Studying Self Propelled Springs

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SPH4UI

10-11-2021

ABSTRACT

Energy is the principle that runs our world from your phone to the rockets that took us to the moon. This lab dives deep into the basics of energy and uses it to find a landing zone for a spring that was launched by a contraption built by a group of students. The purpose of the contraption was to launch the spring at three different angles (30,35,and 40). To make the launching of the spring as accurate as possible, concepts like spring hooke's law, energy and projectile motion were used to derive equations. These equations helped find the exact value they will need to stretch the spring for it to go a certain distance. The students then used those equations to make a chart which was used on launch day to launch the springs. The launching process for the spring was quite simple, there was a small hole where the spring hooks on and from there the bottom of the spring can be stretched to launch the spring. The results from the launch day showed that the prediction made by the students wasn't accurate enough to get the spring into the bucket. This was due to many errors including air resistance and the spring's k value being changed due to overstressing the spring on test day. In conclusion ,The main popourse of this lab was to launch a spring into a bucket as accurately as possible using a launcher. To do that students had to predict the X values needed to get the spring into a bucket placed a certain distance away from the launcher

Introduction

Energy is the principle that runs our world from your phone to the rockets, and a concept that took us to the moon. There are many different kinds of energy that exist around us, like gravitational potential energy, kinetic energy, and electric potential energy. All energies must follow the law of conservation of energy , a law which states that all closed systems must conserve energy. That means that energy cannot be created or destroyed, only converted from one form to another. Even though all of the energies seem similar to one another, they all have different equations that model them.

In this lab, students were given a task to build a contraption to launch a spring. The contraption had to meet certain requirements like, the height had to be 30 cm, and it had to support three different launch angles, 30°, 35°, and 40°. The goal was to launch the spring using the contraption, and into a bucket placed a certain distance away from the contraption. The distance and the launch angles were randomized. There were three possible angles and eight different possible ranges students could get. To achieve this goal, the students had to make calculations using their knowledge of energy, projectile motion, and Hooke's law to predict the amount of stretch needed to be applied to the spring for it to land on its target.

Hooke's law is the relation that ties the force generated by the spring to the spring constant (k), and the spring stretch or compression value. Hooke's law is important because it lets us find the magnitude of the force that the spring will produce when it is launched. This is important because this can be used to isolate the stretch value (displacement of the spring from its rest position) which is needed to launch the spring on to the target because the spring has to stretch by the right amount for it to get the right amount of acceleration for it to reach the target.

Projectile motion is the motion of an object thrown (projected) into the air. After the initial force that launches the object, it only experiences the force of gravity(2). Since spring behaves like a projectile, the only force it experiences is gravity so any other external forces can be neglected which makes the math much easier later on. Both the energy component and the projectile motion properties of the spring will be used to derive the equations for the K and X. After building the contraption, the ranges were measured and marked on the floor. The students launched their spring and tried to get into the bucket. Once they succeeded in getting the right X value they used that to get their spring constant, this was because the students used a spring that best suited that contraption and therefore had different K values.

Hypothesis / Prediction

For the students to launch the springs accurately, some calculations were made to find the exact K value which would later be used to find X. To find the K value the equation was derived from the conservation of energy principle and was subbed into the equation that models the path of the projectiles (the projectile motion equations).

Firstly, the breakdown of the energies involved in this calculation:

Ee - elastic potential energy

Ek - kinetic energy

Eg - gravitational potential energy

When the sprint lies on the ramp, it starts off with Eg but it can be ignored due to the fact the bucket is the same height as our ramp which means the $\Delta y = 0$. So the calculations just assume it to be at ground level. The relation goes something like this: the Ee that the spring has when it is stretched is set equal to the Ek because. Once the spring is released and it starts moving, the Ee goes to 0 due to the fact the energy has to conserve and the spring is moving. A statement can be made that the Ee must equal to the Ek of the spring just after launch.

Ee = Ek

$$\frac{kx^2}{2} = \frac{mv^2}{2}$$

$$kx^2 = mv^2$$

$$\frac{kx^2}{m} = v^2$$

$$\sqrt{\frac{kx^2}{m}} = v$$

m = mass of the spring
k = spring constant
x = the stretch value of the spring
v = velocity

Because the Vi is known now it can be substituted into a projectile motion equation which can be rearranged to give the K and X values.

$$dx = \frac{V^2 sin2\theta}{g}$$

$$dx = \frac{\left(\sqrt{\frac{kx^2}{m}}\right)^2 sin2\theta}{g}$$

$$dx = \frac{\frac{kx^2}{m} sin2\theta}{g}$$

$$gdx = \frac{kx^2}{m} sin2\theta$$

$$mgdx = kx^2 sin2\theta$$

This equation can be rearranged to find both K and X

$$\frac{mgdx}{(sin2\theta)k} = x^2 \qquad \frac{mgdx}{(sin2\theta)x^2} = k$$

$$\sqrt{\frac{mgdx}{(sin2\theta)k}} = x$$

The k equation was used to find the k but the k equation can not be solved without knowing the X value. The students solved this issue by guessing the x value needed to get the spring into the bucket and launching the spring of their contraption, once the guessed X value successfully got the spring onto the bucket the students then used the X value to evaluate for the k value.

