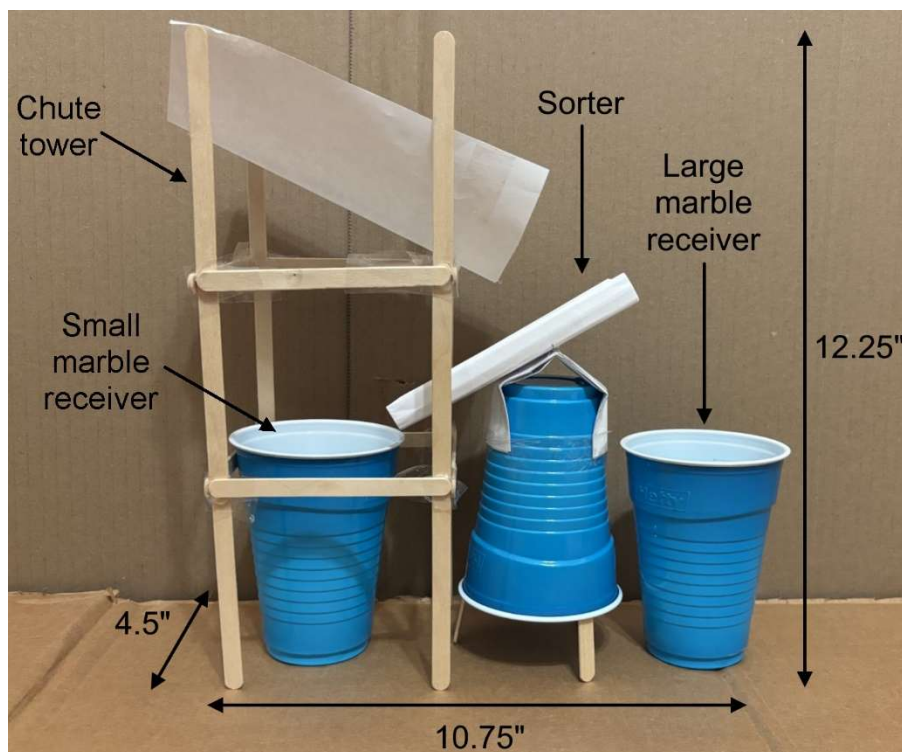


# The Marble Machine

## 1.0 Introduction

The marble machine is a toy and physics demonstration that sorts marbles based on their weight. As shown in Figure 1.1, it is comprised of four major parts: the chute tower, the sorter, and two receivers – one small marble receiver and one large marble receiver. The chute is made of folded paper supported by popsicle stick scaffold, and the sorter is made of folded paper attached to a plastic cup on popsicle stick stilts. The machine is 10.75" long, 4.5" wide, and has a height of 12.25". Marbles are input one-by-one through the chute at the top, and the sorter uses the marble's momentum to separate them into either receiver cup. Small marbles end up in the cup under the chute (small marble receiver), while large marbles cause the sorter to tip like a seesaw and land in the large marble receiver. Through constructing and using the marble sorter, children will learn the concepts of mass, momentum, and inertia. These concepts are fundamental to physics and easily demonstrated through the marble machine.



**Figure 1.1:** Marble Machine.

## 2.0 Description of Parts

The marble machine consists of four major parts: the chute tower, the sorter and the two receivers. It also comes with two types of marbles to sort through the machine.

