Inclined Plane

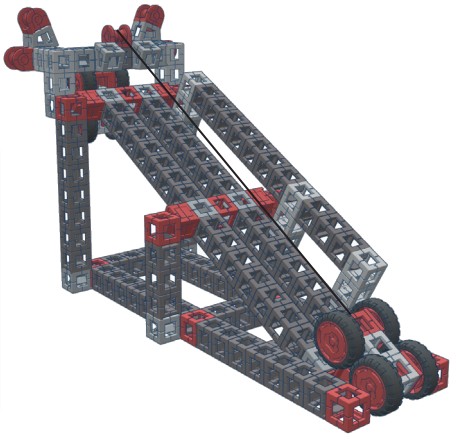
STEM-Maker CURRICULUM

v2.0

Progression: Applications in Design & Engineering - Section 1 | **Curriculum Packet**

Introduction

This Rokenbok STEM-Maker lesson will use the following steps to learn about the inclined plane.



1. Learn

- Elements of an inclined plane
- Purpose of an inclined plane
- Real world applications
- Mechanical advantage in an inclined plane

2. Build & Modify

- Build an inclined plane
- Test an inclined plane
- Modify an inclined plane from 2:1 to 3:1 mechanical advantage

3. Design & Engineer

- Design and engineer an custom inclined plane to solve a challenge

Learning Objectives

- Understand the basic elements and purpose of an inclined plane.
- Gain a basic conceptual understanding of mechanical advantage.
- Calculate the amount of mechanical advantage in an inclined plane.
- Modify an inclined plane to increase mechanical advantage.
- Design and engineer a custom inclined plane.

Resources

SnapStack Module

*4 Students Per Module

or

Programmable Robotics Module

*4 Students Per Module

Key Terms

Simple Machine: A device that transmits or modifies force or motion.

Inclined Plane: A flat supporting surface tilted at an angle, with one end higher than the other, used as an aid to raise and lower a load. It is also referred to as a **slope**.

Rise: The vertical height of an inclined plane from the base to its highest point.

Mechanical Advantage: The amount a machine multiplies force.

Force: A push or a pull.

Work: Using a force to move an object a distance.

Effort: A force applied to a machine to do work.

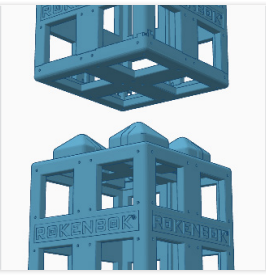
Load: The object or weight being moved or lifted.

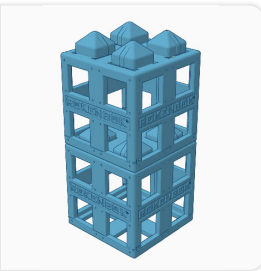
Rokenbok Building Basics

The following tips will be helpful when using the Rokenbok Student Design & Engineering System.

Connecting/Separating ROK Blocks:

ROK Blocks use a friction-fit, pyramid and opening system to connect. Simply press pyramids into openings to connect. To separate blocks, pull apart.



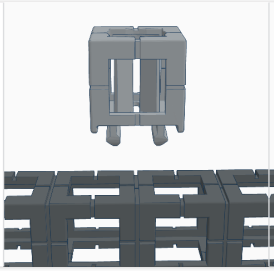


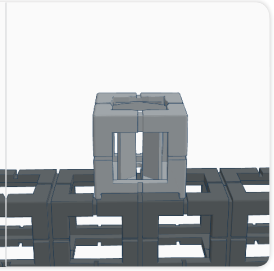
Connecting/Separating Rokenbok Components:

Smaller Rokenbok components use a tab and opening system to connect. Angle one tab into the opening, and then snap into place. To separate, insert key into the engineered slot and twist.

Snapping Across Openings:

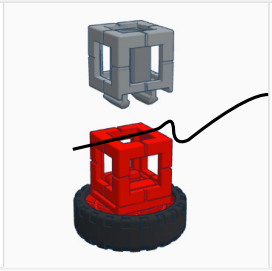
The tabs on Rokenbok components can also be snapped across openings to provide structural support to a design. This will also allow certain designs to function correctly.