The X value that was successful at getting the spring onto the bucket, in this case, was 7cm from the spring rest position which was measured to be 17 cm. The rest position of the spring is when the spring exceeds no force or in other words, when the Ee of the spring is 0 this is when the spring is not stretched or compressed. The angle that was used in this case was 30 degrees and the distance the students launched their spring from was 2m.

$$k = \frac{mgdx}{(sin2\theta)x^2}$$

$$k = \frac{0.0103\times9.8\times2}{(sin2(30))0.07^2}$$

$$k = 47.56$$

So the k value was approximated to be 47.56 using this the students can now find the x values needed for their predictions.

- For this calculation, the angle is 30 and distance as 5m

$$\sqrt{\frac{mgdx}{(sin2\theta)k}} = x$$

- The know values have been plugged into the equation

$$\sqrt{\frac{0.0103 \bullet 9.8 \bullet 5}{(sin2(30))47.56}} = x$$

- So the x value for this scenario was estimated to be

$$x = 11.06\ cm$$

Since this is only one of the many launch possibilities that the students could get a list with all the launch possibilities were made.

Table 1 = The table with all the possible launches

$Angles\ \theta$	3.5m	4cm	4.5cm	5cm	5.5cm	6cm	6.5cm	7cm	7.5cm	8cm
30	8.26 cm	9.90 cm	10.50cm	11.06cm	11.60cm	12.12cm	12.62cm	13.01cm	13.55cm	14 cm
35	8.89 cm	9.50 cm	10.08cm	10.62cm	11.14cm	11.64cm	12.11cm	12.57cm	13.01cm	13.44cm
40	8.68 cm	9.28cm	9.77 cm	10.83cm	10.88cm	11.37cm	11.83cm	12.28cm	12.71cm	13.13cm

Experimental Design

An apparatus was built to launch the spring and the picture of the apparatus is shown in (Figure 1).

The materials used to perform this lab is listed below

Materials

- Ramp
- Pencil
- Masking tape
- A 37cm high bucket
- Measuring tape
- Calculator
- An algorithm (to compute the calculations)
- A computer (to run the algorithm)
- Spring
- Meter stick

Figure-1, the apparatus that was used to launch the spring

Procedure

Day 1 (prep day)

1. A device was built to launch the spring.
2. First, the students started by measuring the different ranges (using a measuring tape) and marked them on the floor (using the masking tape). The marks ranged from 3.5m to 8m from the target
3. The students then began by figuring out the k value of the spring(as explained in the hypothesis section)
4. A 37cm high bucket was placed 8m from the ramp
5. An algorithm was used to compute the x values needed to launch the spring
6. To make the launch of the spring more effective the students used a pencil to launch the spring.
7. The spring was hooked onto a small hole at the top of the contraption and was stretched to the necessary x value calculated by the algorithm. A built-in ruler in the contraption let the person know exactly where the end of the spring was located increasing the accuracy of the launcher
8. The students launched their spring. They started from 1m (dx) and moved their way up to 8m (dx) once they were successful at getting the spring onto the bucket.

Results

On launch, the students were given eight attempts to try to get the spring into the bucket. The range and the angle were randomized. The angles were randomized by using dice and for the range, a bucket filled with random ranges was used to decide the range for the launch. A table is presented below showing the results of the 8 launches for this group of students.

Table 1 = The table with all the possible launches

Angle	Attempt	Attempt	Attempt	Attempt	Attempt	Attempt	Attempt	Attempt

35°	1	2	3	4	5	6	7	8
Range 5.5	5.3 cm L	5.3 cm	5.3 cm	5.25cm L	5.25 cm	5.3 cm	5.5 cm L	5.3 cm L

L = to the left of the target , R = to the right of the target , blank = it was head on with the target , In = was successful at getting the spring into the bucket

The results from the table above show that the students were not successful at getting the spring into a bucket. In their first attempt, they fell short by 20cm and their shot was slightly aimed towards the left. The second and the third attempt were the same, spring landed 20cm short but was head-on with the bucket. The rest of the attempts were off by a couple of cm ranging from 20 - 25cm off the target. Attempt seven however was very close to going into the bucket the students nailed the range but launched it slightly to the left of the target. Percent error calculations can be made to show how accurate the students were in their attempts to get the spring into the bucket.