### 2.1 The Chute Tower

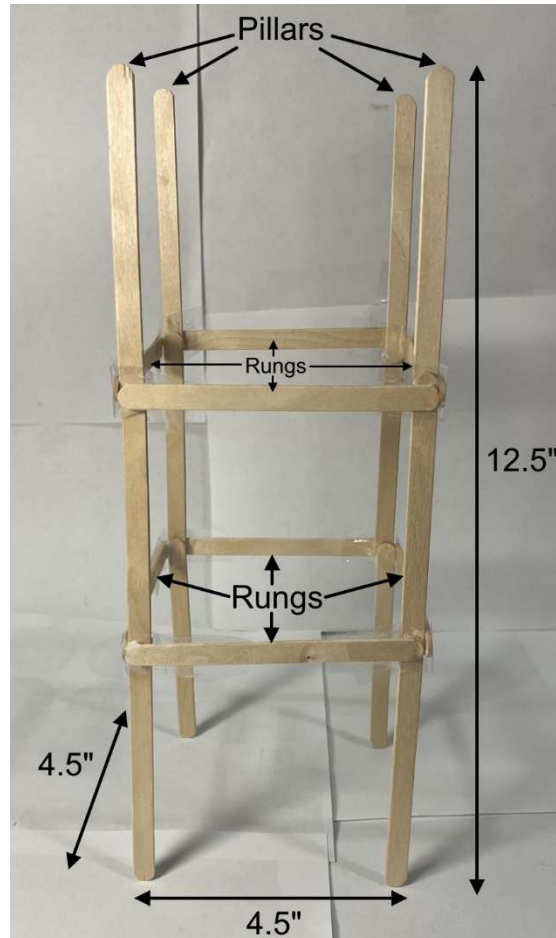
The chute tower is an elevated structure where marbles are input to be sorted. As shown in Figure 2.1, it is comprised of the chute, a paper slide where marbles are placed, which is attached atop the scaffold, a wooden support structure. The chute is elevated and angled downward toward the sorter so marbles can approach the sorter from above. When marbles are placed onto the chute tower, they roll down the length of the chute gaining speed toward the sorter. The small marble receiver sits under the chute tower.



**Figure 2.1:** Chute Tower

### 2.1.1: The Scaffold

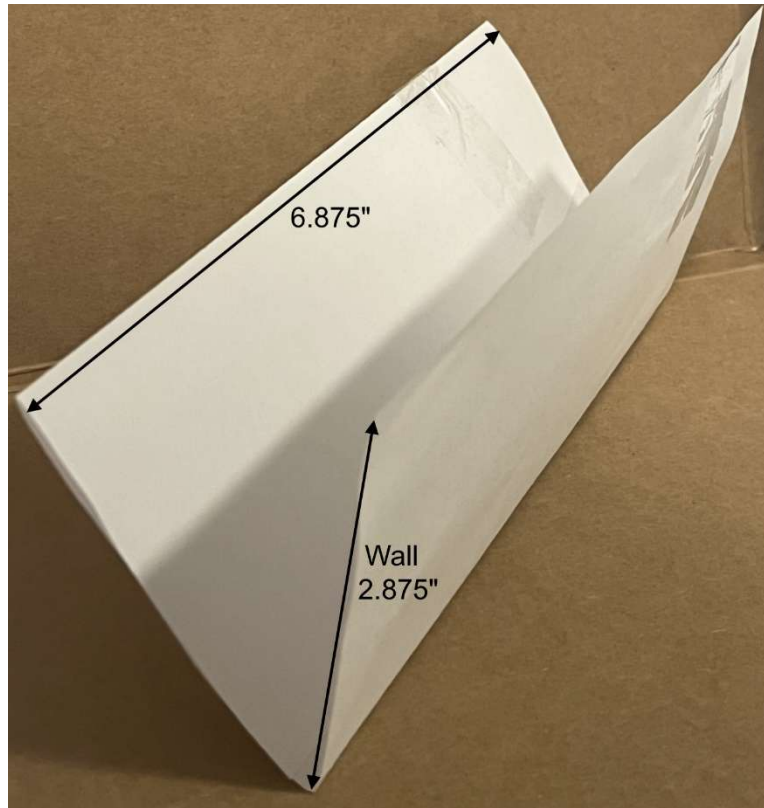
The scaffold is an open wooden structure that supports the chute. It is arranged in a rectangular prism shape and positioned vertically. As illustrated in Figure 2.2, it consists of two subparts: the pillars and the rungs. Both parts are made of wooden popsicle sticks and arrive pre-assembled into the scaffold. The four pillars make up the vertical component of the scaffold and are composed of three popsicle sticks glued end-to-end. Wherever two popsicle sticks overlap in a pillar, a rung is attached perpendicularly to connect two adjacent pillars together. The rung is a single popsicle stick, measuring 0.375" wide, 4.5" long, and 0.0625" thick. The pillars, made from three of the same popsicle sticks, measure about 12.5" tall, giving the scaffold a roughly 12.5" tall by 4.5" wide footprint as displayed in Figure 2.2. The chute attaches to the top end of the pillars.



