Prosthetic Arm Engineering Challenge Final Report

By

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Our final virtual model on White Box Learning was named,

“Mackenzie Final”.*

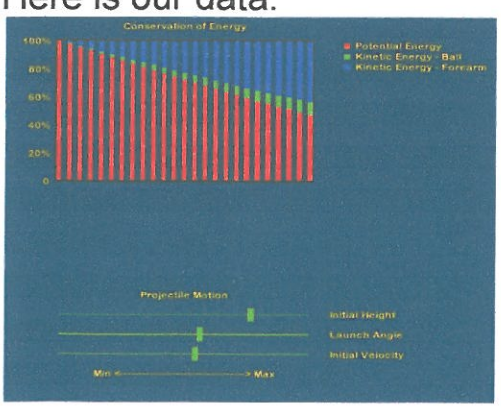
Here are the output specs of our model:

Design Inputs	Minimum	Maximum	Designed
Arm Length	150 mm	225 mm	220.0 mm
Arm Angle	45 deg	65 deg	45.0 deg
Forearm Length	200 mm	250 mm	250.0 mm
Pullback Angle	–	85 deg	65.5 deg
Forearm Tricep Handle Offset	15 mm	40 mm	40.0 mm
Arm Tricep Handle Offset	30 mm	100 mm	100.0 mm
Forearm Bicep Handle Offset	15 mm	60 mm	20.0 mm
Arm Bicep Handle Offset	15 mm	60 mm	45.0 mm
Total Material Length	–	2000	1363.2 mm
Number of Rubber Bands	–	3	3

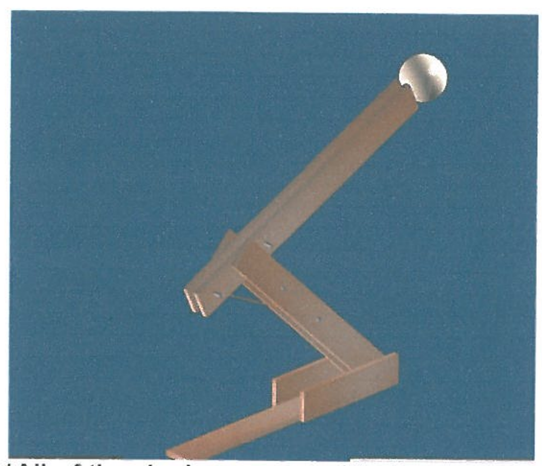
Here are our competition results:

	Mackenzie Final
	Hebron MS
Target Range	7.50
Actual Range	7.50 m
Distance (Miss)	0.00 m
Specifications	IN SPEC

Here is our data:

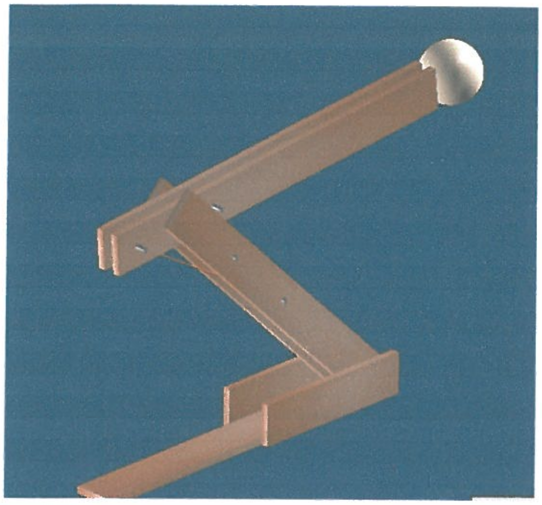


Here is our final design:



*All of the designs are on Mackenzie's White box learning account.

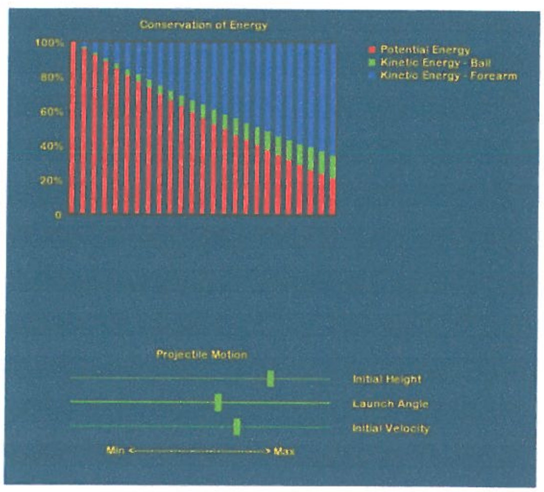
The Next Model: **Mackenzie 14**



From Model 1, we changed things based on trial and error until we got to this point.

This arm is in spec, unlike the last one.

Knowing that it was in spec, it went 9.44 meters, we were off by 1.94 over the target.