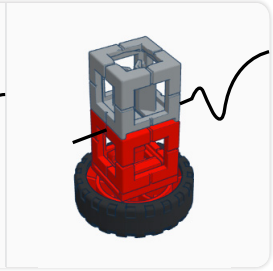




Attaching String:

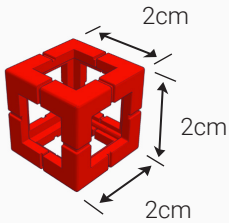
In some instances, string may be needed in a design. Lay string across the opening and snap any Rokenbok component with tabs or pyramids into that opening. Be sure that the tabs are perpendicular to the string to create a tight fit.

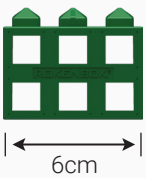




Measuring:

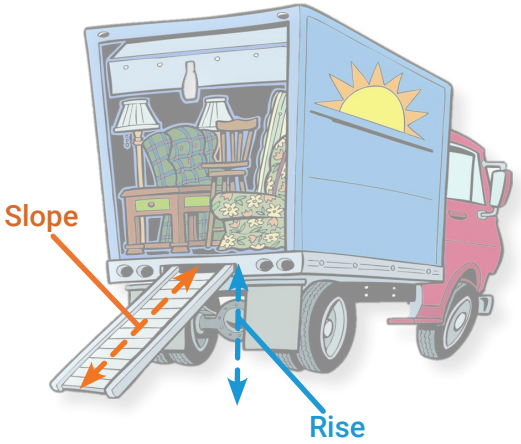
The outside dimensions of each Rokenbok connector block are 2 cm^3. This means the length, depth, and height are each 2 cm. To determine the size of a Rokenbok build in centimeters, simply count the number of openings and multiply by two. Repeat this process for length, depth and height.





The Inclined Plane

An inclined plane is a flat supporting surface tilted at an angle, with one end higher than the other. There are two elements in an inclined plane: the **slope** and the **rise**. In the example to the right, the slope (incline) is represented by the ramp. It is used to load and unload the furniture in the truck. The rise is the amount of increase from the horizontal surface (the ground in this case) to the top of the slope.



Purpose

An inclined plane is used to make work easier by **creating mechanical advantage**.

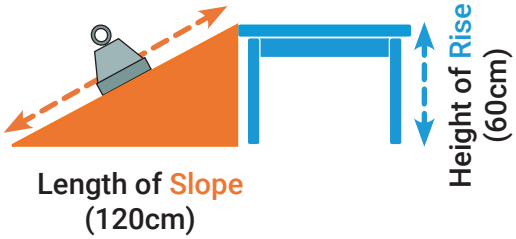
Creating Mechanical Advantage

The inclined plane makes work easier by reducing the amount of effort that must be applied to raise or lower a load. This is done by increasing the distance along the length of the slope that the load will travel.

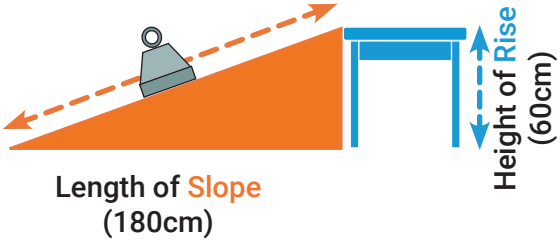
In Example 1, the length of the **slope** (120 cm) is two times the distance as the **rise** (60 cm).

In Example 2, the length of the **slope** (180 cm) has been extended to three times the distance as the **rise** (60 cm). In this example, the load will travel a further distance than Example 1, but the amount of effort needed to raise or lower the load will be reduced.

Example 1 - Inclined Plane



Example 2 - Inclined Plane



Real World Applications

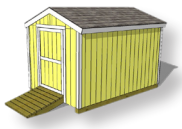
Inclined planes are used in many different ways to make work easier. Here are some real world examples.