**Figure 2.2:** Side view of the scaffold.

### 2.1.2: The Chute

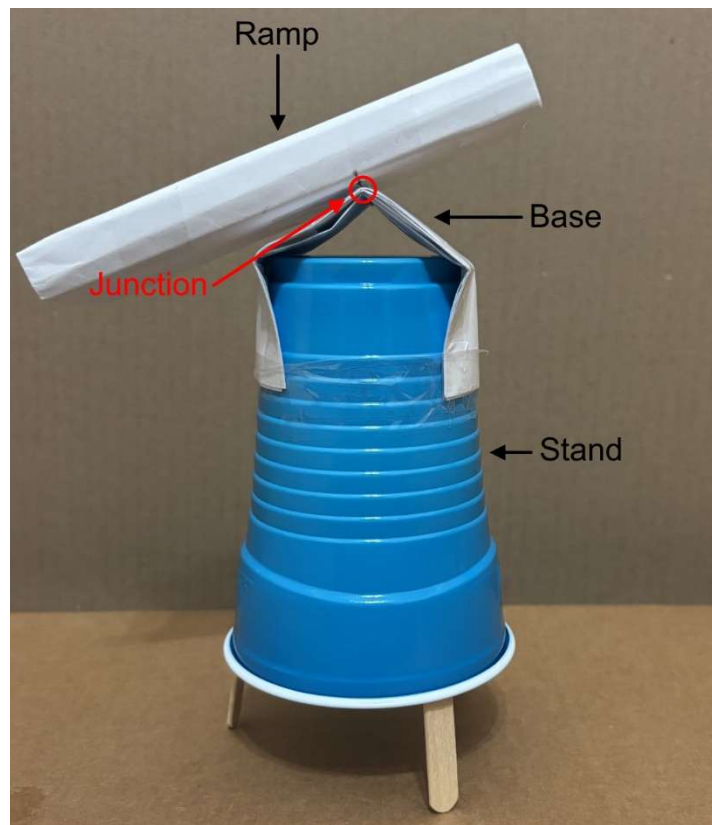
Positioned atop the chute tower, the chute enables marbles inserted by the user to roll down onto the sorter. It is made of a piece of paper folded into thirds lengthwise, with two thirds taped together to form an elongated V shape. It is 6.875" in length and its two walls are 2.875" tall, as shown in Figure 2.3.



**Figure 2.3:** Oblique view of the chute.

## 2.2: The Sorter

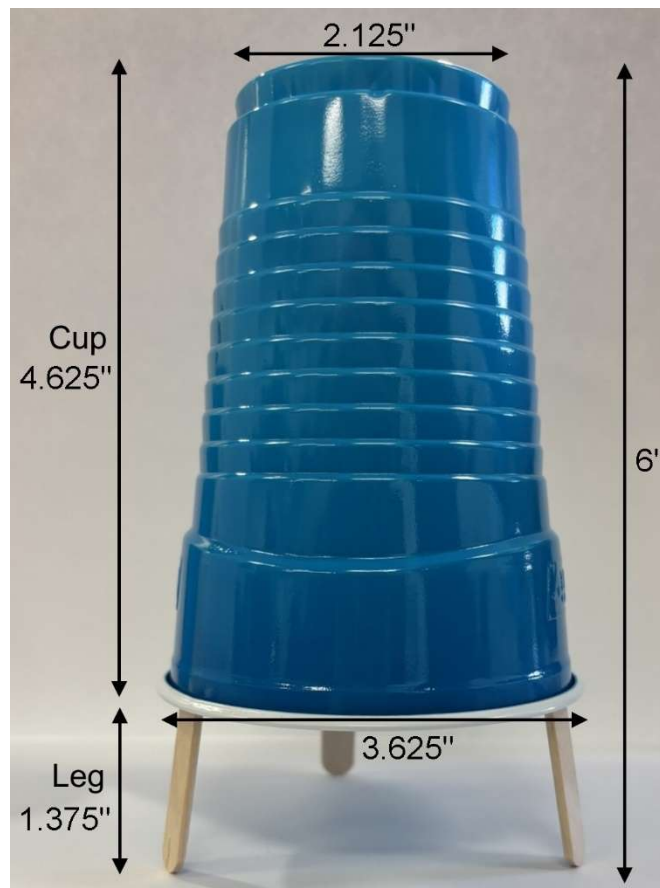
The sorter is a three-part structure that separates marbles based on their weight. As seen in Figure 2.4, its components include the ramp and the base, made of paper, and the stand made of a blue plastic cup and popsicle sticks. The components are pre-constructed but must be assembled into the sorter. The base is taped at its sides to the top of the stand, forming a peak to which the ramp is connected. At this junction, the ramp meets the peak of the base slightly off-center and is tilted towards the small marble receiver by default. When small marbles are inputted, they do not carry enough weight to tip the ramp and therefore follow the default tilt into the small marble receiver. On the other hand, large marbles cause the ramp to tilt, falling into the large marble receiver.



