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1.0 Introduction

This written report was made to look at the advantages and disadvantages of a trebuchet but focusing on the beam, counter weight and sling to increase the accuracy, distance of the payload. Also, will be looking at different designs and materials to insure optimum efficiency. The aim of this project is to make the best working launch and retrieve device with a 30 pounds budget.

2.0 Design

The design of group has decided to is a trebuchet. A trebuchet is a medieval weapon which is used to raid and destroy castles. the reason we have chosen this design is, that it can propel objects a far distance or a short by changing the counter weight, angle and payload. A trebuchet is a very well-balanced device with its planted legs. The disadvantage for using a basket as the counter weight is that the weight isn't fixed within the basket, they will slosh around can give inaccurate results or a misfire.

3.0 Materials

By doing research and to fit the groups budget of £30 they've decided to make trebuchet out of wood. There are many different materials that could have been used such as acrylic where it would fit the group's budget requirements however, the material is too light also too rigid and flexible when bent the wrong way. the group member who has designed the beam of the trebuchet thought of using a steel metal rod. The rod would be too heavy allowing a slow projectile launch for the payload. The designer of the beam has decided to make the beam out of wood. This will fit the budget requirements. Also allows the group to fillet the edges to increase strength and chamfer the edges and finish by sanding for a smooth balanced finish. To take the presentation of the design a step further the beam can be painted.

Sling

The sling which connects the payload to the beam will be made out of string the length is an important aspect to the trebuchet, the length the group will use 3.75 times longer than the counter weight arm, if the angle of the trebuchet is launched from is 45 degrees. This will allow the payload to launch in the right direction with optimum velocity. The reason the designer decided to use string instead of a more stretchable material such as a rubber, is that the results would be inaccurate and very difficult to calculate the efficiency of the trebuchet.

Counter weight

The basket its self will be made of simple plywood because its cheap easy to fabricate and will do all the things the group requires from the material. The weights used to put in the counter weight basket will be the 10g weights used in science experiments. The counter weight will not be fixed the beam nonetheless it will be free moving. This will allow better balance, smoother motion when launched and provide less chance of the weights to fall out.

4.0 Physics

The reason why the pivot point which is connected to the fulcrum, isn't in the centre of the beam because the squash ball will have a speed advantage. The counter weight side of the beam will have a smaller movement compared to the payload side. What differs from a catapult and a trebuchet? The catapult's payload is connected to the beam, where the trebuchet payload will hand from the beam by a sling. This will increase the speed advantage of the payload. To increase or decrease the distance of the squash ball is varied by many difference variables. To increase the group can increase the mass of the effort force or increase the height which the effort force is dropped from.

With a trebuchet we can calculate the efficiency by using trigonometry, and various different equations. First the group would calculate gravitational potential energy (E_{pg}) which is mass of the counter weight times gravity times height (mgh). Given that all the energy from E_{pg} has been turned into kinetic energy of projectile (E_{kp}). To find the velocity of which the pay load will travel the equation one half mass of projectile time velocity squared. Once rearrange for velocity and square rooted the result the group will receive the result for initial velocity.

By gathering information and the motion of the trebuchet is that of a right-angle triangle. The hypotenuse is equal to initial velocity. The velocity traveling along the opposite of the angle is traveling vertically is equal to the velocity traveling along the adjacent therefore traveling in horizontally direction. Considering the angle of the initial velocity is 45 degrees. By using the change in velocity of the different directions and acceleration we can calculate the time. By calculate time the group can then calculate the distance. because distance is equal to velocity times time. Therefore, we can calculate our efficiency which is groups actual result divided by the groups theoretical distance therefore gives the efficiency of the trebuchet

5.0 Further workings

A whipper trebuchet is a slightly different design where the launch position is different the longer arm has almost rotated another 180 degrees. this will raise the counter weight above the main axle thus increasing the gravitational potential energy. However, the disadvantage of a whipper trebuchet is that it's difficult to find the right ratio for the arm, which will affect the direction of the payload.