Slides

Skate Ramp

Wheelchair Ramp

Entry Ramp

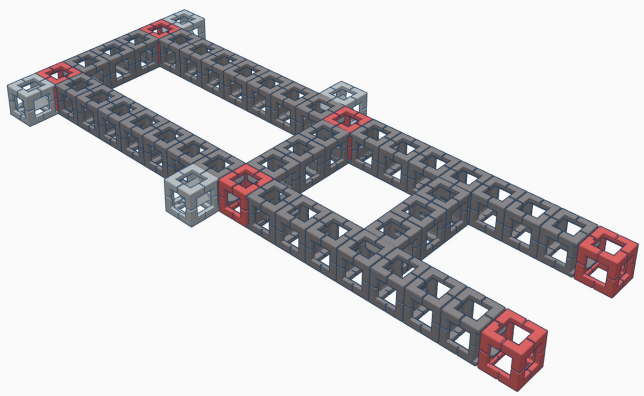


Ski Slope

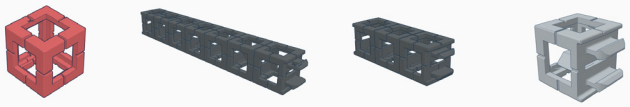
Instructions

Follow the step-by-step instructions to build an inclined plane.

1

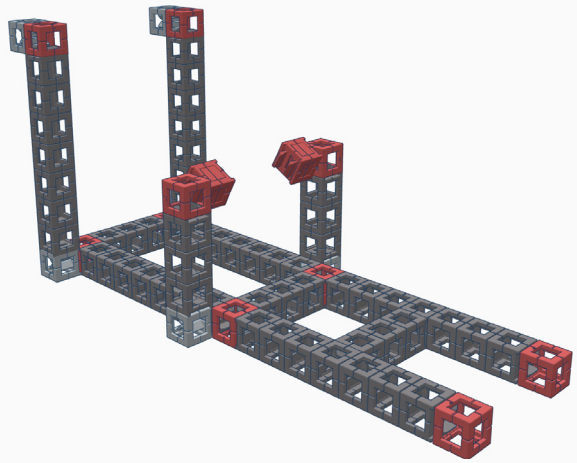


6x Block	4x Beam	3x Half Beam	4x Single Snap Block

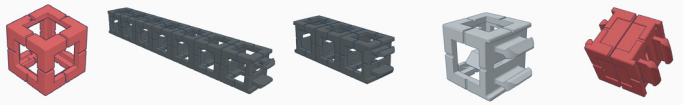


2

Base Structure

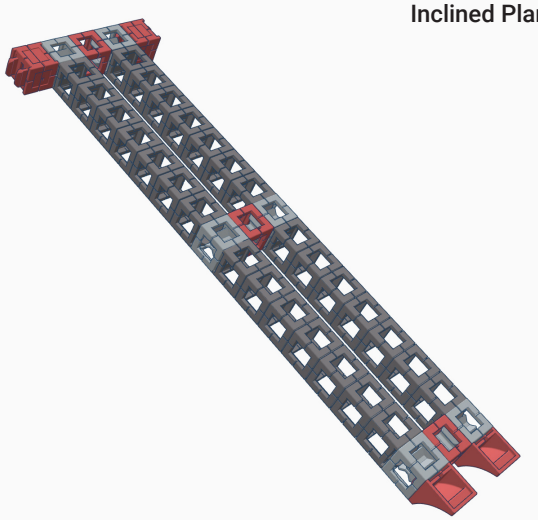