**Figure 2.4:** Overview of the sorter.

### 2.2.1: The Stand

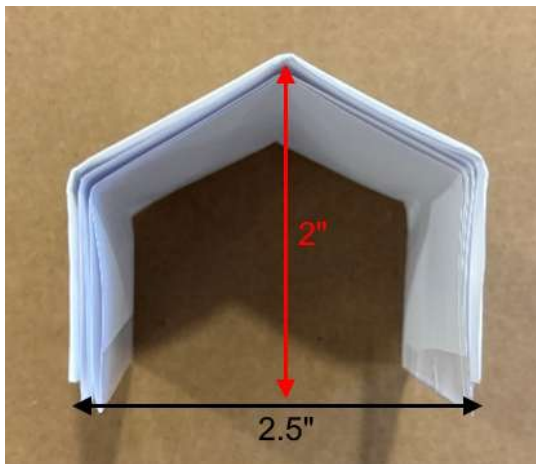
The stand is a stable platform that elevates the sorting mechanism above the receivers. It comes preassembled and is composed of an upside-down ridged blue plastic cup and three popsicle sticks that serve as legs, as seen in Figure 2.5. The popsicle sticks used are the same kind used for the scaffold and are taped to the inside of the cup equidistant from each other for maximum stability. The plastic cup is 4.625" tall, and each leg protrudes 1.375" from the cup, giving the stand a total height of 6". The base will be directly attached to the top of the stand with tape, which will be outlined in the assembly process.



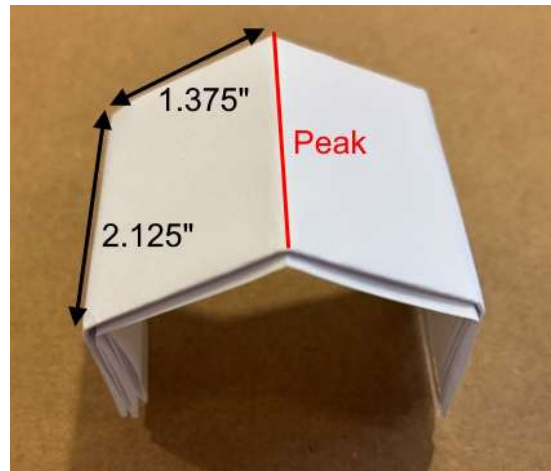
**Figure 2.5:** Overview of the stand with measurements.

### 2.2.2: The Base

The base is a structure that supports the ramp and allows it to pivot, similar to the fulcrum of a seesaw. It is made by folding a letter-sized paper in half three times, creating a multi-layered strip that is then folded into four equal segments. After folding, it resembles a tent with a peaked roof and open sides. It is 2.5" wide and 2" tall, as seen in Figure 2.6, with each of its segments being 2.125" long and 1.375" wide, as shown in Figure 2.7. During the assembly of the sorter, the ends need to be taped to the stand. The peak of the base, indicated by a red line in Figure 2.7, forms the pivot point of the sorter.



