

Introduction

IMechE runs an annual student competition each year where teams compete to create a piece of specified machinery that adheres to a given ruleset. This year the project they have challenge they have set is for students to create a fixed position line launcher. As a team participating this year, we have needed to from scratch create a design that we believe will work with precision, whilst having very little experience between us. In this report we will be outlining our individual roles in the group and what we have each contributed to the final design, as well as justifying the decisions we have made towards the final design. The delegated areas of responsibility are as follows, Nathan – team leader, Abdulazim – aiming and angle of projection, Kyle – Line Management, Jamie – Power generation. Each of us have had to produce our own work, whilst making sure that all the areas of responsibility function with each other to create a cohesive final product. The line launcher that we create has a simple goal, to accurately launch the distances between 2-6 meters, through the report, we each outline how our individual contributions combine into a functioning line launcher.

Jamie (Power Generation and Storage) -

In this design I oversaw the power generation and storage role. My part of the role was to calculate how much power the firing mechanism would need to reach its required distances that have been asked and that it will reach them each time with no errors and that it will function on the day. What else I needed too do was figure out what material would be most suitable for this task. I looked at elastic, which would've been powerful enough to shoot the first couple of times and eventually it will lose its elasticity to shoot and will not perform at the rate we want. The reason why I looked at using an elastic material is because its cheap and will be easy to get hold of. If we did decide to use this material in our final design when it came to the testing day, we would more than likely need to change the firing mechanism as after it gets used it will lose its force that it originally started with and will not shoot with the power that is needed to reach the requirements asked. And with the design that we are going for a spring was more suitable for it. As we are going for a cannon look, if we used an elastic material and it snapped or wasn't powerful enough after it had been used enough it would've been difficult to change it when the design was fully assembled. With a spring it will keep its shape as it will be getting compressed and with an elastic material it will need get stretched and when elastic gets stretched a lot it will eventually lose its shape and become weaker and will break. This won't happen with a spring because they are very durable and will need a lot of use before it stops performing at the standard that we need for the task.

For the final design we decided to use a spring as it will be powerful enough to shoot from all the distances that have been asked. The choice for using a spring is also because it will shoot at the same force for 2-6 meters. It may lose a little bit of its force after it's been used a couple of times, but it won't be enough to effect its shooting distance that needs to be met. We have gone for a spring that will shoot the same power each time and we can just change the angle of the design. The reason why we went for this is because it will be simpler to work on the day as all we'll need to do is change the angle of the design which we would've calculated already, and practice runs would've already happened so we'd know for sure that it will work when we have the trials to do. Also, what was satisfactory with using the spring is that we've got a 50mm spring and the working package is 400mm x 400mm x 400mm and it won't take up much space in the final design. When it comes to assembling our design, it will be easy which is what we want with this project as we didn't want to over complicate everything, and it would be too difficult for us to do.

Calculations

This is a rough estimate on how much force the spring will need to generate for the squash ball to shoot 6 metres:

$$w = mg$$

$$w = 0.025 \times -9.81 = -0.25 \text{ N}$$

$$\text{force on the spring} = 0.02 \times 3700 = 74 \text{ N}$$

(This will be the force that will be pulling down on the ball when its fired from the line launcher).

Acceleration

$$a = \frac{f}{m}$$

$$a = \frac{74}{0.025}$$

$$a = 2960$$

Velocity

$$v^2 - u^2 = 2as$$

$$v = \sqrt{2as}$$

$$v = \sqrt{2 \times 2960 \times 0.02}$$

$$v = 10.88 \text{ m/s}$$

Distance the spring will shoot with the given power

$$v^2 - u^2 = 2as$$

$$s = \frac{v^2 - u^2}{2as}$$

$$s = \frac{10.88^2 - 0^2}{2 \times 9.81}$$

$$s = 6.03 \text{ m}$$

The calculation above is just an estimate of how much power the spring will need to shoot 6 metres with the size of the spring itself. This won't be the outcome of the force needed to shoot 6 metres as all springs are different and would need a different force to shoot the distances that have been asked. The force that I put in was through trial and error for the spring to be powerful enough to shoot, as the place where the spring was purchased from didn't give any specification on the spring, by not having the information of the spring it wasn't possible to calculate the force that is needed to shoot the measurements. On the day we'll be able to calculate a more accurate force, by using the