4x Block	2x Beam	2x Half Beam	2x Single Snap Block	2x Axle Block

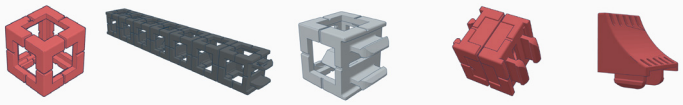


3

Inclined Plane

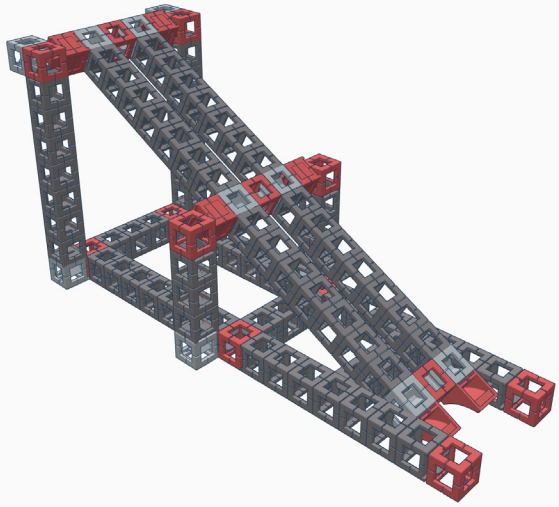


3x Block	4x Beam	6x Single Snap Block	2x Axle Block	2x Corbel



4

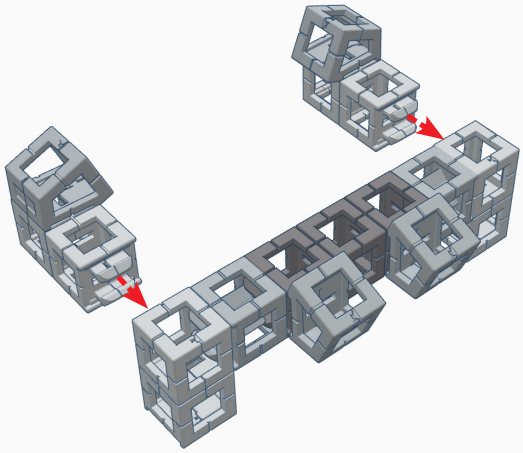
Attach Inclined Plane to Base Structure



Instructions

Follow the step-by-step instructions to build an inclined plane.

