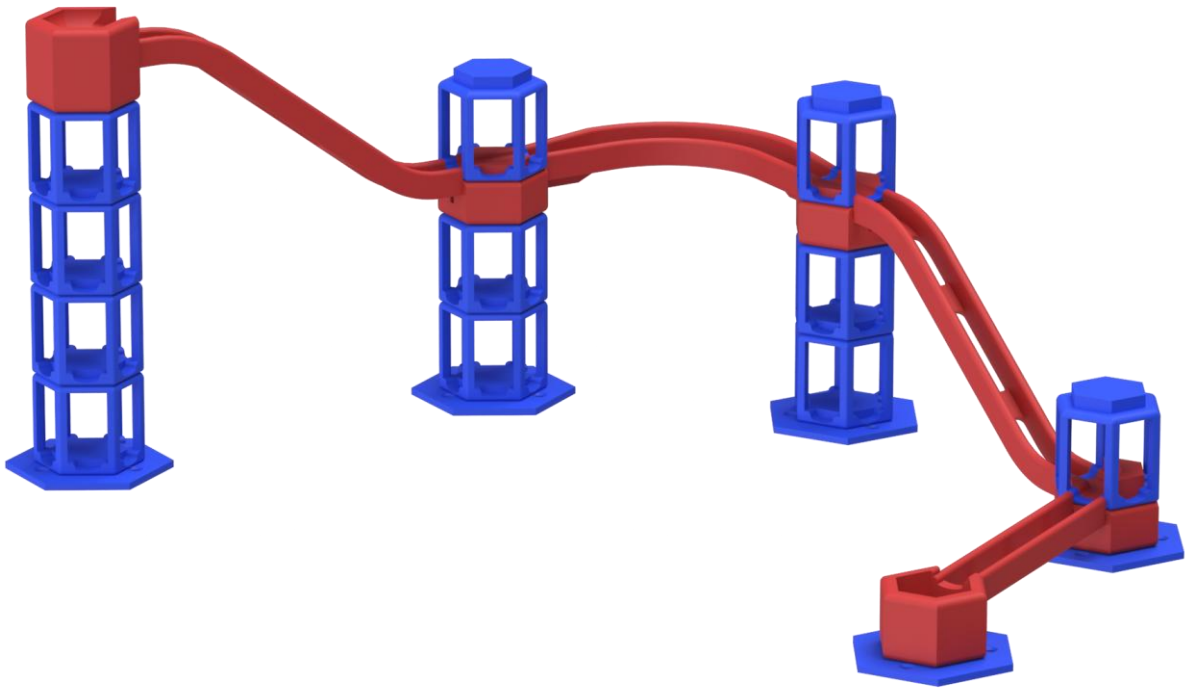
SOLIDWORKS

DESIGN PROJECTS

TEACHER GUIDE

3DEXPERIENCE



MARBLE RUN

DASSAULT SYSTEMES

INTRODUCTION/GENERAL GUIDELINES

Welcome to the Design Projects Teacher Guide for a Marble Run. 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 the result is a model that can be used to explore the aspects of a marble run design. This project is suitable for individuals and teams to eventually design and build their own marble run.

It is recommended that you have a completed model to display to the class during the Presentation. 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 corresponds to the sections of the Presentation PowerPoint (see below). Each section discussed in this guide provides 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 for 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 customize any part of the presentation such as history, design concepts or any STEM related materials.
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 with short easy to follow procedures and video clips as well as overall videos showing the entire process.
    - LINK TO STEP-BY-STEP

BACKGROUND

This section provides students with an introduction to marble runs. This particular design takes inspiration from modular marble run toys. There are many other methods for designing marble runs such as single print designs, wall marble runs, and marble machines. You may want to research these alternative designs and have discussions regarding them.

Since marbles have a long and rich history, there is a brief discussion of their history and when marble runs became popular. There is a slide with a non-modular marble run design that can be used as a discussion for why a modular design may be useful when designing a product.

It is important to understand the different parts of a marble run. Basic marble run 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.

- **Modular Design –** A design approach where a complex system is split into smaller parts, called modules that can be easily connected. This approach increases a product's adaptability and decreases waste during manufacturing because modules can be easily replaced and reconfigured.