same equation just by finding the force from the distance that it is firing. Rather than doing trial and error to calculate how much force will be needed to shoot the required distances. The outcome of these calculation will be similar to these because the spring will still be shooting 6 metres and has the same dimensions applied to the equations above, it will just be more accurate as we will have the measurements that it has produced on the day. The acceleration and velocity that has been worked out above is only when the ball is getting released from the spring, it wont stay that speed during the whole process of it travelling to the bucket.

To conclude using a spring will be our final choice for the firing mechanism, I have been doing research on spring and they are used in a lot of similar shooting designs. For example, they are used in guns, a gun will have a much greater force and has other components in it that will make it shoot further. For what we need spring for it will be enough and will shoot the distances that have been asked and we will not need any other components in the firing mechanism to increase the distance when it is fired.

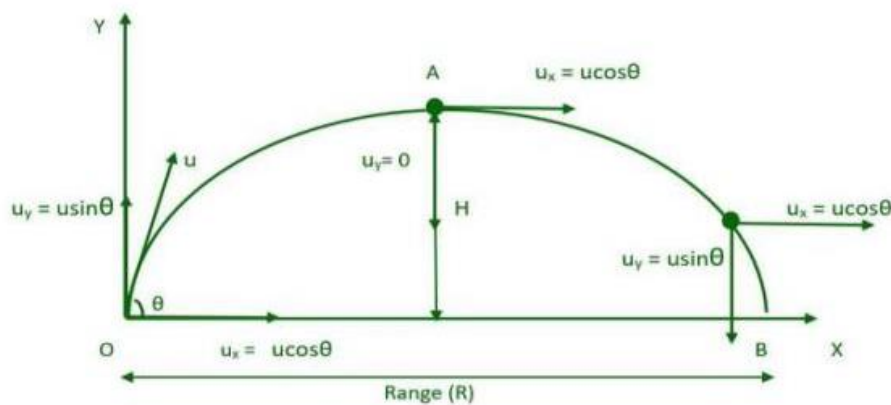
Abdulazim (Aiming and Angle of Projection) -

According to (Helelsmith, n.d.) has state that the projectile motion is defined as the ball is release in the air flowing a horizontal direction this called projectile motion and during its path it makes an angle, before coming to the rest in this paper focuses on how the answer to this question changes depending on the situation. We look at launching projectiles onto different shaped hills, as well as how varying initial velocity and height effect the launch angle. Finally, we add air resistance to the projectile problem and compare two deferent models: air resistance proportional to the projectile's velocity and air resistance proportional to velocity square the concept of this paper is to we examine how to find the optimal launch angle, which is the angle at which a projectile is launched that maximizes its horizontal distance travelled. We find that this angle depends on numerous factors, including the projectile's initial velocity, the effects of air resistance, and the surface upon which the projectile lands.

Equation of motion:

$$V = u - at \text{-----}(1)$$

$$S = ut - 0.5at^2 \text{-----}(2)$$



The horizontal component is $V_x = V \cdot \cos(\phi)$

In the vertical velocity $V_y = v \cdot \sin(\phi)$

<https://www.geeksforgeeks.org/projectile-motion/>

u = is the initial velocity of ball (m/s)

v = final velocity of ball (m/s)

t = time (s)

A = acceleration (m/s^2)

ϕ = is the angle of the projectile

When the ball at its rest $u=0$ and can be resolve in the X direction, but the velocity in Y direction it will move upward while velocity in X direction is constant till Y reach its maximum height above ground and then start coming down under the influence of gravitation acceleration which is $g = (9.81\text{m/s}^2)$. S is the distance between the line launcher and target, we define ϕ to be the angle above the horizontal at which the projectile is launched. To solve this problem, we use the equation of motion to find the optimum angle line launcher we use Trigonometric equation.