(Oaklandballistics.com, 2020)

6.0References

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Moodle.uwtsd.ac.uk. (2020). *UWTSD Moodle 2019/20: Log in to the site*. [online] Available at: https://moodle.uwtsd.ac.uk/pluginfile.php/321420/mod_resource/content/0/2020%20Branded%20IMEchE%201st%20Year%20Spec%20Design%20Challenge%20-%20Project%20Specification%202020%20-%20V1.1.pdf [Accessed 1 Feb. 2020].

Samuel Johns

1804234

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1.0– Introduction

The group has been given a task to design a way of getting a squash ball to get shot, launched or propelled at a target that will change distance and angle, therefore, the device needs to be able to calculate how much thrust is needed and also needs a way of turning to aim at the target. Each group member has been given the task of designing a part of the device which then need to join together. The parts that need to be designed are:

- Mounting System
- Power Generation and Storage System
- Energy Release and Safety System
- Aiming and Range Adjustment
- Projectile launch and management

Each member must research their area and come up with a design that they think would be best for the task in hand.

2.0– Research

2.1– Duel Leg Mounts

An army mounted gun has a very simple design, it has two legs nearer the barrel of the gun giving it stability. At the rear of the gun, there is another resting point for the gun to sit making it a very stable design for it to not fall over.

Figure 1 shows an example, having the legs spread out evenly results in the device not rocking back and fore and will result in an accurate shot. It gives good freedom for the device to be aimed at properly also as there isn't anything in the way to hinder the device.

However, a gun is very easy to aim as all that needs to be done is point the nozzle at a target and fire a bullet that travels 1800mph. The device that our squash ball is going to be launched out of doesn't need that much propulsion

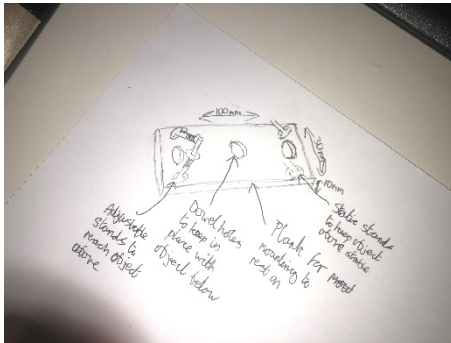


Figure 1

as it only needs to travel several meters, therefore, to aim our squash ball, we need a device that has to rotate horizontally and vertically. This design would have to be altered for it to fit onto a rotating system that aims the barrel higher, lower, to the left and to the right.

Alterations to this design would have to include putting the legs on a platform that is connected to the rear mount which include some tapped holes in the platform for it to then mount onto the rotation device. Obviously, the group won't be using a gun so the legs will be adjustable to fit whatever device will be designed. The rear resting point will also be fixed to the rotation device, however there would be a gap if needed for, as an example, a catapult sling to drop down so that the sling isn't restricted.

Sketch 1



Sketch 1 shows the ideas come into fruition. The design consists of 4 legs/struts being the main feature that will mount the object above onto it. Two of the legs are static and the other

two are adjustable meaning this design can alter to the object above. To attach itself to the object below, the design has 3 holes meant for dowels. They will hold the mounting system and any other components above it stable to the component below. The ideal material for this design would be steel due to the fact it is very strong, rigid and cost effective. The struts/legs would be steel and the metal base below would be a cheaper, weaker material as its job isn't as important as the struts.

2.2 – Tripod

A tripod would be a natural go-to design for this task. The figure 1 concept is very similar; however, it does have a lot of vital differences, one being that a tripod has all 3 legs going to the Centrepont, spreading the weight of the device evenly across all 3 legs. Figure 2 shows a tripod being used for a camera stand but it can be replaced by multiple different objects and devices by altering the mounting system ever so slightly.

