Ages 5 - 10 | Design Thinking | Test | Simulation & Modeling | Variable Constraining

Physics | 120 min | Educator's Guide

Catapult Toss

Summary: Learners will apply their knowledge of force and motion by using the Unity3D game engine to simulate catapult tests.

Key Concepts

Force & Motion

Software

Unity

Instructional Objectives

Learners will be able to:

1. Compare the use of force and motion through a simulated 3D catapult test

Learning Outcomes

- Analyze and explain force, motion and velocity using a catapult test simulation
- Utilize simulations of varied masses and forces to influence launch velocity and achieve various objectives

Real World Application

Force and motion are fundamental physics concepts used in engineering.

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1. Lesson Overview

	Activity	Innovation Skill
Introduction (20 min) **Slides 1 – 8**	Introduction to Catapult Toss. Introduce how catapults work as they launch projectiles through the air. Introduce the physics concepts of force, motion and velocity.	
Development (90 min) **Slides 9 – 27**	Catapult tests. Discover how force & motion changes as the catapult launches objects. Monitor how forces are applied at different stages of the catapult toss.	Design Thinking (Test)
	Catapult Challenges. Run through the catapult scenarios to adjust the force generated by the objects. Apply the tweaks to the force and refine the catapult's accuracy.	Simulation & Modeling (Variable Constraining)
Conclusion (10 min) **Slides 28 – 30**	Summarize and conclude the lesson.	

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2. Session Preparation

Logistics

Items
Laptop, Desktop or Chromebook (Recommended: 2 learners per laptop)
Pencils and elastic strings

Installation

1. Install Unity 3D account registration. Install Unity 3D game engine. Extract the Assets folder onto the desktop.
2. Other things to note:
    - For hardware requirements, please refer to the minimum hardware requirements from the software provider.
    - The catapult toss folder must be added into the unity3D hub before the learners can open the folder.
    - Ensure that learners do not try the challenges **(slides 13 - 15)** beforehand. The slides are meant to give learners a competitive challenge.
    - Learners should have Unity3D accounts set up prior to use, and the computer should have unity3D hub installed with the free license activated for use.
    - The pencil and elastic strings are used to demonstrate the catapult **torsion method**.
    - Safety glasses are available for learners.

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3. Activity Guide

Introduction (slides 1 – 8)		
Duration	**Slide**	**Activity**
20 min	1	Introduction to lesson.
	2	Provide learners with an overview of the lesson: ▪ Observe the force and motion acting on a catapult. ▪ Calculate the velocity of the ball. ▪ Experiment with the strength of the force applied to catapult launches.
	3	Ask learners the following questions to establish prior learning: ▪ What is a catapult? ▪ Have you seen one before? ▪ What does it do and what is it used for?
	4	What is a catapult? Learners discover some background knowledge of the catapult, its origins, and uses in history, particularly medieval times, when it was used in warfare to destroy castle walls.
	5	How does a catapult work? Learners can see how the torsion method works by wrapping two lengths of elastic string around a pencil and twisting the string to create energy on the pencil as it spins around. Make sure learners are wearing safety glasses. Get them to hold the pencil down on the table before twisting. Learners discover the torsion method is a way of generating a lot of force on the catapult. As the rope is twisted, the rope's tension forces the arm back, only to be stopped by the top bar of the catapult. As you pull down the catapult and release, it springs back and launches the ball into the air.

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3. Activity Guide

Introduction (slides 1 – 8)		
Duration	**Slide**	**Activity**
	6	Learners watch a short video to learn about force and motion.
	7	Learners find out how force & motion work in a catapult: The torsion rope is used as the driving force to pull the arm back, only to be stopped by an opposite force and the mass of the ball. The opposite force holds the catapult arm back. As long as there is an equal or greater force, the catapult will not launch. It will launch only when it is removed from the catapult.
	8	Show learners how to measure the speed & velocity of a moving object: As the ball is launched, we can calculate the ball's average velocity by dividing the total distance by the time. Velocity is the direction of the average speed (25km/h in a northerly direction, for example).

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3. Activity Guide

Development (slides 9 – 27)		
Duration	**Slide**	**Activity**
90 min	9	Introduce the Unity3D Engine: Unity3D engine is a powerful program that allows you to create games and simulations.
	10 - 14	Learners create a catapult in Unity3D: ▪ Learners start Unity Hub and add the Assets folder into their game. ▪ Introduce the Unity3D game engine and ensure all learners have logged into Unity 3D before proceeding.
	15 - 16	Navigating Unity3D: ▪ Learners work through the navigation guide on the slides. ▪ Explain that they will only be using three of the seven tools in the tab (move, rotate, scale)
	17	Setting up the catapult toss test: ▪ Learners open the Physics Config window and add the window to the Unity3D program. They should ensure that this window does not block the view of the scene. ▪ When they have done this, they press the play button (at the top of the screen). Learners should see a distance/gravity/velocity meter in the top left-hand corner of the scene. ▪ The delta.time meter is a game engine visualization. Learners can use that statistic to measure the time taken for the ball to launch and divide it by the distance to calculate the average speed/velocity.