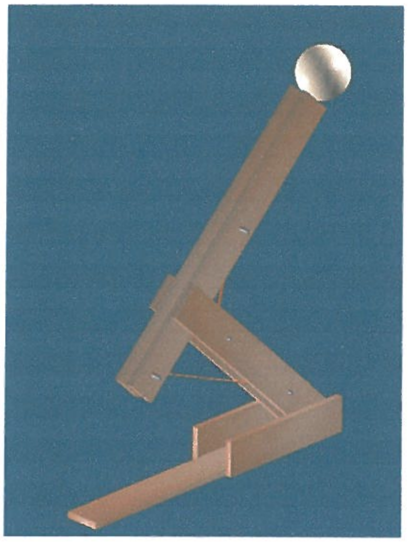
	Mackenzie 14
	Hebron MS
Target Range	7.50
Actual Range	9.44 m
Distance (Miss)	1.94 m
Specifications	IN SPEC

From Model 1 we changed a lot of things:

- Arm Length: 185.0mm– 250.0mm
- Forearm Length: 225.0mm- 250.0mm
- Pullback Angle: 45.0deg- 85.0deg
- Forearm Tricep Handle Offset: ****50.0mm**- 40.0mm
- Arm Tricep Handle Offset: **120.0mm**- 100.0mm
- Forearm Bicep Handle Offset: **62.0mm**- 20.0mm
- Arm Bicep Handle Offset: 40.0mm- 45.0mm
- Total Material Length: 1,243.2mm- 1373.2mm
- Number of Rubber Bands: **6**- 3

The **red numbers are the ones that were out of spec on the first model.

Our First Model: **Mackenzie 1**

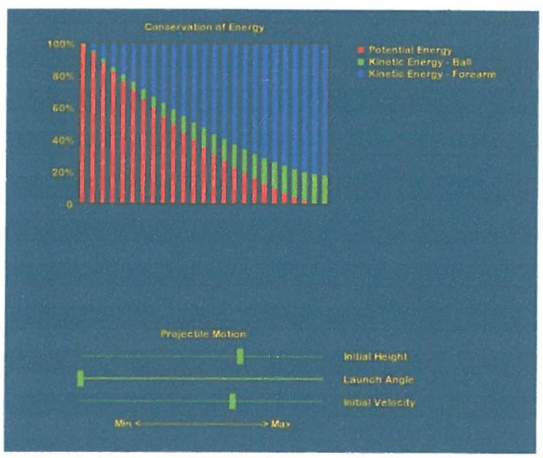


For our first model we decided just to add or subtract about 5 or 10 mm, cm, or degrees to the default measurements.

When we did this, we noticed that it was out of spec.

Even though it was out of spec, it went 2.34 meters, we were 5.16 meters off.

We noticed, also that our graph looked good, but since it was out of spec, so we couldn't compete.

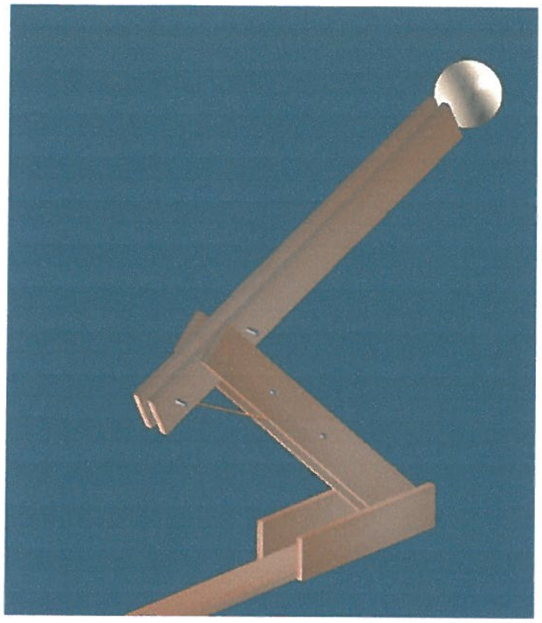


Our Forearm Tricep Handle Offset was out of spec, as well as the Arm Tricep Handle Offset, the Forearm Bicep Handle Offset, and the Number of Rubber Bands.

We made a few changes on each model, we are only showing a couple along the way to the last model so you can see what we changed until the end.

	Mackenzie 1
	Hebron MS
Target Range	7.50
Actual Range	2.34 m
Distance (Miss)	5.16 m
Specifications	OUT OF SPEC

The Next Model: **Mackenzie 24**



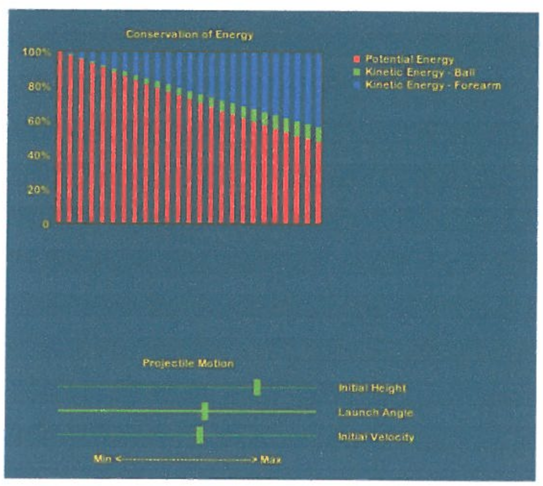
From Model 14 on we changed one thing at a time.

