LESSON

Balance Scale

Overview

In this lesson, students will:

- Children learn to compare object sizes from a very young age. It's a useful skill in identifying the largest piece of cake or biggest pile of candy. As adults, we measure weight to determine how much a package costs to mail, if a truck can safely cross a small bridge or whether we may need to buy new clothing in a larger size. A balance scale is an objective way to compare the weight of two different objects directly. This tutorial describes how to build a working balance scale and ways in which students may use it to explore the concepts of balance, weight and size.

THE OBJECTIVE

- Learn what it means for objects to have different weights
- Understand the concept of balance and what it means for an object to be balanced
- Understand how a balance scale indicates differences in weight between two objects
- Explore the relationship between size and weight of objects made from the same material
- Compare the weights of objects made from different materials
- Use small objects as a unit of measure to find the weight of larger objects

GRADE LEVEL:	DIFFICULTY
PRE-K to 3 (Elementary)	Easy, but an adult will need to perform wire cutting and bending
SUBJECTS	**DURATION**
Measurement, Math	60 minutes
STANDARDS	**VOCAB**
CCSS.MATH.CONTENT.K.MD.A.2 Directly compare two objects with a measurable attribute in common, to see which object has "more of"/"less of" the attribute, and describe the difference. CCSS.MATH.CONTENT.1.MD.C.4 Organize, represent, and interpret data with up to three categories; ask and answer questions about the total number of data points, how many in each category, and how many more or less are in one category than in another CCSS.MATH.CONTENT.3.MD.A.2 Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l).1 Add, subtract, multiply, or divide to solve one-step word problems involving masses or volumes that are given in the same units	Balance, Weight, Calibrate

Supplies

SOFTWARE:

- Glowforge App

MATERIALS & TOOLS:

- Proofgrade Medium Draftboard
- Proofgrade Medium Acrylic - any color
- 2 or 3 medium size paper clips
- Assortment of small items to weigh on the scale
- Wire cutter
- Needle nose or pointed nose pliers

DESIGN FILES:

- BalanceScale.svg
- Washers.svg
- CalibrationWeights.svg
- BalanceWeights.svg

Description

LESSON OUTLINE:

- Build a working balance scale
- Explore how a balance scale compares the weight of two objects
- Estimate objects' weights and test estimates with the scale
- Compare objects of varying sizes to observe how size and weight are related

ASSESSMENT STRATEGIES:

FORMATIVE ASSESSMENT: Circulate the classroom and observe students at work, are they collaborating and/or using teamwork, and any other items you wish to assess.
SUMMATIVE ASSESSMENT: Use the Magical Things Journal to document student learning.
STANDARDS

Lesson Instructions

Step 1: SETUP

Description

This activity requires a sheet of Proofgrade Medium Draftboard, a small amount of Proofgrade Medium Acrylic, a paper clip, wire snippers and pointed-nose pliers to construct the balance scale. While the scale is easy to use, an adult will need to supervise the construction - particularly when cutting and bending the paper clip.

Additional weights, scaled in multiples of a fixed base unit may be cut from any uniform sheet material, such as draftboard or acrylic.

Step 2: INTRODUCTION TO WEIGHT AND BALANCE

Ask students if they know what weight is. What does it mean for objects to be heavy or light? If they are given two objects, how can they tell which is the heavier of the two? Is the bigger of two objects always heavier than the smaller one? How do we measure the weight of objects in our everyday lives?

Ask the students if they know what "balance" means and if they can name examples of things that are balanced. For example, when they attempt to balance themselves on one foot, they are trying to stay upright. If they've ever played on a see-saw in a playground, they may have noticed that it is much easier to operate when the people on either side are about the same weight. What happens when a see-saw is not very well balanced - i.e. when the weights on both sides are unequal?

If you feel like introducing more advanced concepts, ask the students whether it makes a difference where the riders sit on a see-saw. If an adult wanted to play on a see-saw with a child, where should the adult sit to make it pivot more easily?

Step 3: IDEATE

Design Thinking Cycle:
Now that students have an understanding of the lesson, introduce them to the Design Thinking Process and how they will use that to complete the lesson. (Copied below, update the description of each step so it is relative to the lesson.)

SETUP-
INTRODUCTION TO WEIGHT AND BALANCE-
IDEATE - come up with as many ideas as you can
CREATE - Decide on an idea to pursue and prototype.
TEST - Students test their prototypes to see if it works
DISCUSS AND REFLECT-