$$V_x = v_0 \cos \phi; V_y = v_0 \sin \phi - at$$

The acceleration in x- direction is zero, while in Y direction is move slowly one it reached its maximum height under the influences of gravitation an acceleration toward the ground to find those angles, we used the equation below,

To calculate the time of the line launcher we used the first equation stated above and rearranged to get, t which is time taken during its travel. To design an effective line launcher we must focused on force acting upon the line during its trajectory, as the ball been firing horizontally in the air which is experiencing only a gravitation acceleration and it travel with a parabolic trajectory because the gravitation acceleration has impacted, in other hand as the firing was moving upward with a constant speed it has no horizontal force acting upon projectile and it has no horizontal acceleration of the projectile.

To calculate the total Time of the firing ball flight from initial speed till it hit the target we can simply use the equation below by knowing the angle of the launcher, speed, and height of the line launcher.
 $t = 2u_0 \sin \theta / g$

Maximum height reached by ball, $H = u_0^2 \sin^2 \theta / 2g$

Horizontal range of ball, $R = u^2 \sin 2\theta / g$

First one a ball has fired horizontally from its trajectory from the height of 3m, with initial velocity of 11m/s and it makes an angle of 45degree, what is maximum height does the ball reach, and how long does it take in the air? find the total range.

To solve this problem, we need to find the initial velocity in Y direction and the initial velocity in X direction, using trigonometry equations.

Maximum height of the projectile

$$V_{0y} = V \sin \theta$$

$$V_{0y} = 11 \sin 45 = 7.8 \text{ m/s}$$

$$V_{0x} = V \cos \theta, = 11 \cos 45 = 7.8 \text{ m/s}$$

To find maximum height we use last equation $v_f^2 = v_0^2 + as$ where V_F is final velocity and v_0 is initial velocity and A is gravitation acceleration (-9.81 m/s^2), and S is height of the trajectory. $S = (0^2) - (7.8^2) / (2 \cdot -9.81) = 3.10 \text{ m}$

Total time in the air we rearrange the first newton is law of motion $V_F = v_0 + at$

$$V_f - v_0 / a = t$$

$$T = (0 - 7.8) / -9.81 = 0.795 \text{ s}$$

We know that total time is the time taken to travel upward and downward so we going to multiplied by 2 to get the total time which is 1.59s.

The range and this can be defined as the displacement in X direction.

$$R = (V_x)(T_x) = (7.8) \cdot (1.59) = 12 \text{ m the range is going to be 12 metre.}$$

Optimal angle of the projectile launcher

$\Delta x = 2(v^2) \cdot \sin \theta \cdot \cos \theta / g$ this equation is come by rearrange the equation of motion and substitute into trigonometry equation to come up with equation above, as the launcher during its travel in air it move in vertical direction and horizontal direction which is making triangle in every point till reach its maximum height and then do the same when it come under the gravitation acceleration.

We use the equation mentioned above to find three different optimal angle to shoot the target.

$$\text{At angle } 85^\circ \Delta x = (2 \times 7.82) \times \sin 85^\circ \times \cos 55^\circ / 9.81 = 1.08 \text{ m}$$

$$\text{At angle } 20^\circ \Delta x = (2 \times 7.82) \times \sin 20^\circ \times \cos 20^\circ / 9.81 = 3.98 \text{ m}$$

At angle 80° $\Delta x = (2 \times 7.82) \times \sin 80^\circ \times \cos 80^\circ / 9.81 = 2m$

At angle 40° $\Delta x = (2 \times 7.8^2) \times \sin 40^\circ \times \cos 40^\circ / 9.81 = 6.10m$

One of the important approaches in this paper is that projectile motion of the launcher is vertical and horizontal motion are independent of each other. And this angle we approach is needed to relook in the final design of the launcher, in relation to the optimal angle and the power needed to shoot from the distance been shown in the calculation above, the initial velocity of the projectile motion is remained constant, and the higher the angle it will experience a considerable time in the air, also at 45° the line launcher will experience significant horizontal displacement. Angle 90° is the angle zero which the highest angle of the projectile trajectory and then comes downward under the gravitation acceleration and ball will spent greater time in the air. The speed of ball is depending on the height and the distance we are launching from.

