Pre-Design Proposal
Team: Shooters Shoot
Caroline Moore
Tyler Tulanian
Isabel Mayo
Aaron Pridgen

Linear Launch Design:

This first mechanical description and analysis pertain to a linear projectile launcher at a fixed angle. The device is to be constructed from a 3ft long PVC pipe (with a diameter greater than that of a racquetball, 2.25in (McCoy) at an angle of 60 degrees with the horizontal base frame. The base frame (see figure 1) is to be constructed by 2 in x 4 in pieces of wood. Adjustment of the distance to which two 5/8"x6.5" springs on either side of the pipe and attached at the end pointing upward are pulled will enable aim to reach targets placed at any various (1 foot) incremental distance between 3 feet and 12 feet from the front of the launcher. Calibration values (stretch distances) will be predetermined according to the analysis following (and marked on the pipe).

Neglecting the effect of friction between the ball in the pipe and air resistance, the stretch distance can be related to the velocity of the ball leaving the pipe which will be determined using kinematics.

Design parameters (expected to vary to some degree during building/testing) have been obtained based on materials intended for use. Namely, the racquetball mass was found to be 2.7174e-3 slugs ("Choosing…"); obtained from a sporting information website and the spring constant was found to be 1.5417 lb/in ("Everbilt…"); obtained from the product information page.

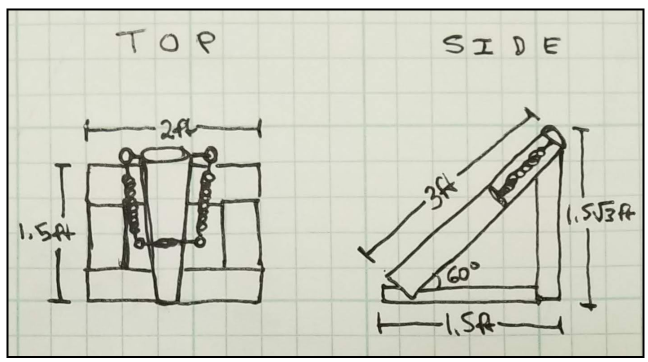

Figure 1. Linear Launcher Diagram

Equations:
Conservation of energy to relate d and v_0:

$$2*((½)kd^2) = (½)mv_0^2:$$
$$v_0 = \sqrt{2(k/m)d^2} \quad (1)$$

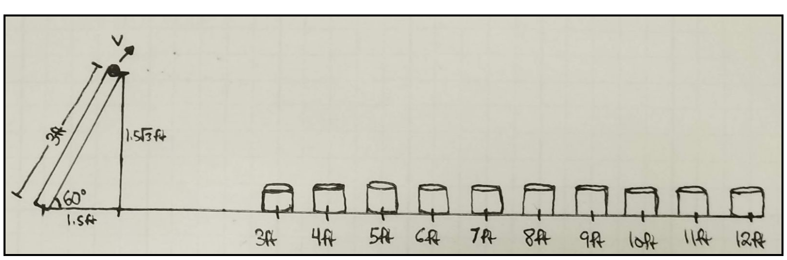

Figure 2. Setup for Kinematic Analysis with Target Distances

Kinematics to determine required launch velocity for varying targets:

In the horizontal direction:

Constant acceleration (0):

$\rightarrow s = s_0 + v_0 t + (½)a_{cx}t^2$

$x = v_{0x}t = v_0\cos(60^o)t$

$\rightarrow t = x / v_0\cos(60^o)$

In the vertical direction:

Constant acceleration (gravity: -32.2 ft/s^2):

$\rightarrow s = s_0 + v_0 t + (½)a_{cy}t^2$

$-1.5\sqrt{3} = v_{0y}t + (-32.2)t^2 = v_0\sin(60^o)t + (-32.2)t^2$

Plug in expression for t: $-1.5\sqrt{3} = v_0\sin(60^o)(x / v_0\cos(60^o)) + (-32.2)(x / v_0\cos(60^o))^2$

Solving for v_0:

$$v_0 = \frac{\sqrt{\frac{-32.2x^2}{1.5\sqrt{3} - tan(60^o)x}}}{cos(60^o)} \qquad (2^{***})$$

Plugging equation 2 into equation 1, the required spring stretch distance (d) can be solved for and use of each respective distance, x will allow for the calculation of calibration values.

Rotational Launch Design:

This mechanical description and analysis pertain to a rotational projectile launcher. The device is to be constructed atop a 2"x10"x2.5' lumber base pictured in Figure 3. A rectangular wooden bar will launch a racquetball from a 45-degree angle. Bar stops will ensure the correct angle of launch and the compressed distance of the spring will vary. The rotational mechanism is composed of a bar, a spring, and two fixed rods made of wood. The bar rotates from 45 degrees and approaches the horizontal wooden base. The spring starts uncompressed and once the bar begins to rotate counterclockwise, the spring is compressed linearly. After a certain distance of compression is reached, the ball is released and leaves the wooden bar at 45 degrees, following the motion of a projectile thereafter. This degree of compression of the spring will determine the initial velocity of the projectile after the bar hits the stops. The ball will then launch from the wooden bar and land at a designated distance away.