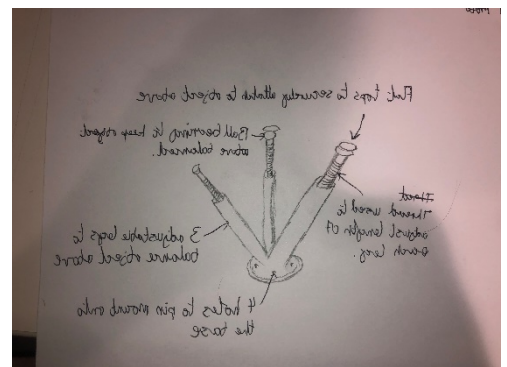


Figure 2

Adjusting the tripod so that the rotation device and range adjustment devices can be planted on top of the tripod would work very well. Having the top of the tripod as a level platform will open a lot of opportunities to mount the rotation device on top of it. Having a flat platform means that whatever the dimensions of the rotation device are, it can be bolted down to the platform. Adjustable struts or legs, like the ones on the tripod, can also be used to steady the

rotation device if parts of the device are loose and can't be bolted to the platform. Figure 3 is a good example; it shows that there is an adjustable strut attached to the seat of a go kart and the frame of the go kart. The reason for it being adjustable is

Figure 3



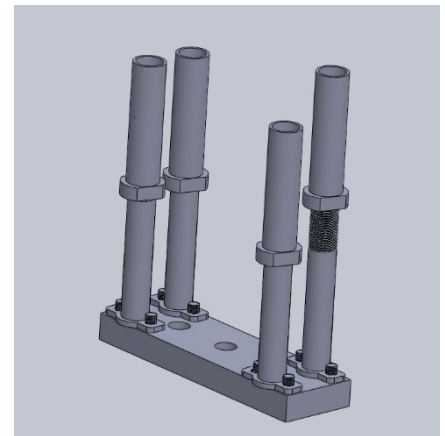
that it can reach parts of the seat that the fixed blue struts can't, making the seat more stable when it travels. It's the same thing for the rotation device. When fired, the device will move and if not supported properly, it may become unbalanced.

Sketch 2 shows the ideas of this design. Based off of the normal tripod however to help aid attaching to the component above, it has been flipped upside down so that there is more area in contact with the object so that it has an easy way of resting on the mounting system. Each of the legs are adjustable, much like figure 2 but the difference on the ends of the legs is a ball bearing with a flat plate on top of the ball bearing. This way, the legs can adjust to the height needed and the ball bearings can adjust the angle to help fit to the component. On top of the flat plate is some rubber-based material top grip onto the component above to stop it from moving around when shot. The struts/legs idea was taken from the adjustable karting struts, which are made out of steel, therefore the entire design of this mounting system would be mainly steel as it is strong and cost effective.

Sketch 2

3.0 – Final Concept Design

A group member designed what they thought was the best ideal design for the project. The CAD Design 1 image shows that they mixed up parts from both concept designs. They took the idea of having the karting struts on the base of the dual leg mount design, except this design has four struts that are adjustable, not one is a static strut. This will help balance the component above. Another feature that was taken from the dual leg design were the dowels. These will allow this component to attach onto the component below securely. The struts were taken from the tripod design, all legs can be adjusted with a nut to lock the adjustable arm in place, this means that the component above will be secure and won't become unsettled. The struts are screwed down and are not permanent, this is because if they get damaged, they can be easily replaced or altered if a better design is created.



CAD Design 1

4.0 – Evaluation

All designs were good and had some key features that will probably make it on the final design, however there are a lot of reasons why these concept designs will not be the final design:

The dual leg design is a good starter. Its reliable and unlikely for much to go wrong apart from a few things. Mainly the design is too narrow, the component above this design would have to be limited to a very thin design otherwise there is a high chance of it not working. Secondly there is nothing for the object above to grip onto, this will result in the potential energy created from the launching system moving the components above the mounting system and endanger them of falling off as they aren't securely fastened to the mounting system.

The tripod concept is a step forward in terms of attaching itself to the object above as it has those grippy rubber-based plates above the ball bearing, however the design is still flawed. The base of the tripod is simply too small and won't be able to withstand much weight on one side. The surface patch is very small meaning that the slightest bit of movement could topple the entire launcher. This would either have to be fixed onto the object below or have a wider surface patch so it balances better.

The final concept design is again another step forward. It has lost the balancing issues that the tripod suffered and has also solved the case of having adjustable arms on all corners. However, if it had the ball bearings and rubber-based material on top of those plates, then it would be an even greater component. Like the dual leg mount, the base is still too small, resulting in a very thin platform for the component above to fit onto. Having a ball bearing in the bottom of the struts would also help the balancing of the product and would also make the area bigger for the component above to be placed on.