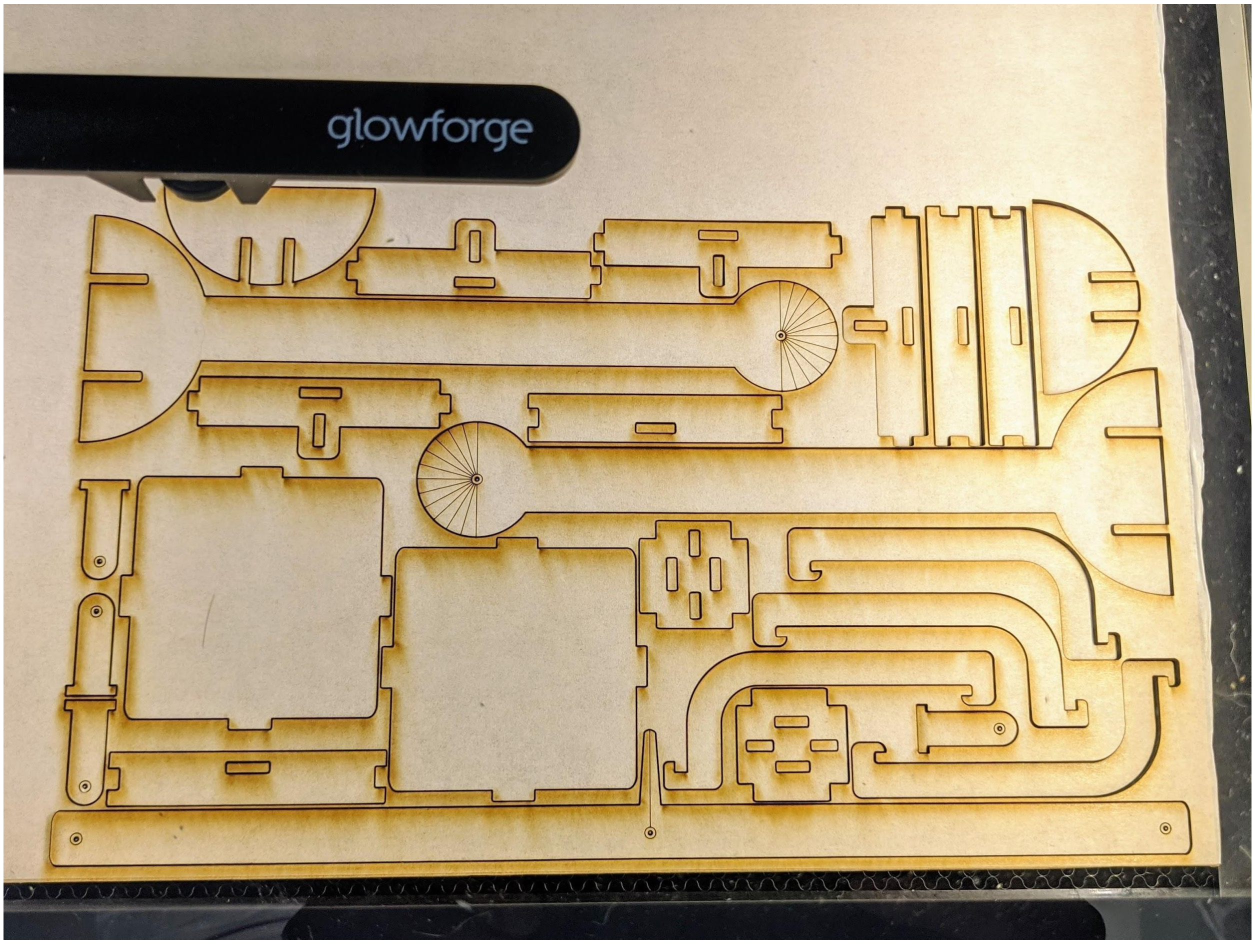
Ask the students to think of methods they could use to determine which of two objects is heavier without using an electric scale. Do the methods they come up with work well with very small objects (e.g. pennies) and very large objects (e.g. trucks), or are different techniques required to compare weights of small and large objects?

In this lesson, students will build and use a balance scale to directly compare the weight of different objects to each other. A balance scale has a long, straight arm (balance arm) which can pivot about its center. If two objects are placed at opposite ends of the arm, equidistant from the pivot, the balance arm will tip, lowering the heavier object and raising the lighter one.

Step 4: CREATE

Create your invention!

<u>Print the Balance Scale Parts</u>:

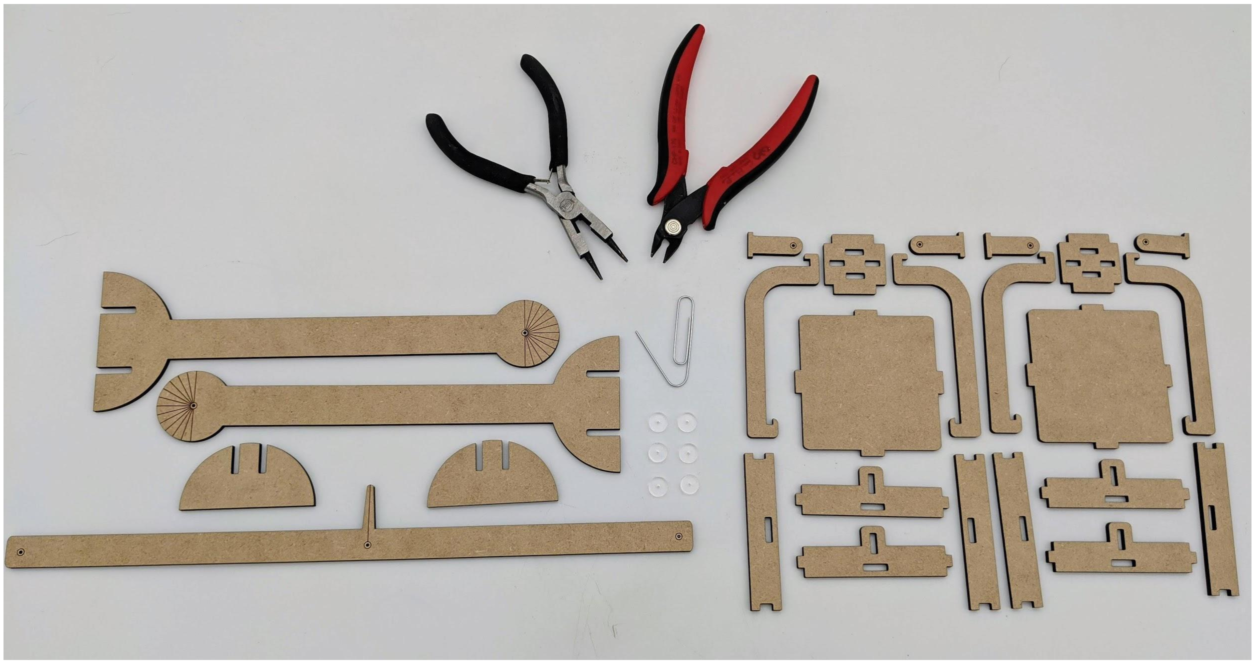


Place a sheet of Proofgrade Medium Draftboard onto the Glowforge print bed and open the Glowforge App. Click the **Import Artwork** button in the Glowforge app and select **Upload** Upload to import the design file "BalanceScale.svg". This file contains outlines for all wooden parts to construct the scale. The black lines in the file should be set to **Cut** and all red lines to **Score.** Be careful not to cut along the score lines when printing the pieces of the scale. Once the settings are correct, print the wooden pieces, remove them from the Glowforge and peel off all protective paper.

The balance scale design uses six small washers cut from acrylic to help the scale rotate easily. Place a piece of Proofgrade Medium Acrylic on the Glowforge print bed.

Delete any design files from the Glowforge app, and click the **Import Artwork** button in the Glowforge app, then select **Upload** Upload to import the design file "Washers.svg". Cut the washers from the acrylic, remove them from the print bed, and peel off any protective paper. The six washers are very small and can be hard to see if they're cut from clear acrylic, so put them in a place you will be able to easily find them later.

Assemble the Balance Scale:

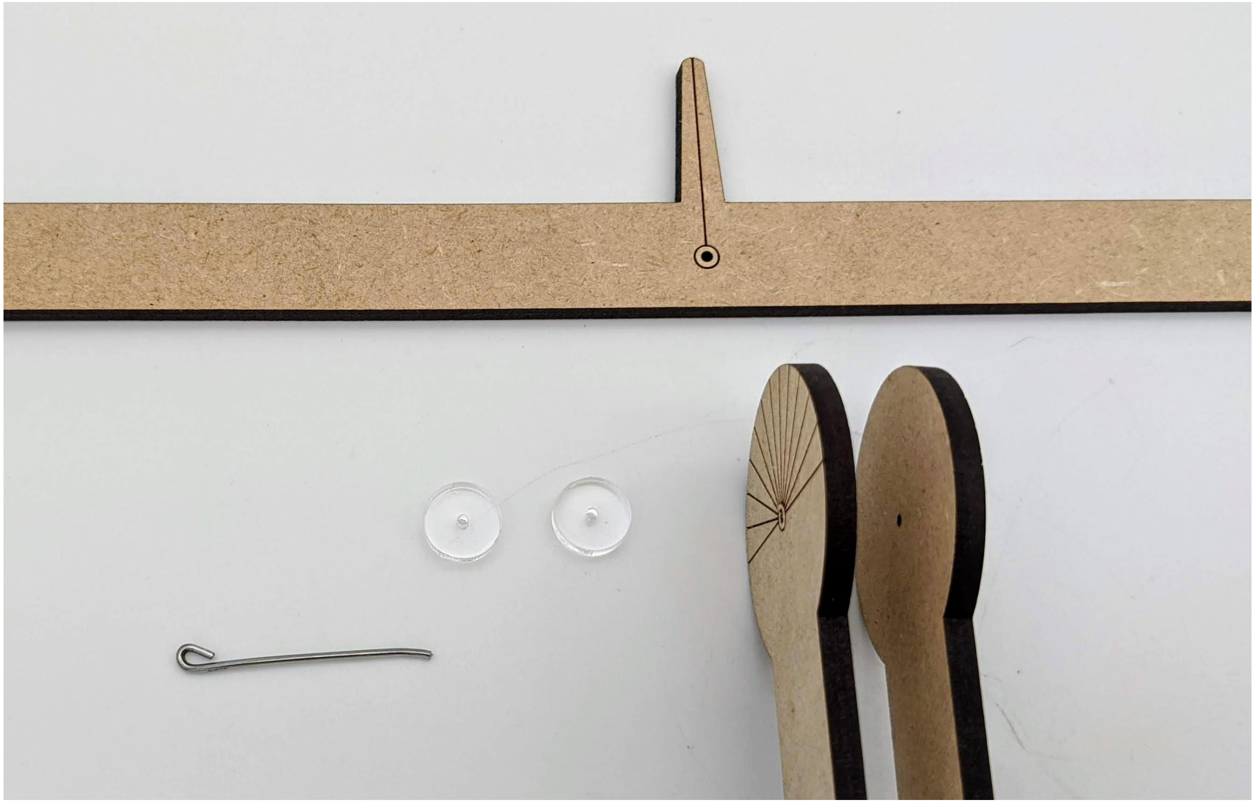


The scale mechanism consists of a main body, with a pivoting "arm" and two baskets which can pivot around the ends of the arm on "axles" constructed from cut paper clips.