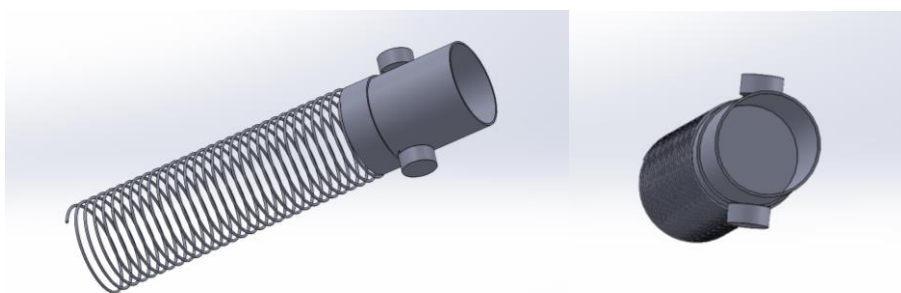
Nathan (Team Leader) -

In creating and overseeing this design I had to make sure that all pieces of it would fit together correctly, as well as ensuring that the design is cost-effective and material selection was appropriate. Each part of the final design needed to be able to suitably function in tandem with each other in order to be fired accurately at targets within the range of distance of 2 – 6 meters. When reviewing each component that could be potentially used for the launcher, I had to consider whether it was first of all, realistic for us to be able to produce, cost effective, would fit within the $40cm^3$ working envelope set by IMechE and how it would function in relation to other components that we had either chosen or were considering. Through careful consideration of the likely dimensions and materials needed for each component the configuration of the design was created.

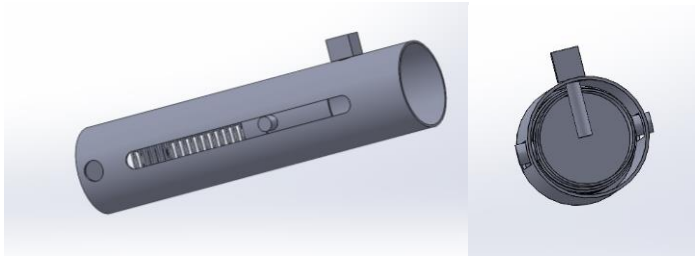
The main elements which make up the design are, the outer cannon style shell, the single solenoid connected to a 9-Volt battery, the spring cocking system and the line holding cylinder. Each of these have their own very specific reasons in regard to dimensioning and materials for being chosen. The cannon shell of the design was chosen quite early on in the project as it seems like a logical and simple way to create a line launcher within the design envelope. The key advantage to this is the large pipe which could easily host a spring cocking mechanism along with the ball, due to its long shape. Since the shell is essentially just a pipe supported by two wooden blocks, this gives us quite a large amount of potential length when creating the mechanisms inside as the working envelope can be almost entirely taken up by the pipe. While we could consider materials such as carbon fibre or various metals to create the shell, these are far too costly and hard to machine for our experience level. Instead, we opted for a cheap MDF wood for the inner mechanism and support structure, that could far more simply be laser cut to the dimensions and shapes we require compared to other options. MDF wood is also a tough and rigid material, giving it a good resistance to any push back from the spring - (Dmitri Kara, Parade of Homes, 2017). Additionally, this gives the cannon a heightened resistance to recoil, MDF wood can absorb the energy efficiently helping to prevent the cannon from moving when in use - (Montauk Hardwood Bikes, 2020). As for the pipe this will be purchased cheaply and made from PVC and will have two adjacent slots cut into it to allow the lever of the cocking mechanism to be pulled back manually. To allow the cocking system to work the ball and spring would need to lock in place until firing was desired, to do this I found an electrical

