## Trebuchet Design Challenge

## Design Statement

You will be designing a trebuchet to toss a small bouncy ball the longest distance possible.

## Design Constraints

**Frame**

* The frame will be built out of ½” OSB plywood
* The height of the support arms may not be greater than 12”
* The base dimension will be 5” x 14”

**Arm**

* The total length of the trebuchet arm may not be greater than 16”
* The arm will be built in two pieces neither of which can exceed 9” in length.
* You may add fastening materials such as screws, glue or duct tape to the beam.
* The maximum width and height of the arm is 1.5” wide and ¾” thick.
* You will be limited to 6 in3 of ABS plastic (Volume as calculated by Inventor).
* No wall or plastic feature may be thinner than 0.100”
* Tolerance on the printer is +/-0.010”. Consider this as you design mating features.

**Counterweight**

* The counterweight will be contained inside a 250mL water bottle.
* Sand, rocks and/or water will be provided as filler material.
* You may use any material you can legally and safely obtain to fill the bottle.
* A screw hook mounted in the lid is suggested for hanging the bottle.

**Pivot**

* Two 0.75” diameter wheels and a 6” long 8-32 threaded rod will be provided to support the arm

**Projectile**

* The projectile will be a 1” diameter bouncy ball with a weight of 0.028 lb.

## Deliverables

1. Use the simulator at <http://virtualtrebuchet.com/> to optimize your Trebuchet design Record simulation values in a spreadsheet showing how you came up with your optimum design. Show at least 10 variations that lead to the preferred design. It is best to change one variable at a time. Values must be realistic (Individual, 10 pts)
2. Sketch of your preferred design showing all dimensions and features. (Individual, 10 pts)
3. Use AutoCad Inventor to model your Trebuchet Arm. Submit AutoCad Inventor part files for two halves of the arm design (2 each .ipt & .STL) (per team, 20 pts)
4. Functioning trebuchet. (per team, 10 pts)
   1. The stand will be made from OSB plywood as supplied.
   2. Use glue and a nail gun to assemble the stand
   3. Drill holes for mounting the trebuchet arm axle
   4. Create a sling that will hold the ball until release the ball
   5. Create a sled to allow the ball and sling to slide on the stand.
5. Final report (individual, 25 points)
   1. Table showing how far your ball traveled on each attempt. Describe adjustments made between each attempt.
   2. Simulation values from the actual AutoCad Inventor design including, Volume, Mass, Inertia about pivot point and Lengths of short and long arms measured from the pivot points
   3. Discuss how your design performed compared to the **simulation**. Explain any differences.
   4. Discuss how your design compared with **other designs**. Compare features of the best designs and the worst designs.

## Using AutoCad Inventor to Model your Trebuchet Arm

1. Using what you learned during the tutorial and what you can learn by exploring AutoCad Inventor create a model of a **Trebuchet arm** from your sketch.
   1. Include mounting holes for the pivot bearings. The bearing wheels are 0.75” diameter and 0.25” thick. The rod that threads through them is 0.18”. A 0.200” through hole is recommended
   2. Include an attachment method for the counter-weight. Screw eyes need a 0.0808” diameter hole 7/16” deep.
   3. Include a way to attach your release pin. The suggested nails are 0.060” diameter but they should fit snuggly in the hole. You are free to design your release pin any way you choose.
   4. The arm must fit inside a 1.5” x .75” x 16” profile.
2. Verify that the design does not exceed the 6.0” volume requirement
   1. Select **iProperties** in the **I-PRO** menu
   2. Select the **Physical** tab of the **iProperties** dialog box
   3. Choose **ABS Plastic** for **Material**.
   4. Click Update if necessary.
   5. Enter the value for Volume in your notebook (must be less than **6.0 in^3)**
3. Use AutoCad Inventor to calculate **moment of inertia** for your simulation
   1. The value for inertia will be in **I3** if your design rotates about an axis parallel to the z-axis (**Rz**). Use I1 for rotation about Rx, I2 for Ry.
   2. Inventor calculates Inertia about the **Center of Gravity**. This is the value you will need for your virtual trebuchet simulation.
   3. Enter the values for Mass and I3 in your notebook.
   4. Enter the values of your modeled arm into your virtual Trebuchet simulation and record the results in your simulation spreadsheet. Redesign as necessary.
4. Cut your part into two pieces.
   1. Consider how you will divide your arm into two pieces so it can be manufactured. Neither piece can be longer than 9”
   2. Create a working plane offset from an origin plane where you want to divide the part.
   3. Create a 2-d drawing in this plane that shows how your parts will be connected.
   4. Save your drawing.
   5. Save the drawing again with a new name (like left half)
   6. Save the drawing one more time with another name (like right half)
   7. Delete the parts that are not part of each half from the respective drawings.
   8. Extrude connection features into the remaining parts.
   9. Save each part and verify that the total Volume remains less than 6 in^3
5. Create STL versions of your parts
   1. In the I-Pro menu select **Export->Cad Format**
   2. Change the Save as Type to **STL Files (\*.stl).**
   3. Under **Options**… verify that the Units are **inches**.

### Trebuchet Testing

Test the distance it can toss the object. Measure from the pivot point to where the ball first lands. Bounces and rolls do not count. Make any modifications you can to your design within the design constraints to improve its performance. Observe other designs; note the performance and any design features you can see that contribute to the performance.

**Testing Results**

|  |  |  |
| --- | --- | --- |
| Test Number | Distance | Modifications made before test. |
| Simulation |  | Simulated distance based on the as-built trebuchet |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

Reflection

1. Complete the table above
2. Record simulation parameters used, and discuss how your design performed compared to the **simulation**. Explain any differences.
3. Discuss how your design compared with **other designs**.
4. Compare features of the **best** designs and the **worst** designs