The first step is to construct the stand which holds the balance arm. Take the two long wooden pieces with notched bottom edges and slot them into the two notched half-circles to assemble the stand, as shown in the images above.

The next step is to add the balance arm to the stand. The balance arm is the long, straight wooden piece with a tall bump in the middle. Just below the bump there is a small hole to mount the arm on an axle. You will cut and bend a standard paper clip to construct the axle.

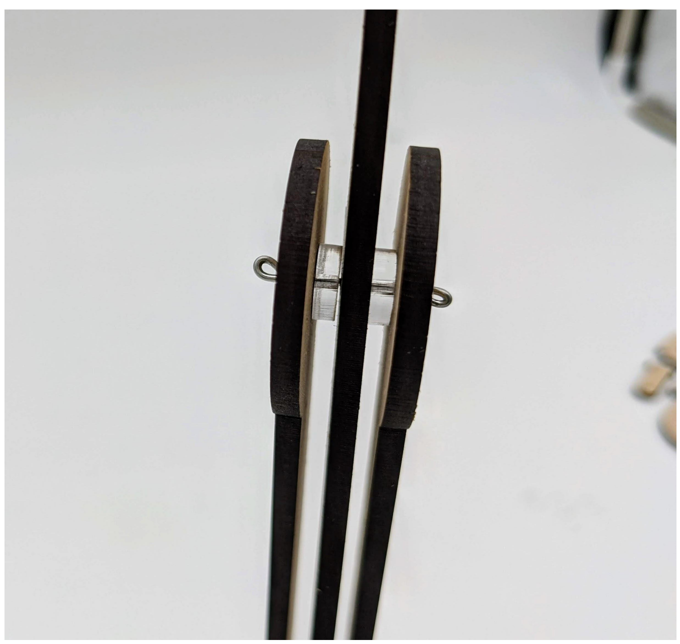
CAUTION: when cutting the paper clip with the wire cutters, small, pointed pieces can easily fly off at high speeds. This part of the project should be done by an adult wearing glasses or safety goggles, with no other nearby observers.



Unbend one arm of the paper clip, and use the pointed nose pliers to curl the free end into a loop. Cut the looped arm away from the rest of the paper clip with the wire cutters. It should look like the wire shown in the image above. **Be very careful when cutting the clip so that the sharp pieces don't fly off wildly, as they can cause injury.**

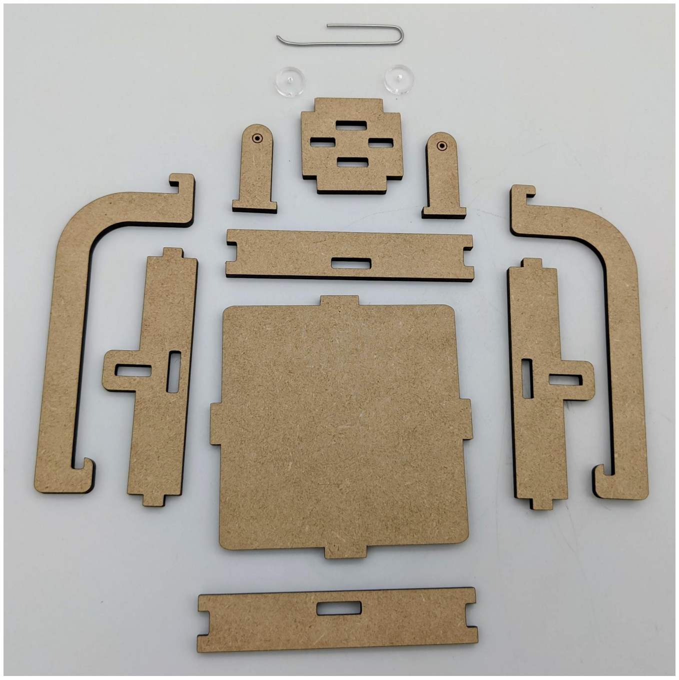
When cutting or bending the ends of the clip, try to keep the rest of the paper clip as straight as possible. The paper clip forms an axle for the balance arm, and the straighter it is, the more easily the balance scale will pivot.

