**NGSS Middle School Standards for the Catapult Project**

The **Catapult Project** aligns with **Next Generation Science Standards (NGSS) for Middle School** by incorporating concepts from **physics, engineering, and mathematics**. Students engage in **energy transfer, motion, forces, and engineering design**, reinforcing core scientific principles through hands-on learning.

**Middle School NGSS Standards Covered**

**Physical Science (PS) – Motion, Forces, and Energy**

* **MS-PS2-1:** Apply Newton’s Third Law to design a solution to a problem involving the motion of two colliding objects.
  + **Connection:** Students explore **how the force applied to the catapult affects projectile motion and impact forces**.
* **MS-PS2-2:** Plan an investigation to provide evidence that the change in an object’s motion depends on the sum of forces acting on the object and the mass of the object.
  + **Connection:** Students analyze **how launch angle, counterweight, and tension affect projectile distance and accuracy**.
* **MS-PS3-1:** Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.
  + **Connection:** Students **analyze how kinetic and potential energy influence projectile motion**, using **graphs and data collection**.
* **MS-PS3-2:** Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
  + **Connection:** Students **explore elastic potential energy in the catapult’s arm and how it transforms into kinetic energy**.

**Engineering, Technology, and Application of Science (ETS)**

* **MS-ETS1-1:** Define the criteria and constraints of a design problem to ensure a successful solution.
  + **Connection:** Students **design and test a catapult to optimize accuracy, stability, and efficiency**.
* **MS-ETS1-2:** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
  + **Connection:** Students **compare different catapult designs and test various adjustments to improve performance**.
* **MS-ETS1-3:** Analyze data from tests to determine similarities and differences among several design solutions.
  + **Connection:** Students **measure projectile distance and accuracy, adjusting variables to optimize launch conditions**.

**Key Concepts Covered in Middle School**

✔ **Newton’s Laws of Motion:** **Understanding force, inertia, and how motion changes based on applied forces**.  
✔ **Kinetic and Potential Energy:** **Exploring energy transfer in catapult mechanics**.  
✔ **Projectile Motion and Trigonometry:** **Using launch angle, sine, cosine, and distance calculations**.  
✔ **Data Collection and Analysis:** **Graphing motion, measuring results, and optimizing designs**.  
✔ **Engineering Design Process:** **Testing, improving, and iterating on catapult prototypes**.

**NGSS High School Standards for the Catapult Project**

The **Catapult Project** aligns with **Next Generation Science Standards (NGSS) for High School** by incorporating **advanced physics, engineering, and mathematical concepts**. Students engage in **energy transfer, projectile motion, forces, and the engineering design process**, reinforcing key principles through hands-on applications.

**High School NGSS Standards Covered**

**Physical Science (PS) – Motion, Forces, and Energy**

* **HS-PS2-1:** Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among net force, mass, and acceleration.
  + **Connection:** Students **measure force, mass, and acceleration in the catapult system to understand projectile motion quantitatively**.
* **HS-PS2-2:** Use mathematical representations to support the claim that the total momentum of a system is conserved when there is no net external force.
  + **Connection:** Students **calculate momentum before and after launch, analyzing how forces influence projectile behavior**.
* **HS-PS3-1:** Create a computational model to calculate the change in the energy of one component in a system when the energy is transferred to or from that system.
  + **Connection:** Students **calculate how potential energy stored in the catapult transforms into kinetic energy during launch**.
* **HS-PS3-2:** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with motion and energy associated with relative position.
  + **Connection:** Students **model and analyze the relationship between kinetic energy, potential energy, and gravitational energy in projectile motion**.
* **HS-PS3-3:** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
  + **Connection:** Students **design a catapult to efficiently transfer stored mechanical energy into projectile motion, optimizing energy conversion**.

**Engineering, Technology, and Application of Science (ETS)**

* **HS-ETS1-2:** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
  + **Connection:** Students **iterate on catapult designs, testing different structural components, launch mechanisms, and force applications**.
* **HS-ETS1-3:** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for various constraints.
  + **Connection:** Students **test and refine catapult designs based on range, accuracy, and efficiency, considering real-world applications**.
* **HS-ETS1-4:** Use computer simulations to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints.
  + **Connection:** Students **analyze projectile motion using mathematical models and simulations to predict and optimize launch performance**.

**Key Concepts Covered in High School**

✔ **Newton’s Laws of Motion & Momentum Conservation:** **Understanding force, inertia, acceleration, and projectile dynamics**.  
✔ **Kinetic, Potential, and Mechanical Energy:** **Calculating energy transformations in the catapult system**.  
✔ **Projectile Motion & Trigonometry:** **Applying launch angle, velocity, sine, cosine, and distance calculations**.  
✔ **Data Collection & Computational Modeling:** **Graphing results, predicting outcomes, and refining designs**.  
✔ **Engineering Optimization & Iterative Design:** **Improving the catapult for maximum efficiency and performance**.

**NGSS Elementary Standards for the Catapult Project**

The **Catapult Project** aligns with **Next Generation Science Standards (NGSS) for Elementary School** by introducing key **physical science, engineering, and mathematical concepts** in an engaging, hands-on way. Through building and testing catapults, students explore **forces, motion, energy transfer, and the engineering design process** at an age-appropriate level.

**Elementary NGSS Standards Covered**

**Physical Science (PS) – Forces, Motion, and Energy**

* **3-PS2-1:** Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.
  + **Connection:** Students **experiment with different launch forces and angles, observing how changes affect projectile motion**.
* **3-PS2-2:** Make observations and/or measurements of an object’s motion to provide evidence that a pattern can be used to predict future motion.
  + **Connection:** Students **track and measure catapult launches, using patterns in motion to make predictions about future launches**.
* **4-PS3-1:** Use evidence to construct an explanation relating the speed of an object to the energy of that object.
  + **Connection:** Students **observe how a catapulted object moves faster and farther when more energy is applied, demonstrating kinetic energy relationships**.
* **4-PS3-4:** Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
  + **Connection:** Students **build and modify catapults to improve energy transfer from stored mechanical energy to kinetic energy**.

**Engineering, Technology, and Application of Science (ETS)**

* **3-5-ETS1-1:** Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
  + **Connection:** Students **design a catapult that meets specific performance criteria, like launching distance or accuracy**.
* **3-5-ETS1-2:** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
  + **Connection:** Students **test different catapult designs, comparing which ones launch projectiles the farthest or most accurately**.
* **3-5-ETS1-3:** Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
  + **Connection:** Students **conduct trials with their catapults, adjusting launch angles, arm length, or force applied to optimize performance**.

**Key Concepts Covered in Elementary**

✔ **Forces & Motion:** **Understanding push and pull, balanced and unbalanced forces, and how objects move**.  
✔ **Energy Transfer:** **Exploring how stored mechanical energy is transferred to kinetic energy**.  
✔ **Patterns & Predictions:** **Observing and measuring projectile motion to predict outcomes**.  
✔ **Hands-on Engineering & Problem-Solving:** **Designing, testing, and refining catapults to improve performance**.  
✔ **Mathematical Measurement & Data Collection:** **Recording distances, launch angles, and adjusting variables**.