- **Design Intent –** In CAD modeling terms, Design Intent is how your model behaves when dimensions are modified. An example of design intent is how you create and dimension a hole in a block. In product design terms, Design Intent is how a product should look, function, and feel to the user.

- **Additive Manufacturing –** The construction of a 3D object by adding material layer by layer. 3D printing is an additive manufacturing process.

- **DFM/DFAM –** Design for Manufacturing or Design For Additive Manufacturing. In this activity, it is important to consider the material and capabilities of the 3D printer in order to achieve a functional design with minimal waste.

- **Nesting –** In manufacturing, nesting refers to laying out cutting patterns on raw material to minimize 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.

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.

Each component in this project is designed to be a perfect fit, but most printers are not completely accurate. It is recommended that teachers print test components and determine the proper tolerances and relay that information to students before they start designing.

It is also 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 component is designed and oriented on the 3D printer will have an impact on this. This can also be an important 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 suit your specific course goals and students needs. Some Ideas may include:

- How much momentum is required for the marble to traverse various tracks? What causes the need for more or less momentum?
- What additional considerations are necessary when designing with modularity in mind?
- Why is modular design useful? When might engineers put extra effort towards modular design?
- How did modular design impact the iterative design process? What parts of the process were easier? Which were harder?

PROJECT TASKS (ASSESSMENT CRITERIA)

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

1. Create the following marble run components in CAD:
    - Straight Track
    - Sloped Track
    - Curved Track and Strut
    - Support and Half Support
    - Straight Connector
    - Turn Connector
    - Start and End Baskets
    - Base
2. Create an assembly of the marble run in CAD.
3. Print the physical components on a 3D printer.
4. Assemble the marble run.

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

- **SUSTAINABILITY** – How much waste is generated in the manufacturing process? Can the parts be reused?
- **ASSEMBLY** – With no adhesives or fasteners, does the model hold together on its own? Are the tracks easily re-configurable?
- **MANUFACTURABILITY** – Do the components fit within the parameters of the 3D printer? Do the components' designs and orientation minimize support material?
- **PERFORMANCE** – Do the marbles stay on the track? Do they make it to the end of the track?

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:

Advanced Track and Mechanism Designs

- **Obstacle Design:** Have students experiment with designing various complex obstacles for their marble run (e.g., zig-zag, plinko, hilly track, loops, stairs, spinning wheels, switch rails, etc.).
- **Mechanism Design:** Encourage students to include hand-operated or motorized mechanisms in their designs so marbles can cycle through the course repeatedly.
- **Race Design:** Students can explore ways to design diverging paths in their marble run design to race multiple marbles. Encourage them to design routes that are well-balanced and don't result in a single route winning every race.

Iterative Design Process

- **Marble Motion Analysis:** Students can explore simulation software to model the path the marbles travel on their marble runs to analyze and adjust their designs before fabrication. Students can then compare their tracks performance in the simulations to its actual performance.
- **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 success rates, failure points, etc.). The results of this analysis can be leveraged to improve designs.

Collaboration

- **Team-based Design:** Have students work in teams to design different parts of a complex marble run, with each team member responsible for different tasks, such as support design, track design, obstacle design, motion analysis, aesthetics, materials, etc.
- **Cross-disciplinary Design:** Combine marble run design with electrical and software engineering by motorizing mechanism designs to create a fully automated marble run.

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

SCIENCE.

- Explore energy transfer: potential energy from gravity converting to kinetic energy and back as the marble traverses the track.
- Discuss how friction effects the marbles' movement on long flat tracks.
- Examine the principles of inertia and how the marble must encounter another force to turn (e.g. banked turns), stop, or speed up.

TECHNOLOGY

- Teach students to use 3D modeling for creating their marble run 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

- Explore designing with modularity in mind to ensure designs are adaptable and reusable – how can a part be designed to be used in the largest number of marble run configurations?
- Discuss structural stability and how to prevent the marble run from falling apart.
- Practice the iterative design process for various marble tracks, track configurations, latching mechanisms, and support designs.

MATHEMATICS

- Calculate track angles, lengths, and heights required for consistent motion.
- Analyze potential and kinetic energy while designing tracks to ensure they work as intended.
- Solve for the velocity of the marble at different parts of the track.
- Have students estimate material costs, factoring in 3D printer filament usage.
- Compare budget-friendly designs to more elaborate ones.