Now slide the straight end of the paper clip through the two parallel holes in the top of the stand. It will pass through both washers and the hole in the center of the balance arm. Starting from the outside of the stand, the wire should pass through these layers in the following sequence:
→ stand → washer → balance arm → washer → stand→

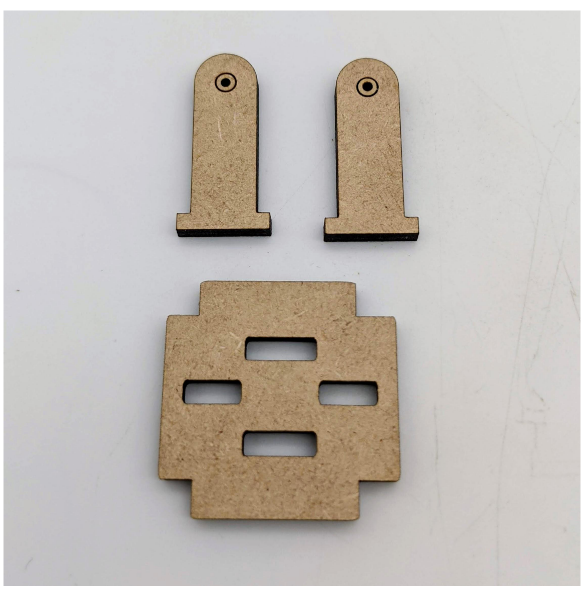


Once the wire has passed through all of the layers, carefully use the pointy-end pliers to curl the loose end of the paper clip wire into a loop, so the wire won't slip back out, and so that no sharp edges are left exposed. While curling the end of the wire, take care not to bend or warp the straight portion of the wire. The balance scale works best if the axle is perfectly straight.

Once the arm is attached, try rotating it to be sure it swivels around the paper clip freely and easily. If there is any kind of resistance to rotation, it will throw off the scale’s accuracy.

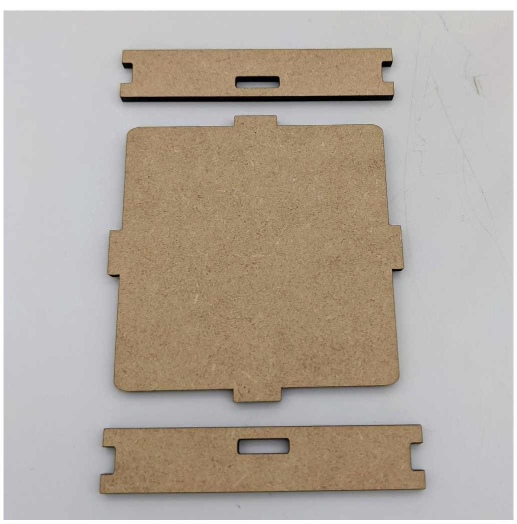


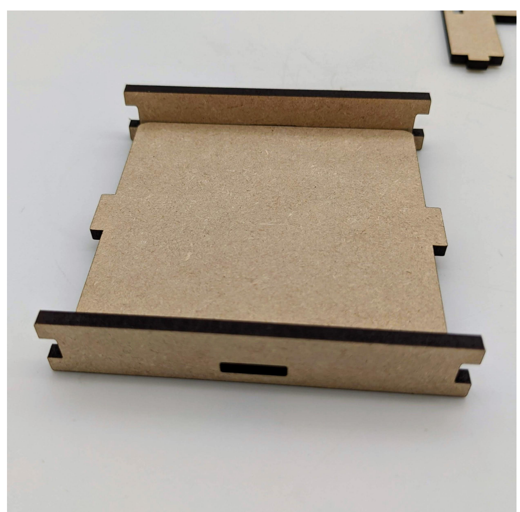
Now set aside the stand and balance arm, and gather the pieces shown above to assemble one of the two baskets.



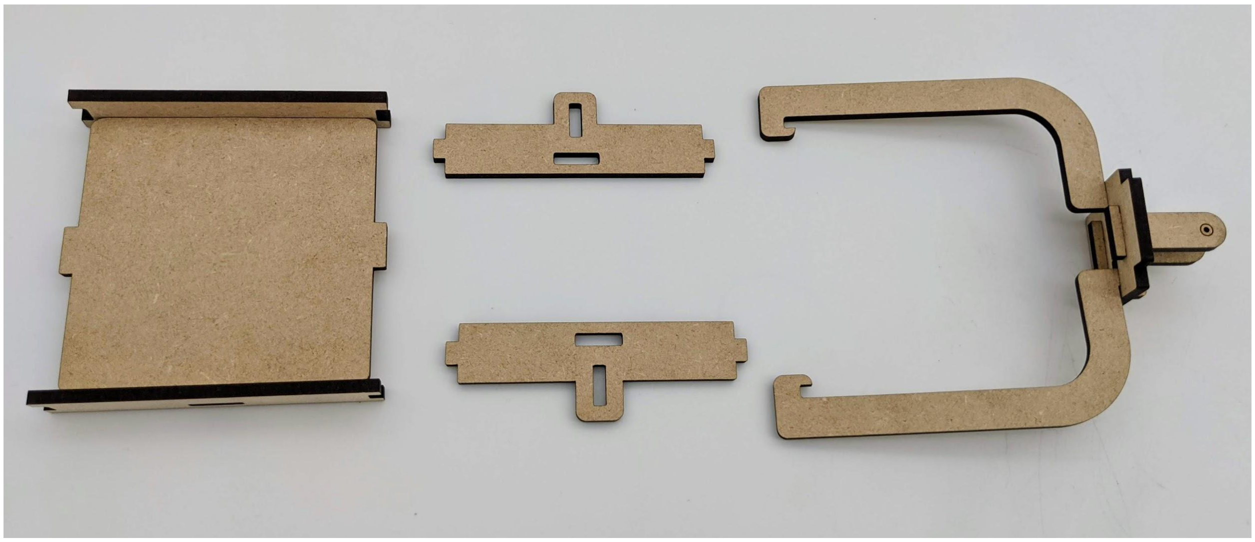
The small piece with four rectangular slits holds the two round-edged wooden pieces to form a pivot. Push the round-edged pieces through the two parallel slits as far as they will go, as shown above.