**Figure 2.6:** Front view of the base.



**Figure 2.7:** Top view of the base.



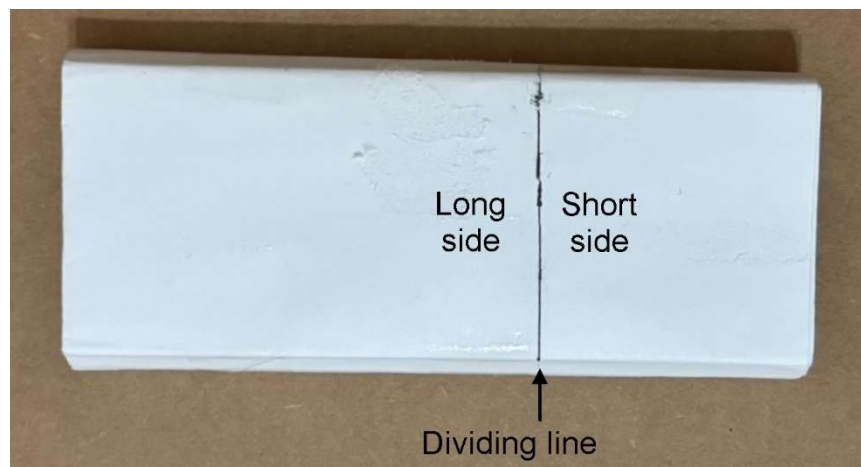
### 2.2.3: The Ramp

The ramp is a flat paper surface with walls on either side, as seen in Figure 2.8.



**Figure 2.8:** Top view of ramp.

Its purpose is to remain stationary when small marbles are sent through the machine, and to tilt like a seesaw to the other side when large marbles are input. The floor, which is 5.5" long, is made of folded paper and is light enough for large marbles to displace it, yet sturdy enough for small marbles to make no impact. The walls, measuring 0.625" tall, prevent marbles from bouncing off the floor, which spans 2.125" across. A dividing line splits the ramp into a long and short side, as seen in Figure 2.9. The long side is roughly 60% of the ramp's length, and the short side is roughly 40%. The ramp is attached to the base's peak at the dividing line, causing the ramp to tilt toward the long side by default.



**Figure 2.9:** Underside of the ramp.



## 2.3: The Receivers

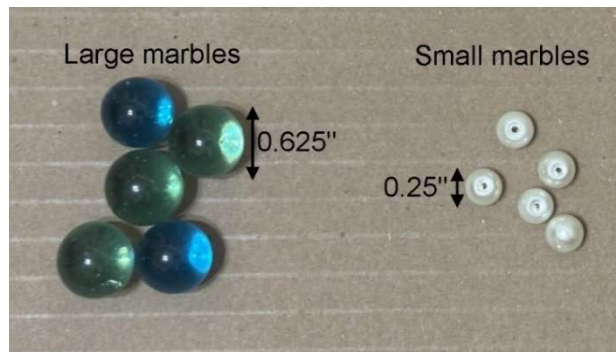
The receivers are plastic cups that have blue outsides and white insides. They have horizontal ridges on their bodies and wide rims at the top. As shown in Figure 2.10, an individual receiver is 4.625" tall, with a rim diameter of 3.625" and a base diameter of 2.125". Two receivers come in the kit: one for catching large marbles, called the large marble receiver, and one for catching small marbles, called the small marble receiver. After the marbles go through the sorter and fall down the ramp, they are sorted into the corresponding receiver based on their size.



**Figure 2.10:** Side view of the receiver

## 2.4: The Marbles

The kit comes with five large and five small marbles, as shown in Figure 2.12. Each large marble is made of translucent glass, colored blue or green, has a diameter of 0.625", and weighs about 5 grams. Each small marble is made of pearlescent plastic, has a diameter of 0.25", weighs about 0.6 grams, and has a hole through its center. The marbles are sorted into their respective receivers by the marble machine.



**Figure 2.12:** Top view of the marbles.

## 3.0: Assembly Guide

Before setting up the marble sorter, you must assemble the sorter and the chute tower out of components included in the kit.

### 3.1: Sorter

To build the sorter you will need three components: the stand, the base, and the ramp. You will also need clear tape for securing the parts together.

#### ***Step 1: Attaching the base to the stand***

Set the stand upright on a flat surface. Next, set the base on top of the stand, aligning its ends with the third ridge line, and hold it in place.

#### ***Step 2: Securing the base to the stand***

Secure the base to the stand by wrapping tape around the stand over the ends of the base. First pull out the end of tape from the dispenser and attach it to the stand halfway between the two sides of the base, as seen in Figure 3.2. Next, while keeping the dispenser pressed against the stand, pull it around the stand until you just pass the start of the tape strip, cut the tape off the dispenser, and secure the end of the strip over the start of the strip. The precise length is not important, the strip of tape just needs to go all the way around the stand, as seen in Figure 3.2.