Timothy Lee **1901664**

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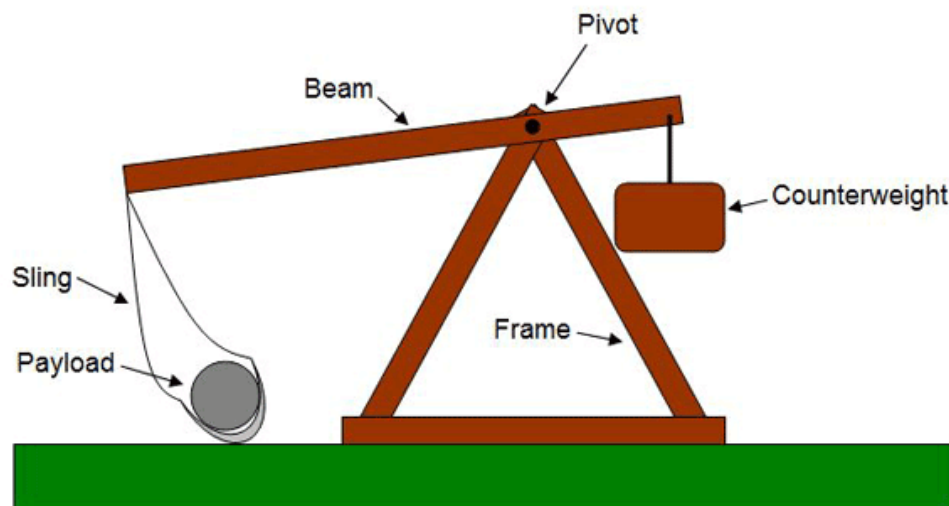
Introduction

Each team member was given an area of the design to research and come up with concept solutions. However, the original designations were too broad and didn't give concise aspects for each of us in the design. Therefore, we as a group decided on these aspects;

1. Timothy Lee - Stand/main body
2. Bilal Mohamed – Trigger and guide
3. Lloyd John – Swing arm/ Counter Weight and research
4. Samuel Johns – Aiming system

Research

Most trebuchets use a triangular shaped body which holds the axle of the ground to give a significant distance for the swing arm to gather potential energy. In addition, it gives a large surface base to ensure that the forces involved cannot act outside the base which would cause it to become unstable and fall over. For example,



[figure 1]

This is an overview of a trebuchet design which shows the simplicity of how a trebuchet works. Relying only on the potential energy from the counter weight, trebuchets have been known to fire 90kg projectiles over 300 meters. However, in our case we only need a max of 6 meters.

From this design aspect I researched into the design fundamentals that all previous designs have applied too. These include

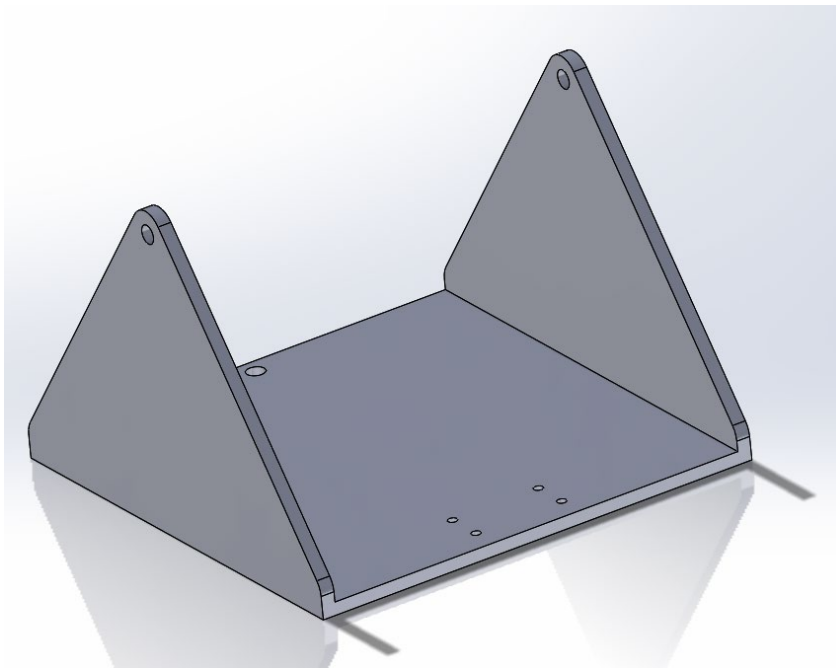
1. The length of the payload arm should be 3.75 times longer than the counterweight arm. [2]
2. The length of the sling should be the same length as the payload arm [2]

