods but are willing and open to test/experiment with something new and give their review/opinion*
    1. Theory presented is sufficient and succinct enough for covered topics.
    2. Each level provides enough time for understanding and solving the puzzle.
    3. I feel that students can grasp physics concepts faster by playing this game.
    4. I would include this game into my "regular" teaching methods.
- *Teachers of gifted students who have experimented with various teaching methods and are willing to compare/review this game against other methods*
    1. Game successfully creates synergy of various teaching methods.
    2. I feel that this game can be mentally stimulating for gifted students.
    3. I would include this game into my "regular" teaching methods.
- *Others (friends, family…), anyone who wants to give their input/opinion and therefore contribute the future development*
    - There are no specific questions for this group. Based on their familiarity with physics they are given one of the previous questionnaires.

As I mentioned before I was somewhat limited when it comes to testing due to summer vacation therefore I will present below suggestions that I have received so far and that I intend to address (full compilation coming in Final report):

- Make relevant physical quantities/units visible at all times (in real time)
- If the player is inactive for a few seconds, indicate the hint button.
- Allow (in-game) transition between the ball and the car model on a click of a button.
- Add appropriate sound effects and ambient music.
- Implement showcase ride/solution for students who can't solve it on their own.
- Add optional narration for tutorial, hints and theory (stretch goal)
- Implement learning pathway in a form of a tree (stretch goal since game lasts 5min)
- Add high scores & leaderboard for competing with friends/classmates (stretch goal)

VI Conclusion

At the end, I would like to devote a few words to my project/prototype and measure where it currently stands against the envisioned goal.
Currently, I have developed several individual levels/sandboxes and I am satisfied how development is progressing. It seems that the game is starting to take the shape of the envisioned product/experience. At first I thought that it might be just me because I am the author of the game and I have personal attachment to it. However, after receiving feedback (somewhat limited so far) I am sure that users understand and see what my goal is. Their feedback convinced me that both users and I are looking in the same/similar direction.

Most of the feedback is realistic to implement but there are few points that are not manageable due time constraint (gameplay needs to be 5 minutes long). Therefore, suggestions that don't fit into project constraints/limitations are left as stretch goals which should/can be addressed in the future updates. This shouldn't be a problem considering, several times mentioned, modular design. One of the suggestions that I haven't mentioned in the "Evaluation" section is that I should implement game difficulty by allowing users to have more or less time per level. I haven't addressed this due to obvious time-limitation.

All in all, I am satisfied with the direction my project is heading because suggestions I have received so far clearly indicate that I have sparked interest in my target audience and they feel the need to contribute with their input. If everything works out, after finishing this course, I would like to leave this game as an open source project where others can contribute as well. This would speed up the development time and allow the game to cover the whole physics curriculum. Besides that it would also be a subject to the test of time which is the only benchmark for how far this idea can evolve. About that and more I will write in my Final Report.

VII References

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P.S.

For referencing I used ACM style as required for this assignment. I used the provided link for rules and instructions:
https://onlinelibrary.london.ac.uk/sites/default/files/files/guides/ACMGuide.pdf
I have two different types of references: “World Wide Web” and “Conference proceedings (Published)“. Therefore I am listing the rules (check the link above) for citing these two types of references:

World Wide Web

Rule: Author. Date. Page. Title. URL.

Example: GRIFFIN, A. 2017. Human embryo editing. Human embryo editing breakthrough is a ‘major advance’ towards controversial treatments for babies. http://www.independent.co.uk/news/health/human-embryo-editing-crispr-9-babytreatment-advance-paediatrics-designer-babies-a7873746.html

Conference proceedings (Published)

Rule: Authors. Title. in Title of conference, (Location of Conference, Year), Publisher, Pages.

Example:

P.S.S.

1) I want to add that for websites of games I entered the date of the game/s release even though pages were probably updated after that.
2) For project that I have developed for ASP with my teammates (my team can be checked if needed) I have referenced only my name as the author since I have continued working on that project after we passed the course (link provided is for my updated version)
3) For the UoL logo I was not sure if I should reference University of London as the author or the author of the Wikipedia article. In the end I decided to stick with University of London and year of the mentioned pdf on that page.
4) Link provided by the university for ACM referencing style does not have a clear example on citing “Conference proceedings (Published)” therefore I have added the link to the article that is my source.