The two long curved pieces shown above are connecting arms which attach the basket to the pivot. Lay out the connecting arms and the pivot base you just assembled in the same orientation shown in the pictures. Insert the top ends of the connecting arms upwards into the two unoccupied slits in the pivot base. Push the ends of the connecting arms upwards as far as they will go, then gently slide each connecting arm outwards towards the edge of the pivot base. In this position, the notch in each connecting arm grips the pivot base to help secure them together.

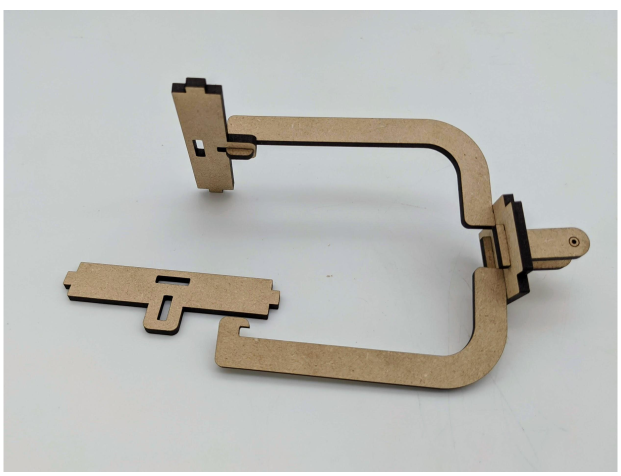


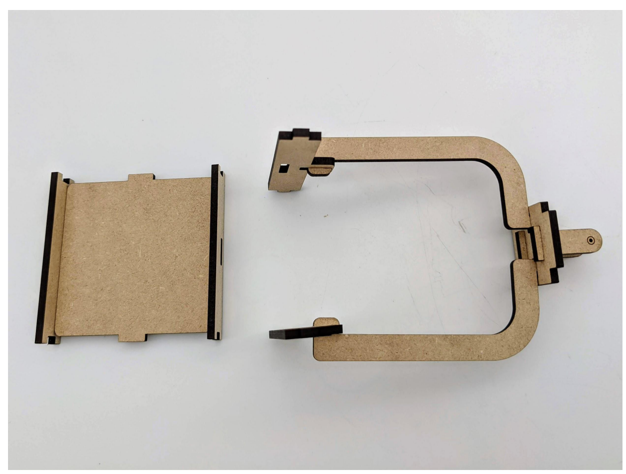


The next step is to assemble the basket. Find the large square wooden piece with tabs protruding from its sides. This piece forms the base of the basket. Take the two straight pieces with notches in their ends, shown above, and slot them over the tabs to form two of the sides of the basket.



Next, attach the basket to the pivot piece. Lay out the pivot with the connecting arms attached, the partially assembled basket, and the two remaining sides of the basket as shown above.





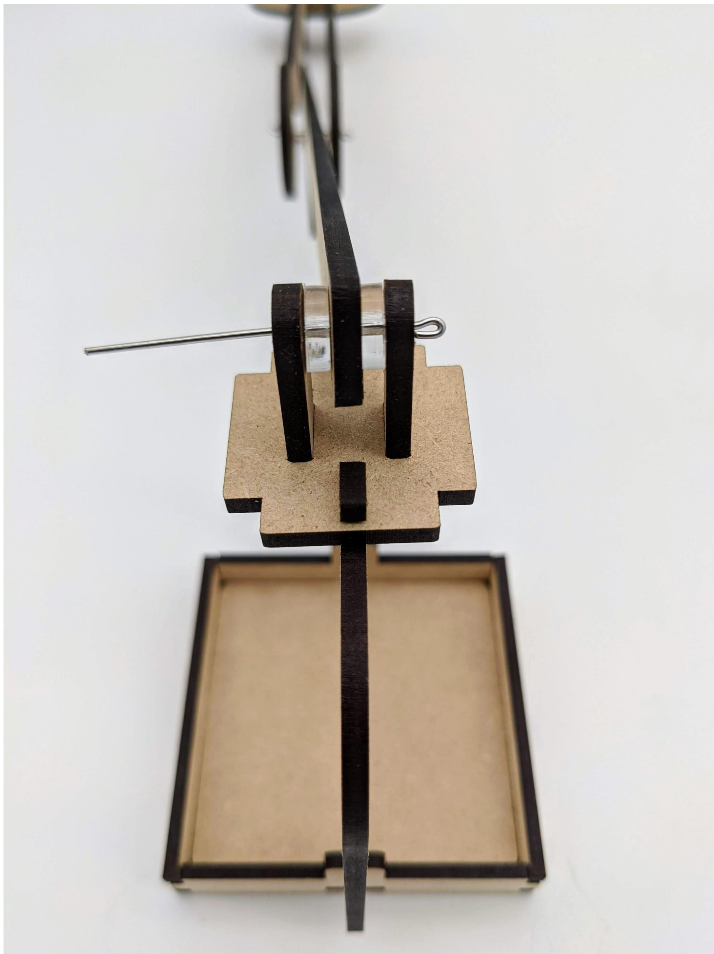
Slide the “hooks” at the lower ends of the connecting arms through the vertical slots in the two basket sides, as shown. Push the hook through the vertical slot as far as it will go, then gently slide the basket side down along the connecting arm into the notch in the hook. This prevents the basket from slipping off the connecting arm.


