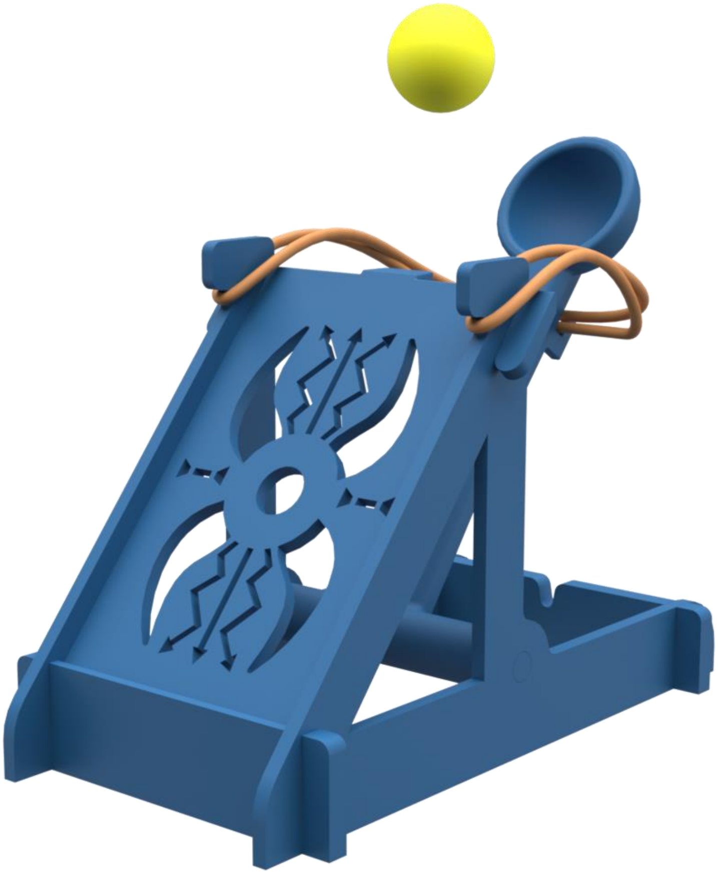
SOLIDWORKS / xDesign

DESIGN PROJECTS

TEACHER GUIDE

3DEXPERIENCE



CATAPULT

DASSAULT SYSTEMES

INTRODUCTION/GENERAL GUIDELINES

Welcome to the Design Projects Teacher Guide for Catapult. This activity presents a wide range of possibilities for the instructor. The individual components are simple enough for beginners to learn the basics of designing with CAD, and is suitable for individuals and teams to eventually design and build their own catapult.

As an instructor, you have several resources at your disposal:

1. **Overview PDF**
    - The initial document that introduces the project providing a brief overview.
2. **Teacher Guide**
    - This document contains information that correspond to the sections of the Presentation PowerPoint (see below). Each section discussed in this guide, provide further details on how you can use the PowerPoint.
    - Also included are additional ideas you may want to use to enhance the activity in the classroom or adjust it for different skill levels.
3. **Student Guide**
    - This document is intended to share with the students, and provides basic guidelines for the activity such as deliverables, tips for creating the individual components and 3D printing guidelines.
4. **Presentation PowerPoint**
    - The PowerPoint is used to introduce the project to the class.
    - Feel free to expand any part of the presentation such as history, design concepts or any STEM related materials.
    - It is recommended that you have a completed model to show the class and pass around.
5. **Video**
    - The video is located on YouTube, and is intended to provide an overall approach to how the model could be created in CAD.
    - You may want to watch it together with the students in class.
    - LINK TO YOUTUBE VIDEO
6. **Step-by-Step Course**
    - This is where every step of the design process is demonstrated in short easy to follow video clips.
    - LINK TO STEP-BY-STEP

BACKGROUND

This section is intended to provide students with an introduction to catapults. This particular design takes inspiration from the Roman Onager. There are other types of siege engines including battering rams, ballistas and trebuchets. You may want to look these up online and have further discussions regarding them.

It is important to understand the different parts of a catapult. Basic catapult construction terminology is highlighted using the project itself to make the connection to the design project.

Also included in this section is a slide for the discussion of key design terms.

- **Flat-Pack Design** – Materials are expensive. Encourage students to create designs that minimize waste *and* meet design requirements.

- **Design Intent** – It is always best to have a clear definition of how a product should look, function and feel to the user. This is referred to as form, fit and function. Spend some time discussing this vital step in the process of designing a solution to a problem.

- **DFM/DFAM (Design for Manufacturing, Design for Additive Manufacturing**) - In addition to Design Intent, the concepts of DFM/DFAM are equally important. When designing anything, the question, "How will this be made?", should be considered. This particular project is designed to be 3D printed. As such, it is important that students understand the capabilities of the machine you have available.

- **Nesting -** In manufacturing, nesting refers to laying out cutting patterns on raw material to minimizing waste during manufacturing processes, such as laser cutting. In 3D printing, it is the process of laying out parts to fit on the bed of the 3D printer to print several components at one time. It is important to discuss how parts should be prepared for manufacture, specifically 3D printing.