This design constraints then lead me to the design regulations on the Institution of Mechanical Engineers 2020 Line Launcher protect which outlines;

- 4.3 The device must fit within a maximum working envelope of 600 x 600 x 600mm at all times during competition, even during firing. [3]

This gives me a limit the size in which I can make the stand. This would include the size of a fully extended swing arm as also decided in these regulations. This limits my axel pivot point to a maximum of 300mm above the table. This allows the payload side of the swing arm to be a maximum of 150mm. however, this wouldn't include the sling size because we would use a loop on the payload return string as the sling. this works because the payload string isn't included in the overall size the machine.

Final Design Concept



This the design concept I designed, this is simple to allows further development. It consists of a base plate and simple axel support struts. This design also includes holes for both the securing pin and axel rods at a Hight of 300mm but also includes the positions for the aiming design proposed by another group member.

Keeping the design simple allows us to add additional feature and items in the future. Theses would include bearing for the axel. The trigger systems and guide are not pictured and therefore would require adjustments to include the into our design.

Evaluation

Because none of our team has ever built or designed trebuchets before much of the design process and later manufacturing will need large amounts of research and design testing. Design testing (trial and error) may product issues with this design and solve problems we do not even know of yet. Our design brief requires us to product a launcher with accuracy and repeatability to award us points. This means our concepts designs are only one step to our final product.

Material and manufacture constraints may change they way we can produce it. From laser cutting to additive manufacture these overall designs will look very different. At the moment, we plan to produce the product from mdf or plywood as they are relatively cheap and easy to manufacture parts from.

References

[1] https://www.sciencebuddies.org/science-fair-projects/project-ideas/ApMech_p013/mechanical-engineering/effect-of-trebuchet-arm-length-or-counterweight-mass-on-projectile-distance

Accessed 01/02/2020

[2] Trever English, <http://shortsleeveandtieclub.com/designing-a-trebuchet-optimizing-weight-and-length/>

Accessed 01/02/2020

[3] Institution of Mechanical Engineers, <https://www.imeche.org/docs/default-source/1-oscar/challenges/design-challenge/2020/imeche-1st-year-design-challenge---project-specification-2020---v1-2.pdf?sfvrsn=2>

Accessed 03/02/2020

Bilal Mohamed

1904401

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1. INTRODUCTION

Since our design base is going to be a trebuchet, the objective of this task is to find the most economical and accurate design possible within the specifications set by the event organizer.

1.1 DEVICE REGULATIONS

For this project, each of the following rules must be followed.

- Devices must be regarded as safe and reasonable as judged by the member/s of staff responsible for the team/s, consideration should be given to guarding if there is risk of entanglement or entrapment.
- All devices must be fitted with a safety mechanism which prevents the device being accidentally fired once armed.
- The device must fit within a maximum working envelope of 600 x 600 x 600mm at all times during competition, even during firing.
- The device must sit above and cannot overhang the edge of the launch table at any point during a heat.
- Devices shall be fixed securely by use of the launch location pin, washer and wing nut to the launch table. Any device or part of device that 'breaks free' during a competing heat or final will not receive any points for that attempt.
- Each device must have a quick and simple method of attaching and detaching the line, which should not require the use of tools. It is up to individual teams as to how this is achieved, but any coupling must not cause the device to violate the control volume dimensions.
- Teams are advised to pay particular attention to line-management during a launch sequence. Line management devices can be reloaded, reused or replaced during a heat or final.
- Devices must be fired remotely via a low voltage electrical switch with a minimum cable length of 2 m. The firing switch and wiring are the only components excluded from the working envelope.
- Parts from existing firing devices (i.e. triggers, barrels, breaches) are not permitted.