solenoid that could easily be attached to the top of the cannon in front of where we want cocking mechanism to pull back to. The solenoid itself is only about 2cm in length so it fits nicely on top with the pin coming down into the pipe. For a £30 budget a solenoid (which cost around £10-15), could be seen as quite costly, but when contrasted against the cheap pipe and wood it is a worthwhile investment. Solenoids are highly reliable and have a low power consumption (Versa Valves, 2022), allowing us to create a dependable line launcher that fits within the design requirements. The solenoid we will be using will be connected via 2 electrical circuit lines to a 9-volt battery, all these components are relatively small which allows the design to remain within the working envelope while in operation. The 9-Volt battery and lines will be provided by the university which makes this an excellent choice as there is no cost here, this also then offsets the initial expense of the solenoid. The mechanism inside the pipe is made up of three main components, the spring, the pullback handle and the line holding cylinder. Each of these components fit together neatly as they can each be created in an equal diameter. To make sure that they as a unit fit into the pipe and that there is no rubbing against the walls of the pipe, they will each be created 5mm smaller than the pipe. This is to account for any tolerances in the materials and to make sure that they definitely will not rub, as the launch needs to be as smooth as possible. Currently the pipe will have a diameter of 60mm, so each component will be either created or sourced, at a diameter size of as close to 55mm as possible. The line holding cylinder that sits on top of the spring and lever will be made of either wood or plastic, this is currently dependant on whether we could source one with an appropriate diameter and length or if we would need to create one. Which material we choose final isn't too important for this part as it will simply need to be fixed to the lever and spring and remain in place, since it has quite a static function either would be fine to use. From the design we currently have I think that the dimensions will be more than reasonable and will fit within the working envelope set by iMechE nicely, as for the cost as it currently stands it should be around the £30 budget, however this mostly depends on how much the solenoid is. The material selection is fairly unambitious, as there is obviously quite a high quality trade off when you compare our selected materials with potential ones, however to keep within our skill level and budget the current choices will suffice.

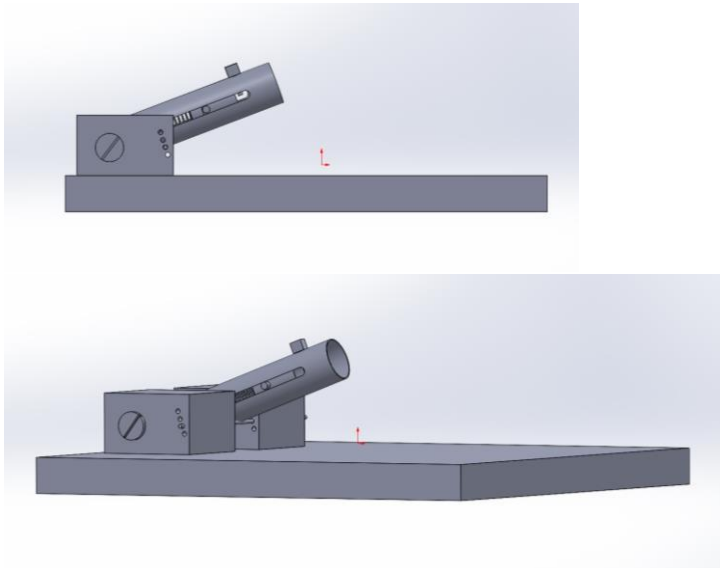
Technical Drawings and 3D Models



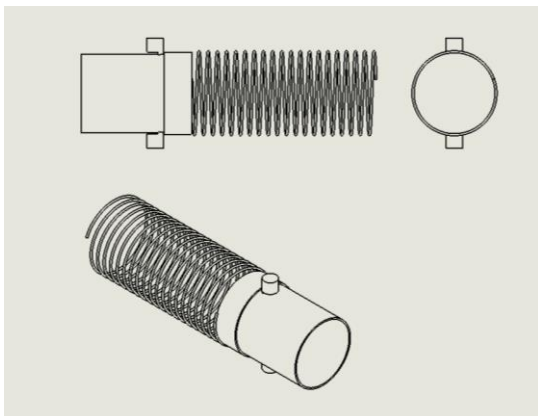
Spring System, Left to right: Spring, Base, Cocking Lever, Line Holding Cylinder