Once two basket sides are hooked onto the connecting arms, raise the pivot upright so that the basket sides align with the open edges of the basket, as shown above. Push the sides together until the slots slip over the tabs.

The basket assembly is now complete. Friction will hold it together quite well, but if you'd like to attach the pieces even more securely, add a few drops of glue where the separate wooden pieces meet to reinforce the connection.

Repeat the construction process with the remaining wooden pieces to create the second basket assembly. When the scale is fully assembled, one basket hangs from each end of the pivot arm. The baskets need to be able to swing freely when the pivot arm rotates, so they'll be secured using the same paper-clip axle technique that attaches the pivot arm to the base.

Place each basket assembly near one end of each pivot arm as shown, The holes in the basket pivots should line up with the holes in the ends of the pivot arm. To attach each basket to the arm, follow the exact same procedure used to attach the pivot arm to the base.



CAUTION: when cutting the paper clip with the wire cutters, small, pointed pieces can easily fly off at high speeds. This part of the project should be done by an adult wearing glasses or safety goggles, with no other nearby observers.

For each basket, take a paperclip, unbend one side, and using pliers, curl the free end into a small loop. **Carefully** cut that side away from the rest of the clip so that you now have a small straight piece of wire with a loop at one end. Take two acrylic washers, and slide the straight end through the holes in the pivot, through the washers and through the pivot arm in the following order. → pivot → washer → balance arm → washer → pivot →

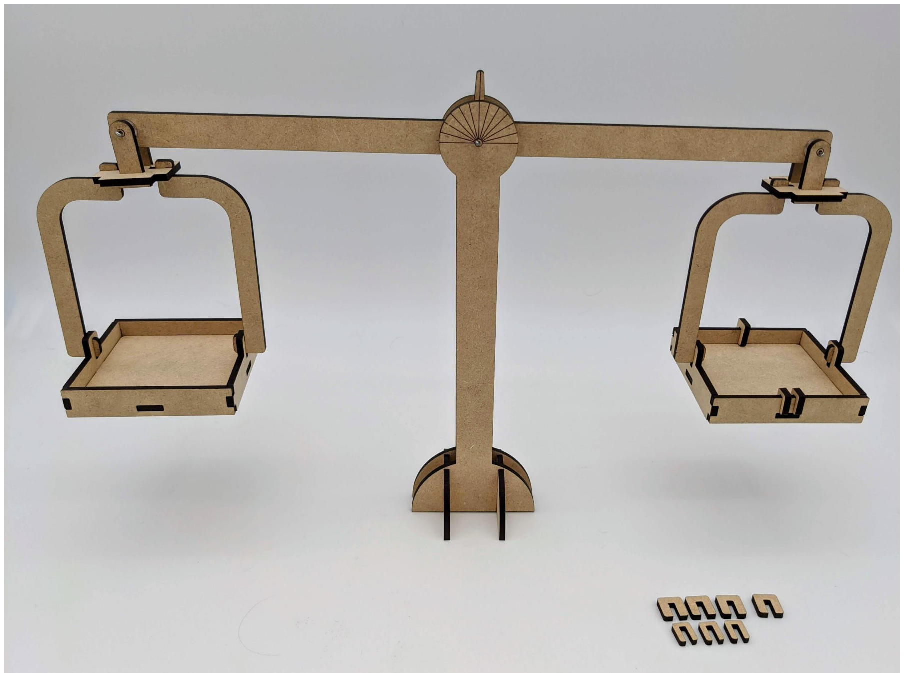
When connecting the basket to the axle, try to keep the wire as straight as possible so that the basket may rotate freely. When the wire is completely inserted, carefully trim and bend the free end of the wire back over itself to keep the axle from slipping out. Be sure that the sharp end of the wire is not left exposed.

Repeat this process to attach the other basket to the balance arm.

Once both baskets are attached, the balance is complete. Test it out and verify that the balance arm and both baskets swing freely and easily when moved. Place the balance on a level surface and let the arm come to rest. If it is balanced, both baskets will sit at the same height. If it is not balanced, as shown in the picture above, you will need to “calibrate” the scale by adding small pieces of wood to the lighter side until it becomes level.

Calibrate the Balance:

If the balance isn’t level it can be “calibrated.” Use the Glowforge to cut the U-shaped clips from the file “CalibrationWeights.svg”. Cut them from Proofgrade Medium Draftboard with all lines on the **Cut** setting.



The calibration weights come in two sizes, and fit over the sides of the basket as shown. Attach the clips one at a time to the lighter basket until both baskets come to rest at the same height when empty.