TREBUCHET

Since the team is working in the different work areas. In this project as we well know from task 1, I will focus on lateral aiming and trigger system.

To continue, we must understand how trebuchet works.

2.1 HOW IT WORKS?

Parts of a Trebuchet

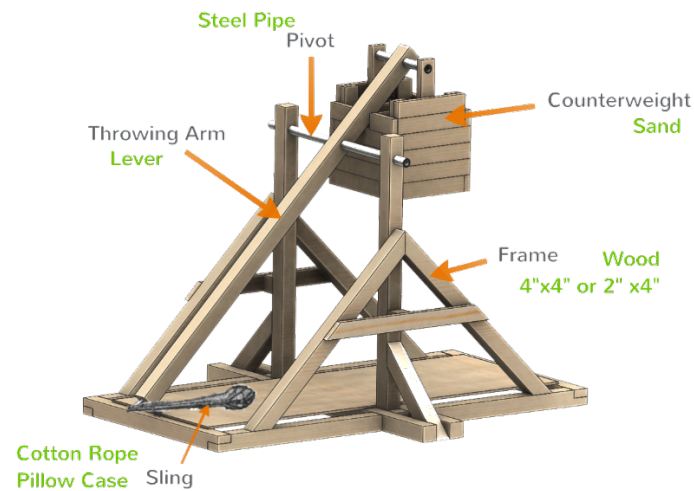


Figure 5. parts of a trebuchet (Warren, n.d.)

The hurling arm is powered by a crew of men, pulling on ropes attached to the short lever arm. (ScienceDaily, n.d.)

A counterweight trebuchet is powered by a very heavy counterweight, acting on a lever arm. (ScienceDaily, n.d.)

The fulcrum of the lever (usually an axle) is supported by a high frame, and the counterweight is suspended from the short arm of the lever. (ScienceDaily, n.d.)

The sling is attached to the end of the long arm of the lever. (ScienceDaily, n.d.)

One end of the sling is captive, while the other end is hooked to the long arm in such a way as to release when the arm and sling reach the optimal hurling angles. (ScienceDaily, n.d.)

The trebuchet is energized by lowering the long arm and raising the weighted short arm, usually with a winch, and is locked into the charged state by a trigger mechanism. (ScienceDaily, n.d.)

Potential Energy

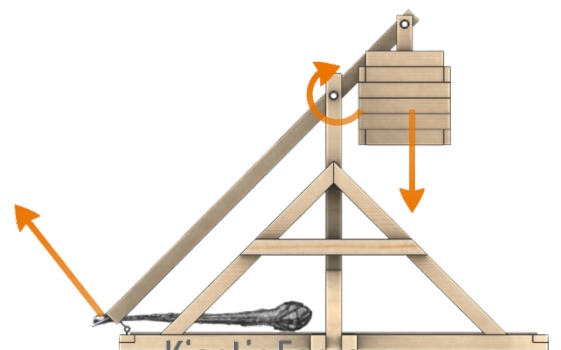
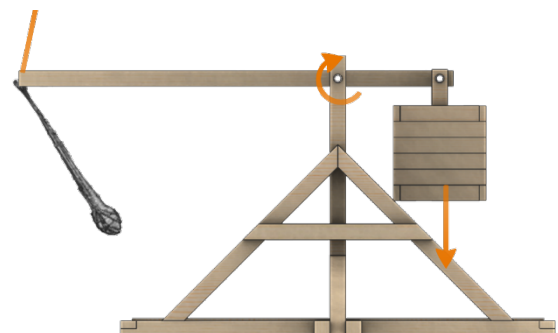


Figure 4. Potential Energy (Warren, n.d.)



With the long arm lowered near ground level, the sling is loaded with the projectile, and laid out on the ground, with the captive and hooked ends away from the target, and the load and pouch laid on the ground toward the target. (ScienceDaily, n.d.)

