How to Build Your Own Hinged Counterweight Trebuchet
by Oakland Ballistics

Let's start by assuming that you have seen pictures of a trebuchet and seen how a trebuchet works. That out of the way, the first thing to decide is what size object you want to throw. A general rule is that you want a ratio of projectile to counterweight (CW) of 1 to 75 or 100. This means that if you want to throw a 1 lb object you will want to have 75 to 100 lbs. of counterweight. Once you have decided how much counterweight to use you can then start to imagine the size of your machine. A marble throwing machine might only be 11" high while a pumpkin throwing machine should be at least 5 ft. in height. Something to keep in mind at this point is that while the machine is firing, the amount of force that is exerted as the counterweight reached the bottom of its arc is roughly ten times that of the original weight. This means that 300 lbs. counterweight exerts 3,000 lbs. force on the machine.

The basic design that we have used is that of an A-frame. The A-frame is a tested design that you can find all over modern day structural engineering. Our designs usually have a base that is 1/3 to 1/4 longer than the height. This adds some stability to the machine, but this can be played with. Our designs usually have a hole drilled through the vertical beam for the axle to rest in. that has proven to work just fine for us. If you are looking for a simpler design for setup and take down, cut a channel out of the top of your vertical beam for the axle to rest in, then put a cover or clamp on top of that to keep from bouncing out of the channel. This allows you to be able to lift the axle on and off without disassembling the whole axle and throwing arm. The angels of the A-frame can be any range. 45 degrees can be the easiest to design and build though not necessarily the most efficient design.

There are several things that need to be determined from here before you can proceed with your design. The length of your arm, the width of your axle and, most importantly, your budget. Wood gets expensive fast so try to keep in mind how much money you want to spend ahead of time to help keep things in perspective as you are building.

Your throwing arm needs to be very strong, this will get lots of repeated use and stress. The vertical strength is the key, consider that the weight is falling down, not left and right. The short end should be thicker than the long end since this will have more force on it. Also, the less weight near the tip of the long end the greater distance you will get. For every one pound of arm the machine must move equals one pound less of projectile.

The throwing arm usually consists of a long end that attaches to the sling and pouch and a short end that attaches to the counterweight. The ratio of the long to short ends is usually something like 4:1 or 5:1. Our designs have all fallen somewhere in that range. 5:1 seems to work best but 4:1 can be the optimal for designs with a high CW ratio.

When cocked, your trebuchet arm should be at least 45 degrees, but we recommend closer to 60. Any more than 60 and you stop gaining momentum, any less that 45 and your machine doesn't have enough time to accelerate and gain maximum energy.

In order to gain maximum energy from your chosen CW, you want your CW to drop as far as possible. You can accomplish this by cocking the arm to the above mentioned angel, but also by adjusting the hanger arms for your CW. Start with your CW hanging but not touching the throwing arm when in the cocked position. Finish by having the CW as close to the trough (your projectiles runway) without actually hitting.

Given the arm ratio, the cocking angel and your budget, you should be able to get an idea of how large you want your trebuchet. From here we can get into the smaller intricacies of your trebuchet.

Remember when we talked about the rule of 10, the force exerted on your machine during firing? Keeping that in mind, we need to decide on your axle. We usually use a 1" threaded steel rod purchased from a local hardware store. These can come in 4 ft. lengths for about $20 or so. This seems to be the most cost effective. We were able to bend one of our with 420 lbs. of CW over repeated firing. One way to fix this is to add bracing, little triangles with channels cut in the top for the axle to rest in and mounted to the vertical support beams. An axle is only as strong as the distance it spans. The shorter the distance, the stronger your axle will be. With your axle in mind, this should give you an idea of how wide your machine can be. Keep in mind room for nuts or fasteners of some sort to keep everything centered.

When considering your CW, keep in mind the cost of materials for the weight and the side-to-side swinging. We first used weightlifting weights mounted with cable. It worked fine, but it swung a lot and therefore, we couldn't mount a whole lot. We quickly went to a box design and mounted with hanger arms and another, smaller, axle. This allows us to have a smaller clearance on each side which translates into more weight.

To trigger your machine, the simplest design is two eyebolts mounted to the frame, one eye bolt mounted to the arm, and a nail or pin going through all three. When it's time to fire, just pull a rope that is attached to the pin and watch it fly. This design has worked well for us for machines up to about 400 lbs of CW. The higher the CW, the harder it is to pull the pin. If you are looking for a great design for higher weights, consider a snap shackle. These are used primarily in sailing and work as if made for this application. They can be expensive, one that we have is rated to 4200 lbs. and the cost was about $65. Obviously they get cheaper the smaller the rating, but they work great.

Mounting an eyebolt directly to the arm is a great way to trigger the machine, it makes for less objects for the sling and pouch to get tangled in. If this isn't going to work for you, then attach a rope of cable to the arm and use that as a loop to slide the pin through.

In order to cock your machine you need to pull the arm down from the resting position of vertical. To do this, you need to have a rope or cable that is strong enough to pull the arm down. The simplest way to do this is to use your sling. In order to gain the maximum efficiency, though, you may want your sling to be a thin and light as possible which might mean it cannot pull down your arm. We tried to have a cable permanently attached to the arm but it got in the way of the pouch and sling causing misfirings as well as adding weight. The option that we have settled on it to use a pole to reach up and hook the eyebolt on the arm. Then pull the arm down with the cable attached to the hook.

Now we can talk about the trough, pouch, and sling. The trough is generally some plywood, cut in to a 1 or 2 foot strip running the length of the machine and possibly longer depending on the length of your sling. The sling is usually the length of your long end or skinny end of your throwing arm. Start with this and then play around with the length. The shorter the sling, the quicker it whips around, the longer the sling, the wider the arc. This is just something to play around with, we really don't have a hard and fast rule. One rope should be mounted to the arm permanently while the other end is usually attached to a metal ring. This ring is what slides off of the release pin.

The pouch is just there to hold your projectile in place and throw it. It needs to be strong enough to withstand the centrifugal force of the arc and durable enough to slide down the trough time and again. Our first and still most tried and true pouch was from one of those folding chairs and tables that people take to sports games and camping. It's canvas material and already-made holes made for easy mounting and durability.

The release pin is the most important aspect of the machine with regards to distance and "tunability". The metal ring on the sling will slide off the release pin at a point when the force is great enough to do so. You can change the amount of force required by bending the pin forward (more force) or backward (less force). The farther back the pin is bent the earlier the pouch will open and the higher the trajectory, and the opposite is true as well. The easiest is a simple nail with the head cut off. This is bendable, strong and easy to mount. We have found that this is a good design for projectiles up to about 4 or 5 lbs. After that, the projectiles motion tends to bend the pin back and must be reset after each launch.

The last item to consider the side to side motion of your machine. The more it sways the more likely your CW is to hit your machine. We recommend using side supports though they are not necessary. The length of the side supports is really up to estimating. Again, we do recommend it though.

Wheels are often talked about as adding distance or subtracting distance. We have found that with a hinged trebuchet wheels have little effect. They can add a few percentage points to your efficiency but not really noticeable. Wheels are necessary on a fixed trebuchet which we will get into later.

Once you have your machine built, some ways to gain efficiencies are: grease from your local auto store or farm store, a lighter pouch and sling, a different release pin angel, a shorter or longer sling and a lighter arm (including sanding the diameter down).

Remember, you are building an actual weapon so please be careful. Even with a small 10" trebuchet you can injure yourself. This is just a guide. By following these tips we hope to help you build a successful and safe trebuchet but anything can happen so be careful always plan on the safe side, don't cut corners.