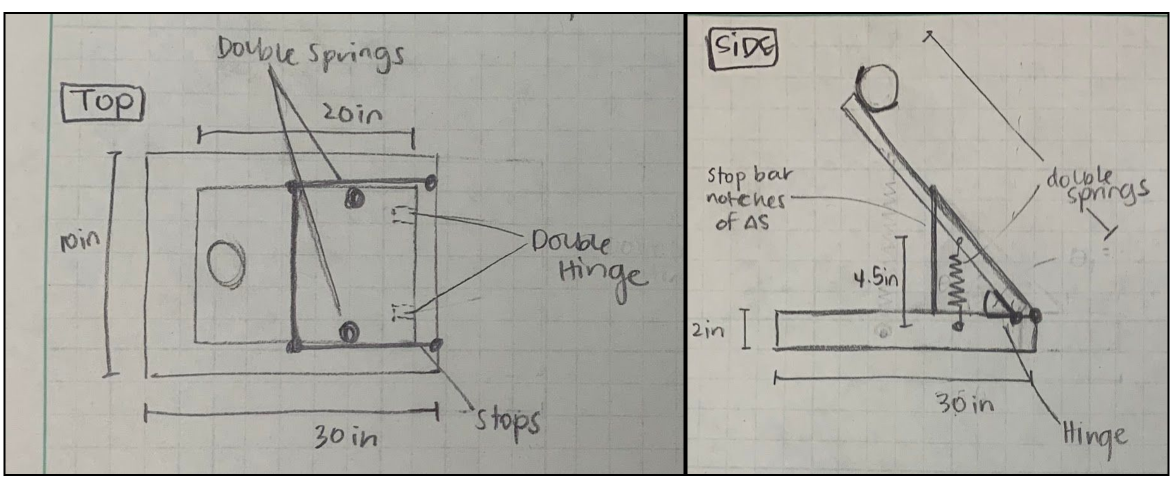

Figure 3. Rotational Launcher Design

Equations:
The conservation of energy equation relates d and v in the same way as the linear launcher due to the double springs. Equation (1) is then substituted into equation (3) with the angle now at a fixed 45 degrees.

$$v_0 = \frac{\sqrt{\frac{32.2x^2}{1.5\sqrt{3}-tan(45^o)x}}}{cos(45^o)} \tag{3}$$

The combination of (1) and (3) will allow us to solve for the compression distance needed to launch a certain distance.

<u>**Compare and Contrast:**</u>

The energy conservation principles that enable the derivation of the spring stretch/compression length and launch velocity relationship apply to the transfer of spring potential energy to kinetic energy of the ball for the rotational model, so the previous energy and kinematic analysis hold true. Distance values obtained will be smaller, as the k value of the spring used for the rotational model of k = 5.16 lb/in ("Compression…") is larger than that of the spring included in the linear version. The noted k value was obtained from McMaster-Carr for a compression spring with a length of 4.5 inches.

Both launcher types should meet the constraints and performance objectives specified based on the calculation made and models derived for use in obtaining calibration values. The linear launcher involves springs being stretched in only one axis, making the path of the ball more predictable. The rotational launcher only requires fewer materials (only 1 spring required), making it the cheaper option to build.

Air resistance and the weight of the lever are being neglected for the rotational launcher; these assumptions are likely to fail, as resistance and the weight of the lever should have some impact on the velocity of the ball after launch and its subsequent distance traveled. The error resulting from neglected parameters relating to the linear model will affect calculation certainties to a lesser degree, as friction should be negligible and the only weight being neglected is that of the small component connected to the springs pulling the ball upward.

The rotational launcher requires a higher level of precision than the linear launcher as the motion of the lever arm may create a more varied path of travel. This would decrease the certainty of predetermined compression values.

The linear launcher is likely to perform more consistently due to the predictable path in which the ball will travel. Additionally, considering the larger k value for the compression springs used, measurement of the difference in stretch length required for differing target distances would likely be more accurate using the linear model.

Considering the aforementioned points of comparison, our team has decided to build the linear launcher for our demonstration, as it seems to be the more promising design in terms of obtaining consistent results.

Bibliography

"Compression Springs." McMaster-Carr, McMaster-Carr, www.mcmaster.com/springs.

"Everbilt 5/8 in. x 6-1/2 in. and 15/32 in. x 4-1/2 in. Zinc-Plated Extension Spring (4-Pack)-16071." *The Home Depot*, The Home Depot, 11 Dec. 2018, www.homedepot.com/p/Everbilt-5-8-in-x-6-1-2-in-and-15-32-in-x-4-1-2-in-Zinc-Plated-Extension-Spring-4-pack-16071/202045467?MERCH=REC-_-PIPHorizontal2_rr-_-202045475-_-202045467-_-N.

McCoy, William. "What Is the Circumference of a Racquetball?" Chron.com, Hearst, 21 Nov. 2017, livehealthy.chron.com/circumference-racquetball-4510.html.

November 07, 2013. "Choosing the Right Racquetball Racquet Using Your Swing Speed, Swing Weight & More." *Holabird Sports*, Holabird Sports, 7 Nov. 2013, www.holabirdsports.com/blogs/news/choosing-the-right-racquetball-racquet-using-your-swing-speed-s wing-weight-more.