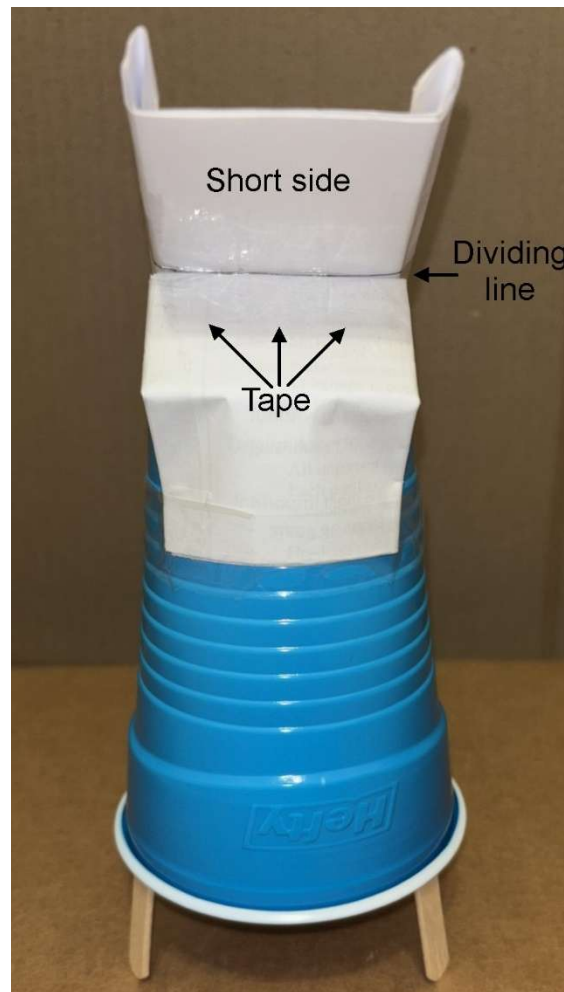


**Figure 3.2:** Base secured to the stand with tape.

### **Step 3: Attaching the ramp to the base**

For this step you will need 6 strips of clear tape that are each around 2” long.

Place and hold the long side of the ramp against either of the top faces of the base, aligning the ramp’s dividing line with the base’s peak, so that the short side points up. Under the short side of the ramp, press one half (lengthwise) of a tape strip onto the center of the base directly next to the underside of the short side, then press the other half up onto the underside of the short side of the ramp. Repeat this taping process on both sides of the first strip, so that three adjacent tape strips are securing the short side of the ramp to the base, as seen in Figure 3.3.



**Figure 3.3:** The ramp’s short side taped to the base.

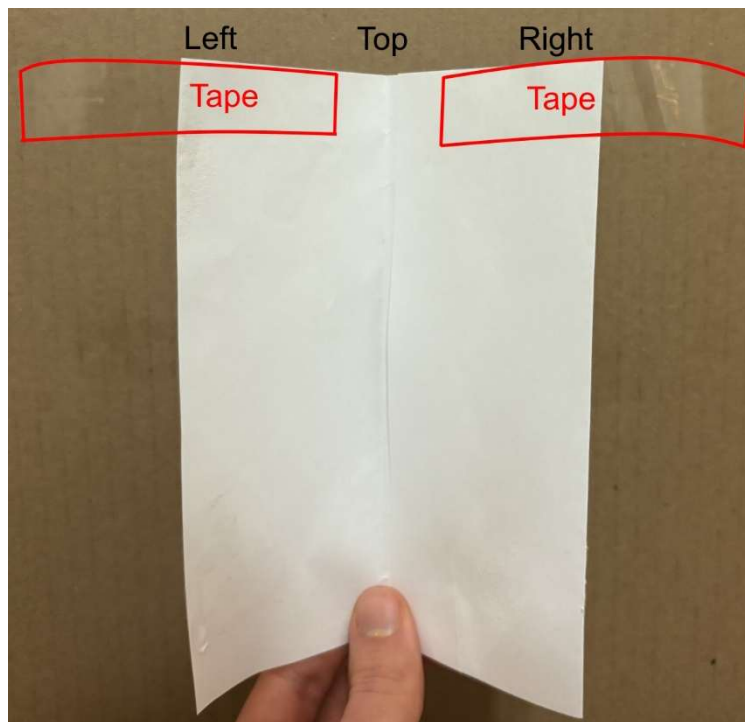
Next, release the long side of the ramp and hold the short side down against the base, so that the long side is hanging over the base’s peak. Repeat the taping process used on the short side of the ramp for the long side, so that three pieces of tape secure it to the base.