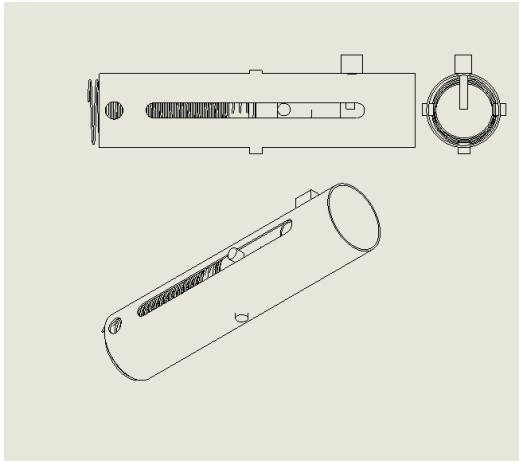
Spring System inside the Pipe with solenoid



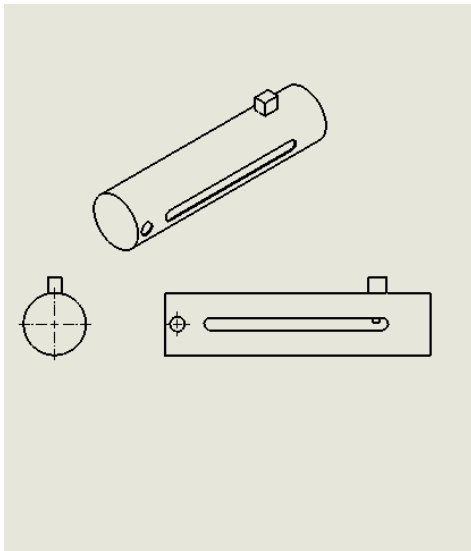
Full 3D model of the line launcher design



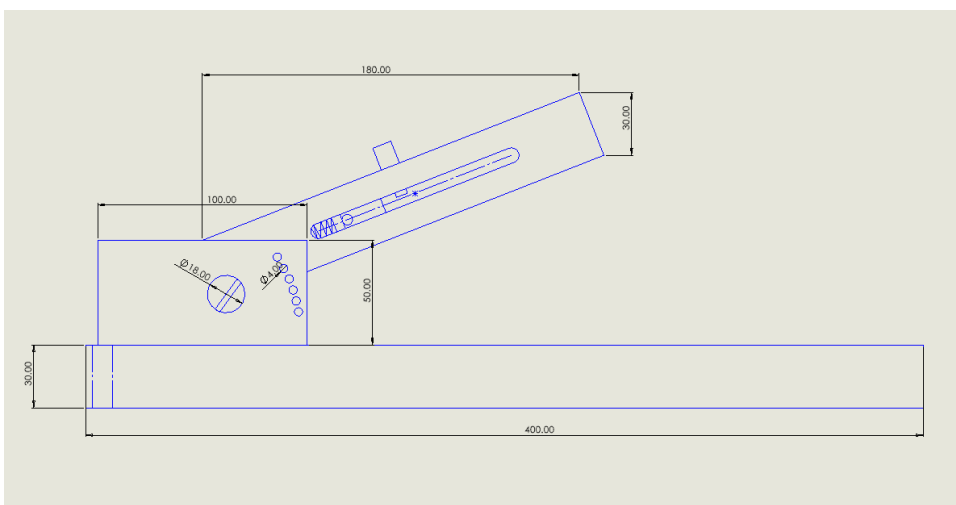
Technical drawing of the spring syst



Technical drawing of the spring system inside the pipe



Technical drawing of the pipe



Technical drawing of the full line launcher design

References

Nathan -

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Montauk Hardwood Bikes (2020) Why Does Wood Absorb Vibration So Well? Available at: - <https://www.montaukhardwoodbikes.com/why-does-wood-absorb-vibration-so-well#:~:text=Wood's%20high%20damping%20capacity%20is%20what%20makes%20a%20smooth%20ride.&text=Since%20wood%20frames%20have%20a,the%20road%20as%20you%20bike>.

Abdulazim -

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