When the trigger is released, the weighted short arm is driven by gravity into an accelerating pendulum motion, causing the lighter, long arm of the lever to revolve around the fulcrum at the opposite arc, which in turn, pulls the sling and its contents into a whipping motion at the end of the long arm. (ScienceDaily, n.d.)

As the arm continues to swing past the vertical position, the counterweight rises causing the lever motion to begin to slow down, while the sling continues to whip forward around the end of the long arm. (ScienceDaily, n.d.)

When the sling reaches its launch angle, one end slips from its hook, releasing the projectile toward the target. (ScienceDaily, n.d.)

Throw

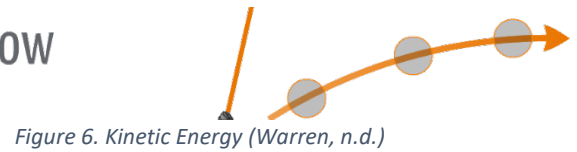


Figure 6. Kinetic Energy (Warren, n.d.)

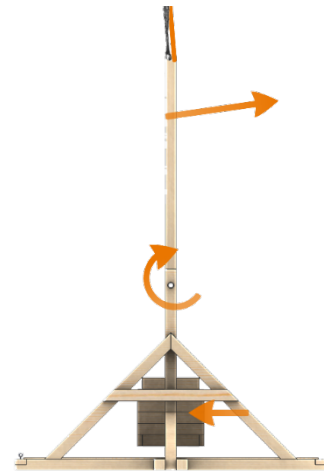


Figure 7. Throw (Warren, n.d.)

3. MODELS

For the improvement of the conventional design and to make the trebuchet more precise we have designed the following piece.

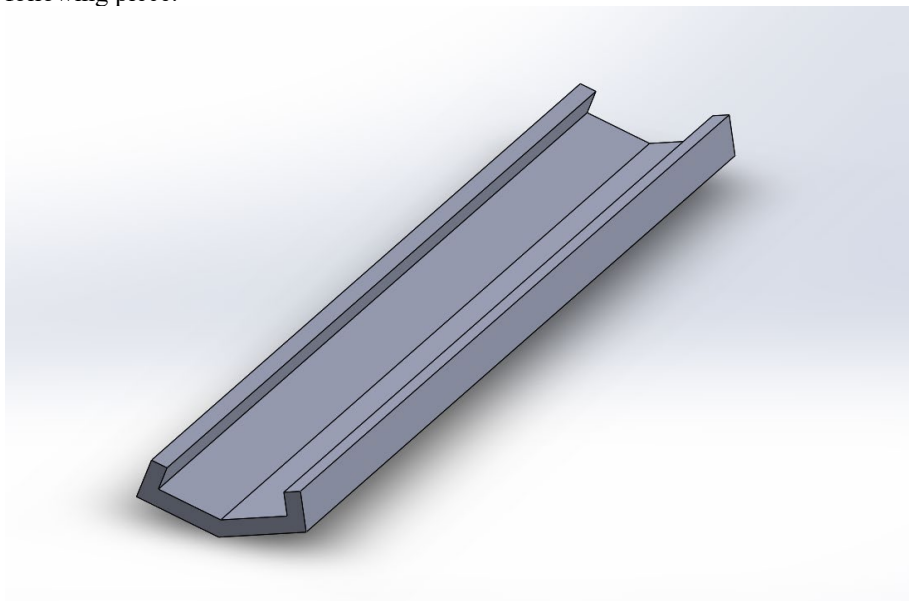


Figure 8

The piece will be planted at the base and will guide our ball. This will help our shots to be much more accurate. The material of the piece does not matter much since he does not need to endure any kind of strength or elasticity. So, we will select a very economical material. The next assembly is composed of 4 different pieces and will be anchored at the base of our trebuchet.