COMPONENT DESIGN

This section contains slides for each of the components. The purpose of this section is to discuss how Design Intent and DFAM is to be applied to each part.

For detailed dimensions and step by step instructions for the parts, refer to **LINK TO STEP-BY-STEP**, in the **ADDITIONAL RESOURCES** section below.

3D PRINTING

This section provides an opportunity to discuss the specific ways the individual components will be oriented and prepared for 3D printing on whatever machines that are available to the students in the classroom.

It is recommended that you develop classroom procedures for using machines and a method for keeping account of materials used. One thing you may want to do is have the students calculate the cost of each project. The way the components are designed and oriented on the 3D printer, will have an impact on this. This can also be an opportunity to discuss sustainability, being mindful of the environmental impact we have when designing and making things.

CLASS DISCUSSION

Included in this section are a couple questions to get the conversation started. The intent here is for you to tailor the discussion to suite your specific course goals and students needs. Some ideas may include:

- How will the trajectory of the ball be affected by changing the angle or size of the area where the basket arm strikes the faceplate?
- How will different types of elastic bands affect the power of the machine?
- What tolerance is needed to be loose enough for easy assembly, yet tight enough to hold the components together?

PROJECT TASKS (ASSESSMENT CRITERIA)

Depending on the goals of the class, at a minimum students should be able to accomplish the following tasks.

- Create the following bridge components in CAD:
  - Side Plate
  - Front Support
  - Back Support
  - Faceplate
  - Basket Arm
- Create an assembly of the catapult in CAD.
- Print the physical components on a 3D printer.
- Assemble the catapult.

Some other possibilities for assessment may be in the following categories:

- **SUSTAINABILITY** – Did the project meet flat-pack design requirements?
- **ASSEMBLY** – With no adhesives or fasteners, does the model hold together on its own?
- **MANUFACTURABILITY** – Do the components fit within the parameters of the 3D printer?
- **PERFORMANCE** – Does it launch the specified foam ball?

ADDITIONAL RESOURCES

[LINK TO DOCUMENTS]

[LINK TO YOUTUBE VIDEO]

[LINK TO STEP-BY-STEP]

The following sections do not correspond to the PowerPoint, and are included here for added benefit.

ADVANCED OPTIONS

For more experienced students, you can challenge them with more advanced concepts and tasks that encourage creativity, engineering principles, and real-world application. Below are some ideas that could be suitable for this level:

Enhanced Catapult Mechanism Designs

- **Lever-Arm and Torsion Spring Systems:** Students can explore using torsion springs or rubber bands as the mechanism for launching the projectile, requiring more complex calculations for the forces involved.
- **Compound Lever Systems:** Incorporating multiple levers or a mechanical advantage system, students could design a catapult with several components working together to launch the projectile, requiring precision in assembly and understanding of forces.

Dynamic Simulation and Testing

- **Projectile Trajectory Simulations:** Students can use simulation software to model the trajectory of the projectiles and optimize the launch velocity and angle for maximum distance or accuracy.
- **Testing and Data Analysis:** Incorporating real-world testing and data collection into the project where students build prototypes, measure their performance, and analyze the results statistically (e.g., creating a report on accuracy, distance, etc.).

Collaboration

- **Team-based Design:** Have students work in teams to design different parts of a catapult, with each team member responsible for different tasks, such as load-bearing analysis, aesthetics, materials, or safety.
- **Cross-disciplinary Design:** Combine catapult design with electrical or mechanical engineering to add functional elements to the catapult. Examples could be incorporating servo motors to create a fully automated or remotely controlled catapult. This could involve using microcontrollers (like Arduino or Raspberry Pi) to control the motion and launching process., such as an winding mechanism, or switches to control launch.

By including these advanced design elements, students will be pushed to develop critical thinking skills and a deeper understanding of engineering concepts.

EDUCATIONAL CONCEPTS

A catapult design and construction project is an excellent way to integrate multiple STEM concepts. Here are some potential teaching approaches:

SCIENCE

- Explore projectile motion: teach students about velocity, trajectory, angles, and gravity.
- Discuss energy transfer: potential energy (e.g., a stretched rubber band) converting to kinetic energy.
- Compare how the principles of levers and fulcrums are mirrored in human body movements.

TECHNOLOGY

- Teach students to use 3D modeling for creating their catapult designs.
- Demonstrate how 3D printers work, from slicing software to the actual printing process.
- Discuss additive manufacturing principles and how they differ from traditional methods.
- Emphasize the importance of DFAM, Designing for Additive Manufacturing, by minimizing waste through smart design.

ENGINEERING

- Explain lever mechanics and how changing arm lengths or pivot points impacts performance.
- Discuss structural stability and how to prevent the catapult from tipping or breaking.
- Introduce failure analysis to identify and fix weak points in the design.

MATHEMATICS

- Analyze the angles required for optimal launch trajectories.
- Calculate angles, lengths, and dimensions for accurate CAD modeling.
- Solve for unknown variables such as range or initial velocity.
- Have students estimate material costs, factoring in 3D printer filament usage.