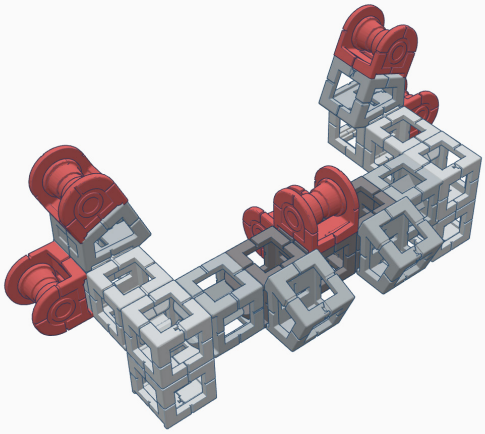
5



1x	4x	4x	2x
Half Beam	Riser	60° Block	Single Snap Block

6

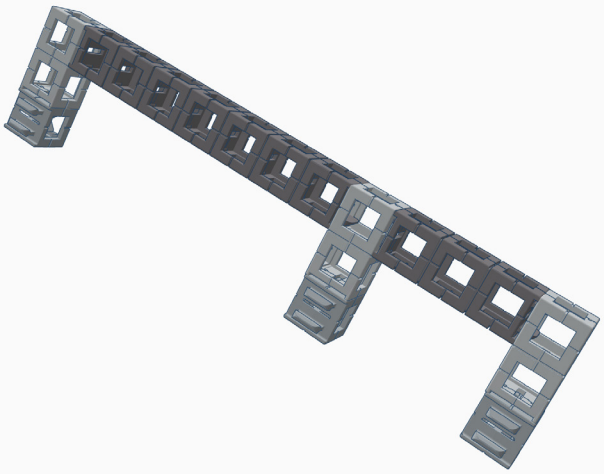
Pulley Bracket



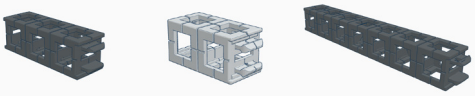
6x
Pulley

7

Guide Rail

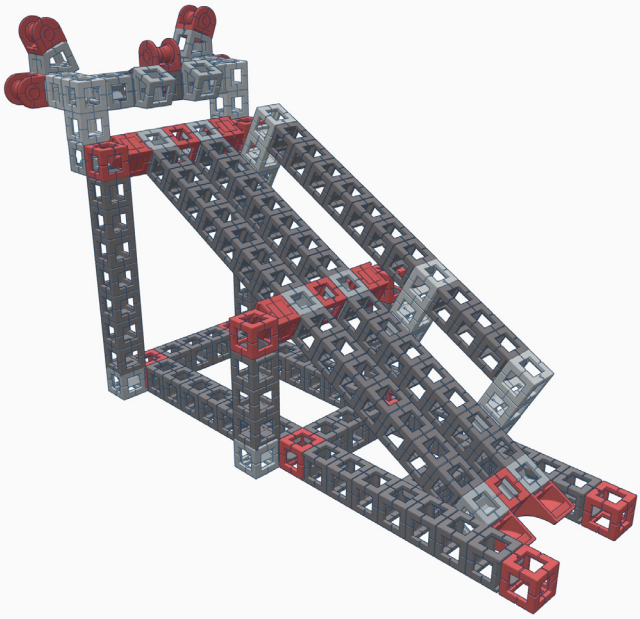


1x	3x	1x	3x
Half Beam	Riser	Beam	Single Snap Block



8

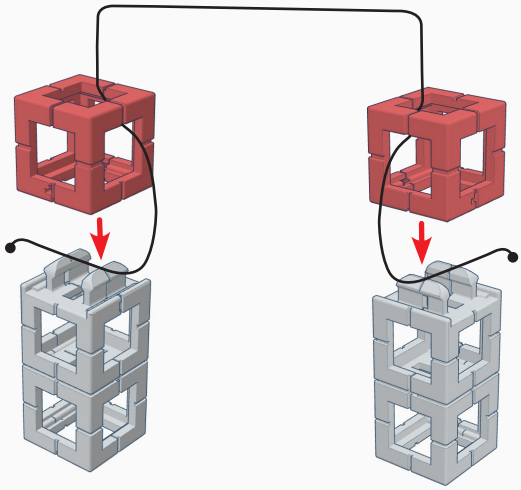
Attach Pulley Bracket and Guide Rail to Inclined Plane



Instructions

Follow the step-by-step instructions to build an inclined plane.

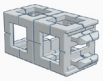
9



Cut off a piece of string that is 54 cm long. Tie a knot at each end of the string. Feed the string through connector blocks as shown. Secure the string by snapping connector blocks into tabs.

2x
Block

2x
Riser



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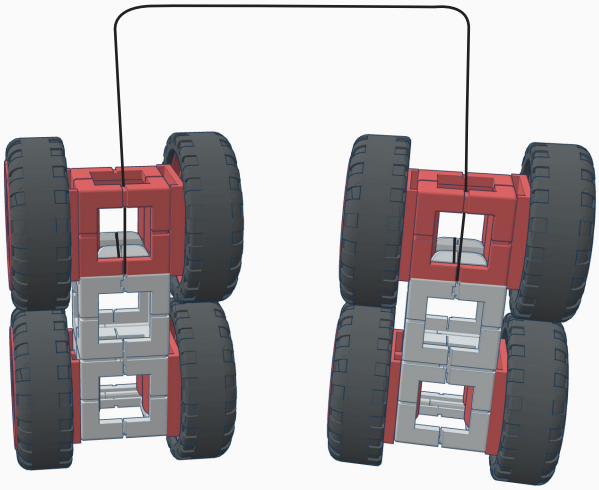


Snap eight wheels into place as shown to finish weights.