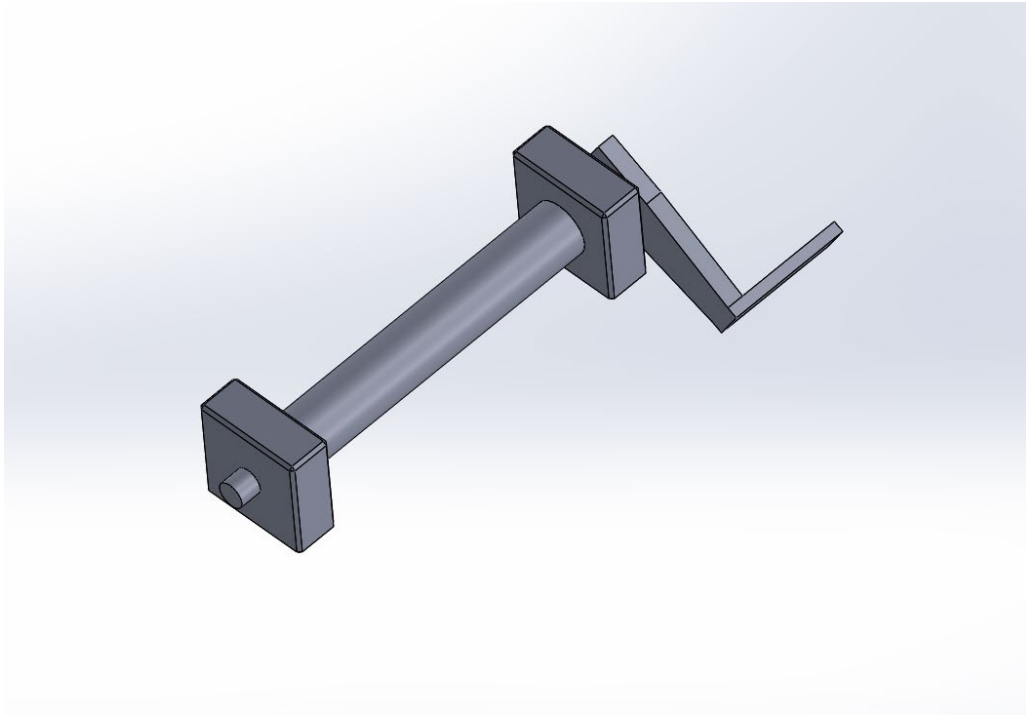


Figure 9

The goal is to pick up the arm safely. For this we will have a rope that will be tied to the trebuchet arm. The final result would be similar to the following photo.

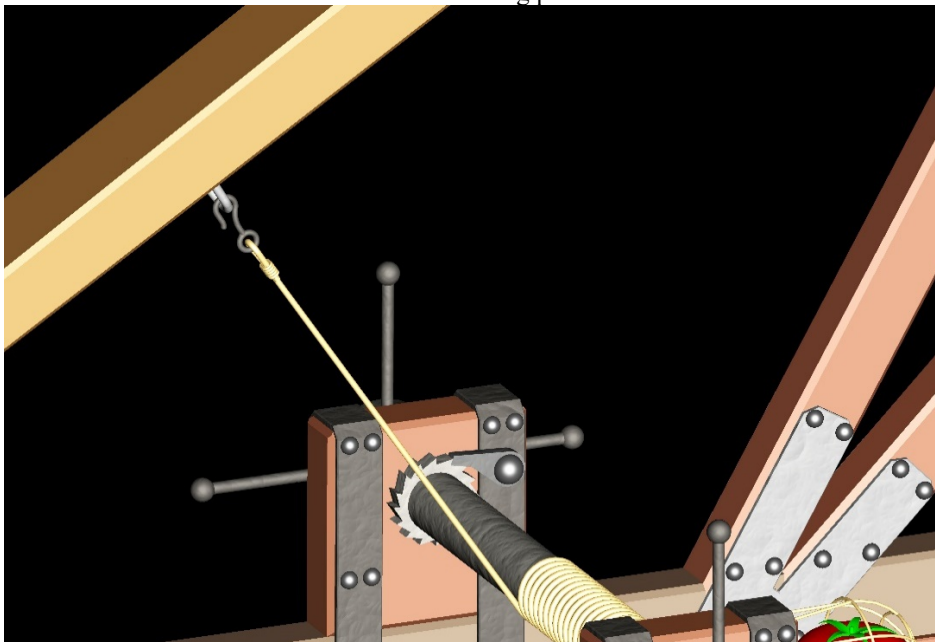


Figure 10 (Moerenhout, 2018)