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3. Activity Guide

Development (slides 9 – 27)		
Duration	**Slide**	**Activity**
	18 - 20	**Step 1: Creating a force test – Newton Force** ▪ As the game starts, learners select the first test on the Physics Config window and proceed to step 1. The game scene shows the catapult preparing to launch with a visual graph to display the force represented in the catapult. ▪ The Newton (N) is the force needed to move 1kg of mass at the rate of 1m per second squared. ▪ Learners observe how Newton forces are applied to the catapult, as each functioning force provides a balance to hold the launcher in place. **Step 2: Launching the Ball** Ask learners if they know the purpose of each force in place. ▪ The spring of the catapult pushes the launcher forward to toss the ball. However, it is being held back by the mass of the ball, and by tension, which could be a hand holding the launcher back. ▪ Notice how the spring does not pull forward as the force needed to pull backwards is equal. **Step 3: Velocity** ▪ Learners observe the statistics shown on screen. ▪ (The Distance/gravity/velocity meter, and how much force is being propelled through the air). ▪ Learners can calculate the velocity of the ball by dividing the distance by the time taken in the simulation.

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3. Activity Guide

Development (slides 9 – 27)		
Duration	**Slide**	**Activity**
	21	Changing the variables: ▪ Learners adjust the values of their catapult once they have finished the force test. ▪ Direct learners' attention to the sliders on the Physics Config window. These change the weight of the ball and the spring power of the catapult. ▪ Allow learners to experiment with the sliders before moving to the energy test.
	22	Changing the Firing Angle: ▪ Learners change the catapult parameters in the game engine. ▪ Learners observe the effects of changing the angle of the catapult's firing arc and the gravity of the 3D world.
	23	Changing the gravity settings: ▪ Learners press play to stop the test. ▪ Select the edit tab on the upper left side of the program, edit → Project settings → Physics. Notice that the gravity panel is at a -9.81. Change the number to -1.0 instead. ▪ Press play again to start the test. Mindset: Design Thinking | Test Learners test, re-design, and re-test prototypes in situations similar to the original problem definition, until a viable solution has been achieved.

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3. Activity Guide

Development (slides 9 – 27)		
Duration	**Slide**	**Activity**
	24	Give learners a series of challenges that let them experiment with the catapult. Ensure that learners do not start the challenges too quickly as they are meant to try to achieve the goals.
	25 - 27	Challenge 1 – Target Practice – Learners win points by hitting the target. Challenge 2 – Box Breakdown – Learners knock down boxes by adjusting the weight of their ball. Challenge 3 – Basketball Showdown – Learners attempt to get the ball through a basketball hoop. The challenges encourage learners to adjust variables to achieve different results to suit their goals. Learners compete to score the highest points or record the lowest number of tries to achieve the challenge objectives. Skillset: Simulation & Modeling | Variable Constraining Learners create parameters to ensure that measurements and recorded data are within the limits of the model to be simulated.

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3. Activity Guide

Conclusion (slides 28 – 30)		
Duration	**Slide**	**Activity**
10 min	28	Learners reflect on what they have learned today with the following reflection questions: ▪ What have we learnt today? ▪ What did you find difficult? ▪ What would you do differently? ▪ What did you feel confident with?
	29	Educator concludes the lesson with a summary of what was learned: ▪ Observed the force and motion acting on the catapult. ▪ Calculated the velocity of the ball. ▪ Experimented with the strength of force applied to catapult launches.
	30	End of lesson.

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4. Troubleshooting Tips

Common Mistakes & Issues

	Issue	Possible Reasons	Resolution
1	3D game engine is slow/freezes.	The software has crashed or there are too many processes running on the computer.	Close other programs that are slowing the computer down.
2	Catapult does not fire, and error message is shown.	The mass of the ball is too great or the spring is too weak.	Change the settings of the ball's mass/spring power.

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5. Assessment Rubric

Focus	Learning Outcome	Approaching Expectation	Meeting Expectation	Exceeding Expectation
 Design Thinking (Test)	Analyze and explain force, motion and velocity using a catapult test simulation.	Unable to articulate how force, motion and velocity are used in the catapult.	Able to articulate how force, motion and velocity are used in the catapult with some support.	Able to articulate with clarity how force, motion and velocity are used in the catapult. Test simulation demonstrates excellent understanding of physics concepts.
 Simulation & Modeling (Variable Constraining)	Utilize simulations to derive different masses and forces to influence launch velocity to achieve various objectives.	Struggled to use the basic functions of the software. Unable to articulate variables or constraints in order to achieve the challenge objectives.	Able to complete the challenges with some support. Able to articulate 1 – 2 variables or constraints in order to achieve the challenge objectives.	Able to refine catapult launches independently to achieve the challenge objectives. Demonstrated excellent understanding of the process of variable constraining.