Make Weights:

Now that the scale is built, students can use it to compare the weights of different items. If you'd like to compare some objects whose relative weights are known, print the weight blocks and their U-shaped stands from the design file “BalanceWeights.svg” When assembled, they look like the image above.

Cut the weights from either Proofgrade Medium Draftboard or Proofgrade Medium Acrylic. Any ⅛” thick, uniform sheet material can work. When cutting the pieces in the Glowforge App, set the black outlines to **Cut** and red letters to **Score**. If the weights are made from Draftboard, friction will hold the weights and their stands together. If they are cut from acrylic, you will need to apply a small drop of glue between each weight and its stand to help them stay together.

Step 5: TEST

Test your creation!
Below are some ideas for activities which use the balance scale:

<u>Activity: Which is Heavier?</u>

Gather some small objects from around the house. Good items to use include coins, paper clips, batteries, candy like M&Ms or marshmallows, or similar objects.

Have students select two different items of similar size. Before weighing the items, ask the students to guess which one is heavier. How can they use the scale to determine which one weighs more? Place each item in a different basket on the scale, and watch where the baskets come to rest. The basket with the heavier item will sink downwards while the other basket gets lifted up by the balance arm. Ask the students if the measurement matched their expectations.

While comparing different items, ask the students if larger items are always heavier than smaller items. Which is larger, a marshmallow or a nickel? Which weighs more? If you have those items on hand, or similar items (e.g. a coin or marble for the smaller item and a cotton ball or folded piece of paper for the larger one), then you can demonstrate that smaller objects *can* weigh more than larger ones.

Gather some small items which are identical to each other, like paper clips (or LEGO bricks, marbles, coins, binder clips, etc..) Using the balance scale, verify that these items do indeed have identical weights. These identical items will be their new units of weight.

Select a different item and place it in one basket on the balance scale. Ask the students to predict how many paper clips (or whatever unit item they are using) must go in the other basket to balance the scale. Have them place their unit items in the basket, one at a time, until the scale balances. Count the number of unit items, and compare their prediction to the actual measurement.

Try weighting a variety of other objects against the unit items, recording students' predictions and the measurements in a chart like the one below. How accurate were the guesses? Did their accuracy improve with practice?

My object	My prediction of how many paper clips it weighs.	How many paper clips did it weigh?

Activity: Weight Detective

Select an assortment of 4 or 5 (or more) different items. On a piece of paper, write a list of the items. Use the balance scale to create a new list containing the same items ordered by their weights, with the lightest item first and heaviest item last.

Activity: How Do the Weights Relate?
(Note: this activity is more challenging than the others, and is best suited for older children)

This activity uses the free-standing pieces labelled “A” - “E”, which may be printed from the file “BalanceWeights.svg.” As long as they are cut from uniform material, the weight of each lettered piece has a fixed relationship to the others. Challenge the students to figure out the relationships between the weights of the lettered pieces. Have them determine the answers to the following questions using the balance scale:

(1) How many “A” weights does it take to balance one “B” weight?

(2) Using the answer from (1), can you predict how many “A” weights will balance two “B” weights? Test your answer using the weights and the balance scale.

(3) Two of the shapes labelled with different letters actually weigh the same as each other. Can you identify which two letters they are? How can you prove they weigh the same amount?

(4) Place a “D” weight in one basket on the balance. By placing only weights labelled “A” and “B” in the other basket, balance the scale. How many different ways can you use the “A” and or “B” weights to make the scale balance?

(5) Repeat (3), but use an “E” weight instead of a “D” weight.

(6) Placing only “B” weights in one basket and only “D” weights in the other, what is the smallest (nonzero) number of weights you can place in each basket to balance the scale?

Answers:
(it is useful to know that the weight ratio of the different lettered pieces is: A::B::C::D::E = 1::2::2::3::4)

(1) Two “A” weights balance one “B” weight
(2) Four “A” weights balance two “B” weights
(3) “B” and “C” weigh the same, even though they are different sizes. The proof is that they balance each other on the scale.
(4) There are two ways to balance a “D” weight using “A” and “B” weights: One “D” weight can be balanced with (i) three “A” weights -or- (ii) one “B” weight and one “A” weight.
(5) There are three possible ways to balance an “E” weight using only “A” and “B” weights. One “E” weight can be balanced with (i) four “A” weights -or- (ii) two “A” weights and one “B” weight -or- (iii) two “B” weights.
(6) Place three “B” weights in one basket and two “D” weights in the other.

Step 6: DISCUSS AND REFLECT

How did your testing go?

Now that they’ve had a chance to try out the balance scale, ask the students what they learned about weight and balance by using it. A balance scale can only measure the weight of two objects against each other. Can they think of a way to use the balance scale to numerically determine how many ounces an object weighs? (One way is to look up the weight of a penny, and see how many pennies are needed to balance their object)

The students might have had to calibrate their balance scale to make it balanced. How might the results of their measurements have been affected if they hadn’t calibrated it?

Students have probably weighed themselves by standing on a digital scale with a numerical display. Ask them in what ways a digital scale is different from a balance scale. Can they think of any ways to improve the scale, or other uses for it?