A percent error calculation will be made of Attempt 2

$$PE = \frac{|Predicted - Exact\ Vaule\ |}{Predicted} \times 100$$

$$PE = \frac{|5.3-5.5|}{5.5} \times 100$$

$$PE = 3.63\%$$

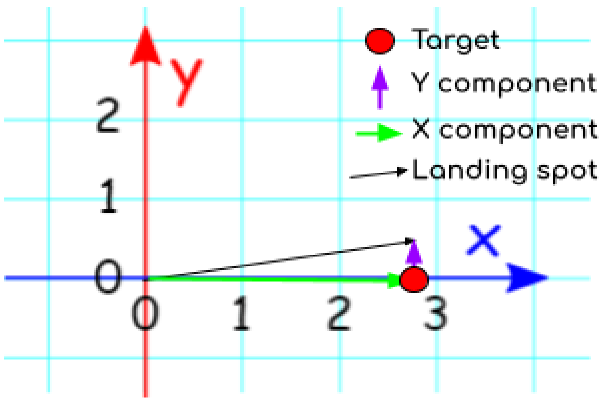
Table 2 = The table shows all the PE values for each attempt

Attempt	1	2	3	4	5	6	7	8
PE	3.63%	3.63%	3.63%	4.54%	4.54%	3.63%	0%	3.63%

<u>Discussion</u>

As with any lab or experiment anomalies are sometimes unavoidable. In this case as shown In the results section, the student failed to land the spring into the bucket. Some of the anomalies that occurred on the day of launch are listed below

- The spring landed shorter than expects



- The base kept moving during the launch
- The spring kept landing to the left of the bucket

With the tables provided in the results section, a relation can be made between the precteded and exact values of the landing spots. Comparing the two values we can see for the first launch attempt their shot was off by 0.20 cm which gives them a PE of 3.63%. The PE in this case only includes the PE in the dx direction but in reality, the PE should have been higher due to the fact there was a PE in the y compound as well this was because the spring landed to the left of the bucket, figure 1 shows a visual representation of this problem. Their second and third attempts were similar to the first attempt but the spring in these two attempts were head-on with the bucket. Secondly, the fifth and the fourth attempts were exact copies of one another both landing 25cm short, Which gives a PE of 4.54%. Finally the 7th and 8th launch, the seventh launch happened to be the most successful out of all the attempts giving a PE in the x of 0 but due to the fact it landed slightly to the left of the bucket, it was unable to make it into the bucket. The eighth shot was just a replica of the first shot.

Figure 1

Figure 2

As shown in the tables (table 1 and 2) presented in the results section,the predictions made by the students were not accurate enough to get the spring into the bucket. Even though the students were very close to getting the spring into the bucket, it became obvious that certain errors weren't accounted for, which caused anomalies during launch. Firstly, air resistance could have been the reason why the spring landed shorter than expected. Air resistance, a type of friction between air and another material(1). Due to the fact air resistance is just a type of friction, it will act against the motion of the spring causing it to slow down. This will make the spring fall short of its target. This conclusion can be made due to the Ee the spring started with will not only be converted into Ek but also be converted into heat due to friction causing the Ek to be lower . Due to the fact Ek is a relation between mass and velocity and mass cannot change the velocity must get lower. Secondly, from table 1 provided in results, the shots tended to land to the left of the bucket sometimes, this was due to two main reasons. The first reason, the base was not secured to the ground properly causing the launcher to slide around the ground throwing off the trajectory of the spring. The second reason, the launcher didn't have anything to guide the spring into the right trajectory. The launcher had a flat and smooth ramp to launch the spring - as shown in figure 3 - this helped reduce friction but caused a different problem that affected the trajectory of the object. Finally, the spring constant could have also played a part in the accuracy of the shots taken by the students. The students have been testing the spring for hours on the day before the launch day. The spring was stretched multiple times during the test launch, this could have caused the k value of the spring to reduce. If the K value changes the calculation done early in the hypothesis section would differ and would result in new x values.

Improved Procedure

- While setting up the ramp tape would be used to secure the ramp to the floor
- During test launches, a fixed amount of launches would be conducted to make sure the K value doesn't change.
- While launching the spring the springs X value could be slightly increased to account for air resistance

This experiment was valid because everything was planned accordingly before starting and concepts from physics class were used to complete the experiment.

Conclusion

The main purpose of this lab was to launch a spring into a bucket as accurately as possible using a launcher. To do that, students had to predict the X values needed to get the spring into a bucket placed a certain distance away from the launcher. An equation was derived by the students to calculate the k value needed to predict the x values. This allowed the students to make predictions on where the spring would land, using this, the students created a chart with all the possible launches that they may get on launch day(Table 1). The results from the launch day showed that the predictions made by the students weren't accurate enough to get the spring into the bucket. This was caused by air resistance, the base of the ramp not being secured to the floor, and the k value changing due to overusing the spring on test day. Some improvements to the procedure were also developed by the student which would increase the accuracy of the launches if they were to repeat this lab. Some of the improvements made to the procedure included taping the ramp to the floor to secure it to the ground, setting a limited amount of test launches to avoid overstressing the spring, and accounting for air resistance by slightly increasing the x value.

Works Cited

1)"What Are Water and Air Resistance?" *BBC Bitesize*, BBC, 5 Oct. 2020, https://www.bbc.co.uk/bitesize/topics/z4qtvcw/articles/zfvmt39.

2)OpenStax. "Physics." *Lumen*, https://courses.lumenlearning.com/physics/chapter/3-4-projectile-motion/.

3) all picture were made by the students