8x
Snap-In Wheel

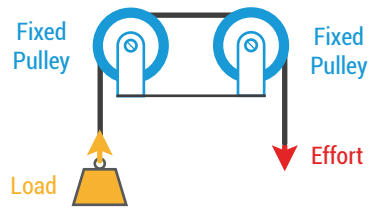
Testing Inclined Plane

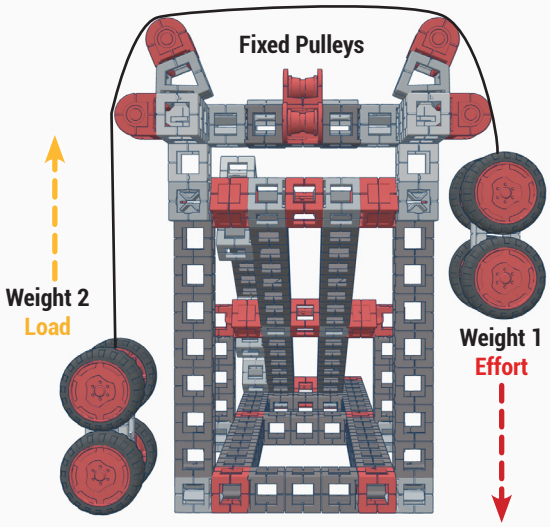
Follow the instructions below to test both sides of the Rokenbok Inclined Plane model.

Testing Fixed Pulleys

Turn the inclined plane system so that the weights can be tested on the fixed pulley system. Place the weights over the fixed pulleys. Test and observe how the weights balance each other equally. Pull down on weight 1 and observe how weight 2 moves an equal distance in the opposite direction.

Fixed Pulley System





Testing Inclined Plane

A. Move the inclined plane to the edge of a table or desk. The fixed pulleys should be hanging over the edge of the desk or table as shown in Figure A.

B. Place the weights over the inclined plane as shown in Figure B. Pull Weight 2 down to the bottom of the inclined plane. Release Weight 2 and observe what happens.

Inclined Plane

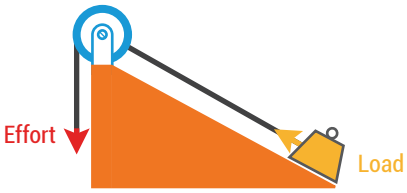


Figure A

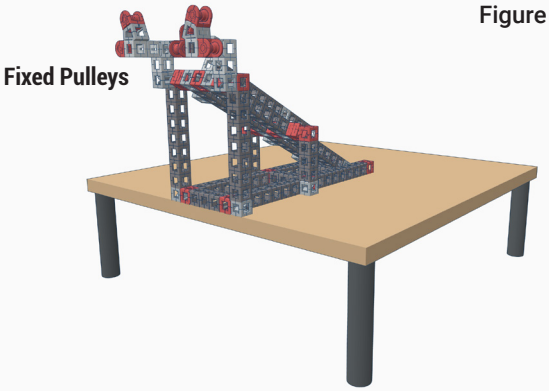
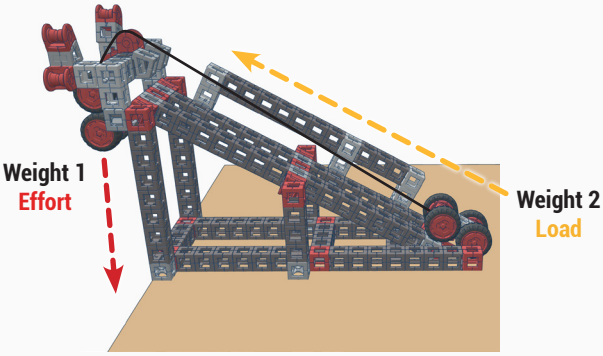


Figure B



Understanding Mechanical Advantage

The main purpose of a simple machine is to make work easier. This is done by either redirecting motion or creating mechanical advantage. **Mechanical Advantage** exists when the output force of a machine is greater than the input force that was applied to it. To accomplish this, the machine must trade increased time or distance for reduced effort.

Calculating Mechanical Advantage

The inclined plane reduces effort by creating mechanical advantage. This is done by raising or lowering an object a further distance on a slope or incline to reach the desired height, instead of directly lifting or lowering the object straight up or down. To determine how much mechanical advantage exists in an inclined plane, divide the length of the **slope** by the height of the **rise**.