### 3.1.2: Chute Tower

To assemble the chute tower, you will need the scaffold, the chute, and two strips of clear tape about 4" long.

#### ***Step 1: Preparing the scaffold and chute***

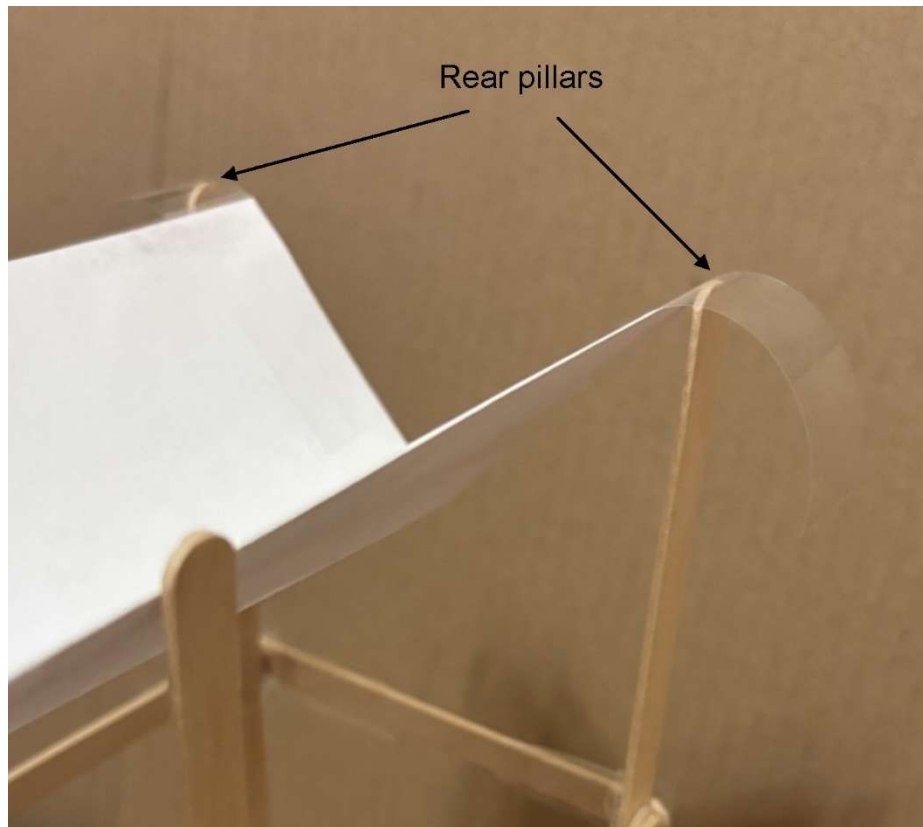
Set the scaffold upright on a flat surface, with the thin sides of the pillars facing you. Next, attach half of a strip of tape, lengthwise, to the inside of the top left of the chute, leaving the other half hanging, as seen in Figure 3.4. Repeat for the top right of the chute, also as seen in Figure 3.4



