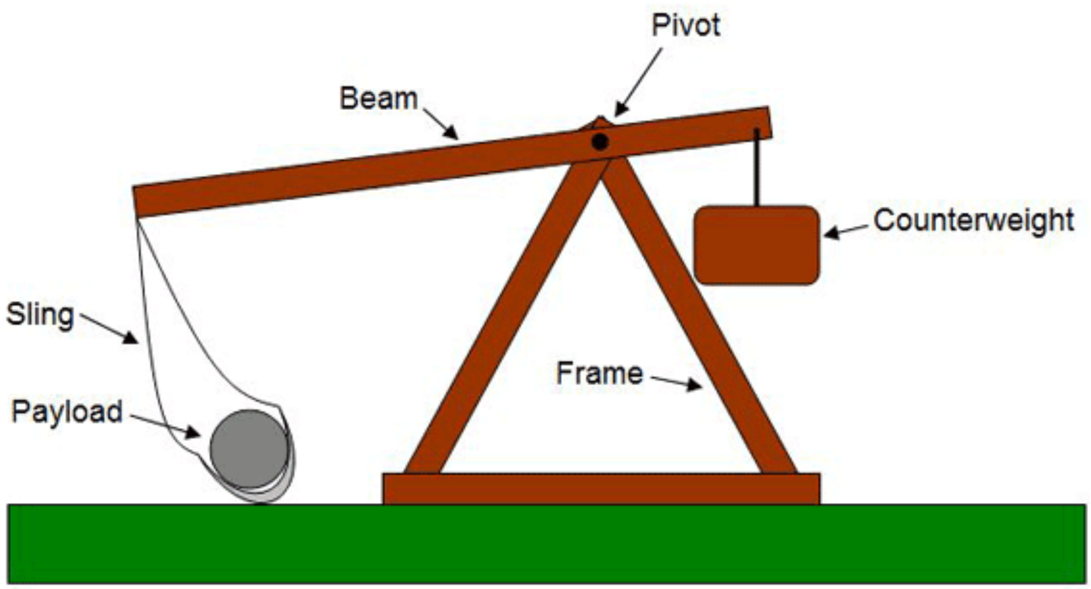
Group members: ______________________ Date: __________

STEM Trebuchet Design Project ~ Team 1

1. Make sure a design is agreed upon and a final draft is drawn and labeled on graph paper. Include estimates of dimensions and materials of each part.
2. **Construct/prepare the sling and counterweight prior to building the frame and beam.**
3. **Before constructing the frame, beam, and pivot—mark (in pencil) the exact locations where you need cuts to be made and/or screws.**



Trebuchet Physics — How A Trebuchet Works
(http://www.real-world-physics-problems.com/trebuchet-physics.html)

A trebuchet works by using the energy of a falling (and hinged) counterweight to launch a projectile (the payload), using mechanical advantage to achieve a high launch speed. For maximum launch speed the counterweight must be much heavier than the payload, since this means that it will "fall" quickly.

As you can see, the counterweight pivots around a much shorter distance than the payload end. The advantage of this is that the payload end of the beam reaches a much higher linear velocity than the counterweight end of the beam. This is the principal of mechanical advantage, and is what allows the payload to reach a high launch velocity. However, because the counterweight pivots around a much shorter distance, its weight must be much greater than the weight of the payload, to get a high launch velocity. However, increasing the mass of the counterweight beyond a certain point will not help, since the limiting speed of the falling counterweight is free-fall speed.

As the beam rotates clockwise (due to the falling counterweight), the payload experiences centripetal acceleration which causes it to move outwards (since it is unrestrained). This results in a large increase in linear velocity of the payload which far exceeds that of the end of the beam to which the sling is attached. This is the heart of trebuchet physics and is the reason a trebuchet has such great launching power.

The optimal trebuchet design is one that launches the payload the farthest horizontal distance. This makes sense intuitively since range is a key factor when staging an attack on an enemy. The challenge then, is to find the optimal design to maximize the range. This is not a trivial task given that there are many variables one can adjust. Fortunately, such an optimization is greatly simplified given that trebuchet physics can be modeled with computers, saving a lot of time.

According to Donald B. Siano, in his analysis of trebuchet physics (*Trebuchet Mechanics*, March 28, 2001), the optimal release position and design, based on his definition of "range efficiency" is such that:

• The initial release position is such that the beam on the counterweight side makes an angle of 45° with the vertical.

• The length of the long arm of the beam (on the payload side) is 3.75 times the length of the short arm of the beam (on the counterweight side).

• The length of the sling is equal to the length of the long arm of the beam (on the payload side).

Furthermore, he recommends using a counterweight that has a mass 100 times greater than the mass of the payload. However, it is certainly possible to achieve a good design with a much lighter counterweight than this.

However, it is worth noting that the physics of the trebuchet is not unique to the trebuchet. For example, in a golf swing the same basic physics applies. In fact, you can think of a trebuchet as an upside down golf swing. Thus, the physics of a trebuchet is very similar to the **physics of a golf swing**.