Formula

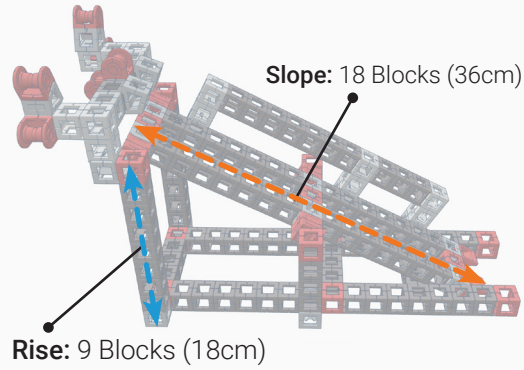
$$\text{Mechanical Advantage} = \frac{\text{Slope}}{\text{Rise}}$$

Understanding Inclined Plane Model

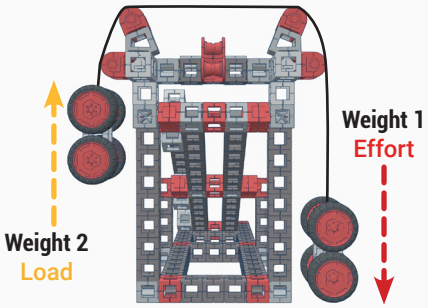
This model demonstrates how an inclined plane reduces the amount of effort needed to raise a load. When the weights were placed on the fixed pulleys, there was no mechanical advantage, so the weights balanced each other equally. In order to raise one of the weights, extra effort or mass would be needed to overcome the mass of the load.

When the weights were placed on the inclined plane, the mechanical advantage of the inclined plane allowed the effort to raise the load to the top of the incline. In this model the **slope** of the incline is 18 blocks (36 cm), and the **rise** is 9 blocks (18 cm). Divide 36/18 and this will give a mechanical advantage of 2:1. Since the **slope** of the incline is twice as long as the **rise**, half the effort is needed to raise the load. This inclined plane is able to output a greater force than the input force that was applied to it.

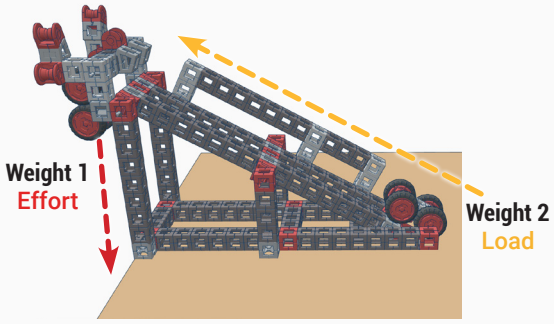
Slope and Rise



Fixed Pulley System



Inclined Plane



Modify: Inclined Plane

Now that you have built an inclined plane that has a mechanical advantage of 2:1 (**slope** is twice the distance of the **rise**), modify the model to increase the mechanical advantage to 3:1.

Design & Engineering Challenge: Inclined Plane

In this challenge, each team must design and engineer a custom inclined plane. Read carefully through the design brief below, then use the design & engineering process to develop a solution to the challenge.