**Figure 3.4:** Assembler holding the chute with tape attached at its top.

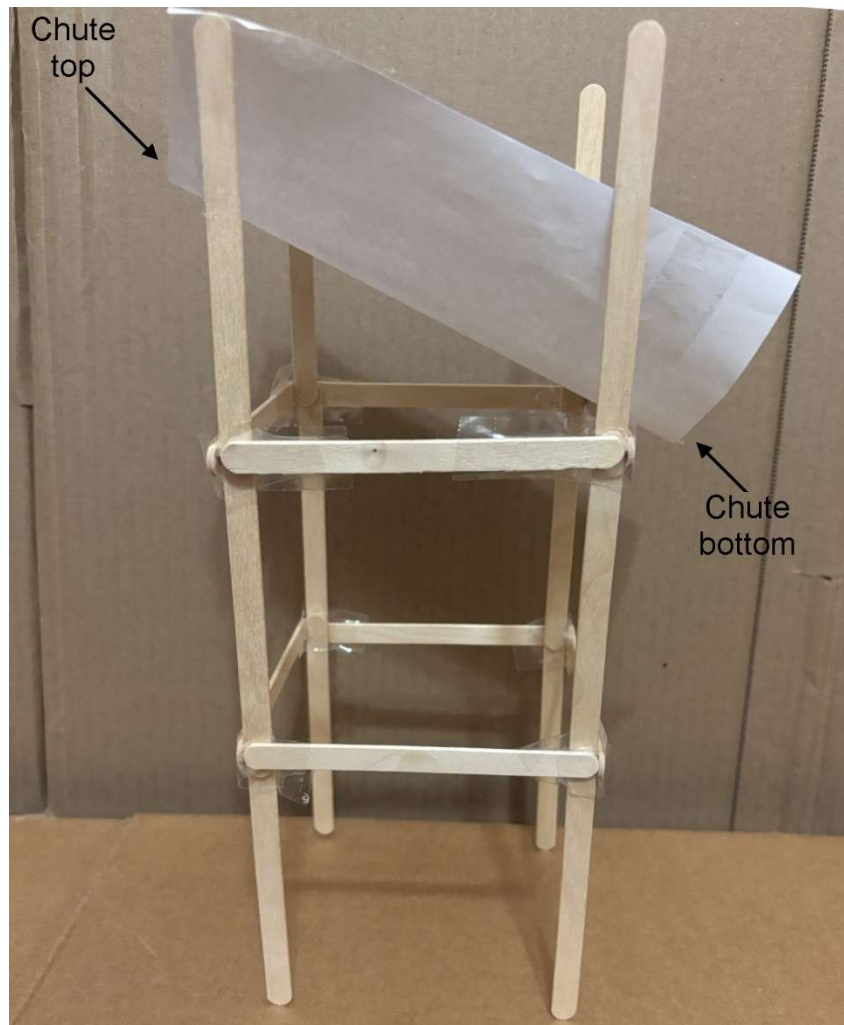
**Step 2: Attaching the chute to the scaffold**

Drape the tape attached to the chute over the rear two pillars of the scaffold, shown in Figure 3.5.



**Figure 3.5:** Tape draped over the scaffold's rear pillars.

Next, press the tape down against and around the pillars, securing the top of the chute to the scaffold. Finally, let the bottom of the chute rest on the rung of the scaffold below it to complete the chute tower, shown in Figure 3.6.



**Figure 3.6:** Completed chute tower.



## 4.0: User guide

Before using the marble sorter, you will need to complete a quick setup process.

### 4.1: Set-up

To set up the marble sorter, all that's left to do is positioning the major components the proper distance from each other.

#### **Step 1:**

Place a receiver upright on a flat surface. This receiver will catch the small marbles.

#### **Step 2:**

Place the chute tower centered over the receiver, so that the lower back rung of the chute tower touches it, as seen in Figure 4.1.



**Figure 4.1:** Chute tower over the small marble receiver.

**Step 3:**

Place the sorter so that the long side's end is directly over the lip of the small marble receiver, as seen in Figure 4.2.



**Figure 4.2:** Sorter with long end directly over the small receiver's lip.

**Step 4:**

Finally, place the second receiver so that its lip is directly under the short end of the sorter, as seen in Figure 4.3. This receiver will catch the large marbles.



**Figure 4.3:** Large receiver with lip directly under the sorter's short side.

## 4.2: Using the Sorter

To use the sorter, drop in either size marble at the top of the chute as seen in Figure 4.4.



**Figure 4.4:** User dropping a large marble into the top of the chute.

Small marbles won't be able to tip the ramp over and will be directed to the small marble receiver. Large marbles will tip the ramp over and will be directed into the large marble receiver. This predictable behavior will hold when putting marbles in the chute one at a time, but what will happen with more than one marble in the chute? What will happen with two different types of marbles in the chute? The only way to know is to experiment and find out!

## **5.0 Conclusion**

The machine is comprised of the chute tower, the sorter, and two receiver cups, each made of common materials. The use of paper, popsicle sticks, and plastic cups as the only materials make this toy accessible and easy to assemble for all ages.

The marble machine is a way for children to construct their own physics demonstration and understand the various parts it is composed of. The chute tower's scaffold teaches the fundamentals of construction, and how to support a structure off the ground. The sorter teaches about levers, and the different marble weights show the effect of various forces on the lever. When heavier marbles are input, the greater mass causes more momentum to transfer to the sorter, causing it to tip. When compared to the smaller marbles, this demonstrates the relationship between mass and momentum. While children may have an intuitive sense for this, the marble machine clearly demonstrates this concept and allows children to develop a more explicit understanding.