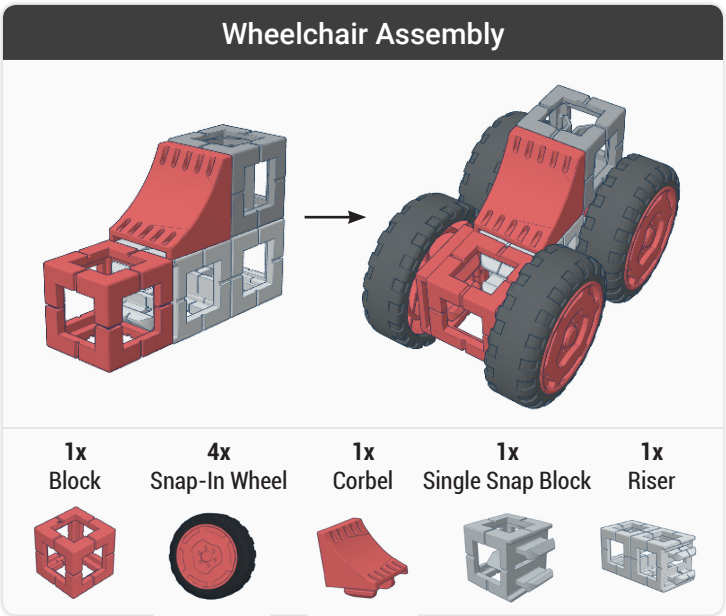
Design Brief: Scenario

An elderly neighbor fell and broke her hip. She now has to use a wheelchair to get around. There are a few stairs in front of her house that make it difficult to get in and out of the house.

Design & Engineering Challenge

Design and engineer a wheelchair ramp that will allow the elderly neighbor to easily get in and out of her house.

***Instructions to build the wheelchair assembly are pictured to the right.**

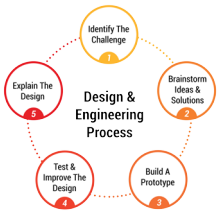


Specifications & Sub-Challenges

1. Teams can work in groups of up to four to complete this challenge.
2. Teams must work through each step of the Rokenbok design & engineering process to design, prototype, and refine a custom inclined plane. Teams will be responsible for written documentation in the Student Engineering Workbook.
3. **Sub-Challenge:** The wheelchair ramp must have a mechanical advantage of at least 4:1.
4. **Sub-Challenge:** The wheelchair ramp must be wide enough for the wheelchair assembly.
5. **Sub-Challenge:** The wheelchair ramp must include a hand rail for safety and assistance.
6. **Sub-Challenge:** With each building component costing $2, the pulley system must cost less than $120.
7. The wheelchair ramp must be aesthetically appealing.
8. Each team will be required to effectively explain all aspects of brainstorming, prototyping, testing and improving the custom inclined plane. Teams will also be responsible for explaining how much mechanical advantage exists in the design.

Design & Engineering Process

To develop a high quality design, teams will work through each step of the design & engineering process. Teams should track all progress in the student engineering workbook.



Design & Engineering Process

Student Engineering Workbook

Challenge Evaluation

When teams have completed the design & engineering challenge, it should be presented to the teacher and classmates for evaluation. Teams will be graded on the following criteria:

- **Specifications:** Does the design meet all specifications as stated in the design brief?
- **Performance:** How well does the design work? Does it function consistently?
- **Team Collaboration:** How well did the team work together? Can each student descibe how they contributed?
- **Design Quality/Aesthetics:** Is the design of high quality? Is it structurally strong, attractive, and well proportioned?
- **Material Cost:** What was the total cost of the design? Was the team able to stay on or under budget?
- **Presentation:** How well did the team communicate all aspects of the design to others?

Grading Rubric	Advanced 5 Points	Proficient 4 Points	Partially Proficient 3 Points	Not Proficient 0 Points
Specifications	☐ Meets all specifications	☐ Meets most specifications	☐ Meets some specifications	☐ Does not meet specifications
Performance	☐ Design performs consistently well	☐ Design performs well often	☐ Design is partially functional	☐ Design does not work
Team Collaboration	☐ Every member of team contributed	☐ Most members of team contributed	☐ Some members of team contributed	☐ Team did not work together
Design Quality/ Aesthetics	☐ Great design/ aesthetics	☐ Good design/ aesthetics	☐ Average design/ aesthetics	☐ Poor design/ aesthetics
Material Cost	☐ On Budget ($120 or Less)	☐ Slightly Over Budget ($120-130)	☐ Over Budget ($130-140)	☐ Significantly Over Budget ($141+)
Presentation	☐ Great presentation/ well explained	☐ Good presentation/ well explained	☐ Poor presentation/ explanation	☐ No presentation/ explanation
Points	.....	.....	.....	.....
Total Points				..... /30