This arm was in spec as well.

Knowing that it was in spec, our model went 7.43 meters, it was 0.07 meters off. We were so close!

From Model 14, we changed quite a few things:

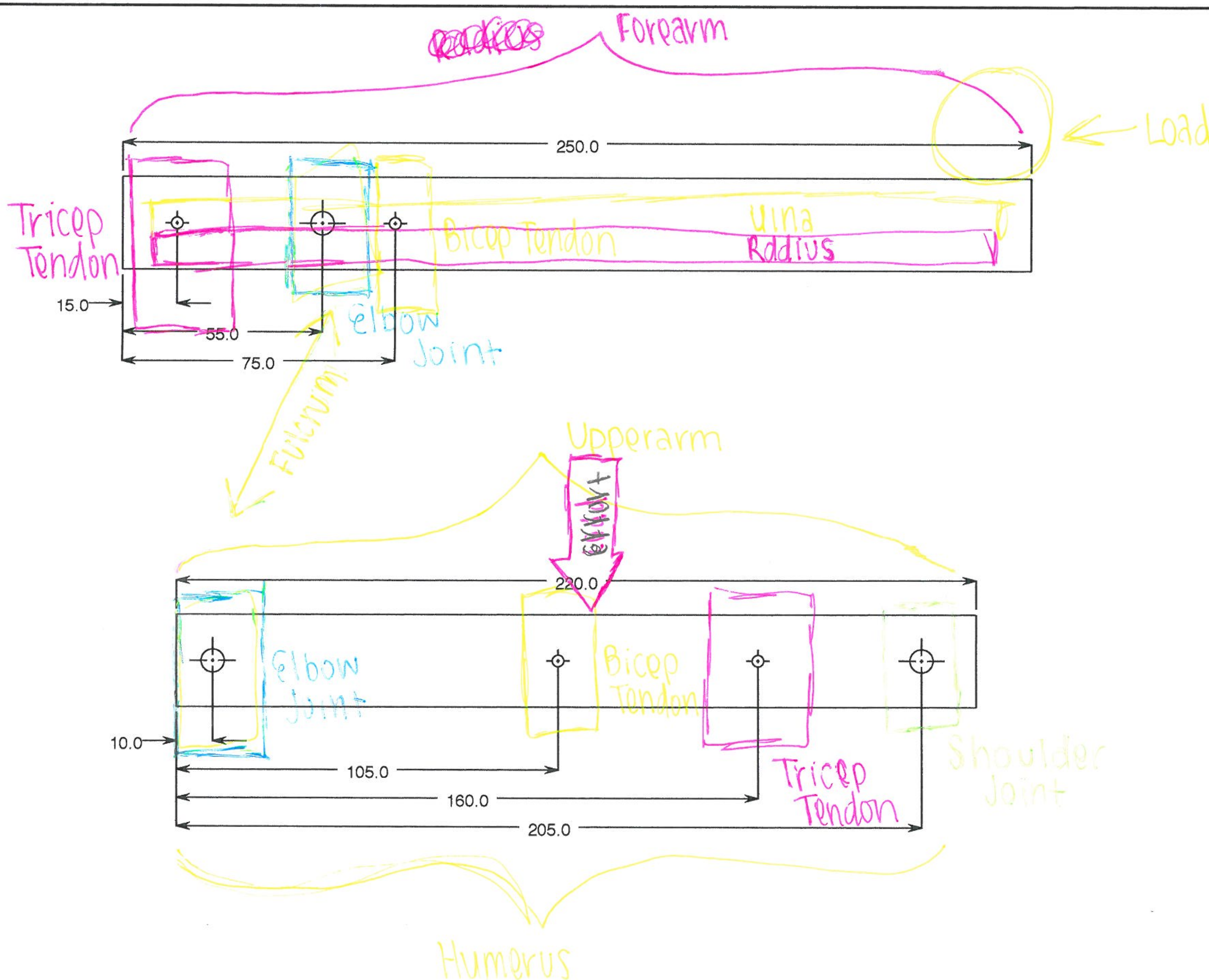
- Arm Length: 225.0mm-220.0mm
- Pullback Angle: 85.0deg- 65.deg
- Total Material Length:
- 1,373.2mm-1,363.2mm



	Mackenzie 24
	Hebron MS
Target Range	7.50
Actual Range	7.43 m
Distance (Miss)	0.07 m
Specifications	IN SPEC

Since we only were off by 0.07meters, we decided that we only needed to change one thing by a little number.

We decided to change the Pullback Angle to 65.50 degrees.



otes: Cut two arms and two forearms

Final Report

Only for virtual model

An object can store energy as the result of its position. For example, a pendulum at its maximum height stores energy as a result of its elevated position. When in this elevated position, the stored energy is referred to as potential energy because the pendulum has the potential to do work. Another form of potential energy is elastic potential energy where energy is stored by the stretching or compressing of elastic materials. In the prosthetic arm, the pulling back motion adds energy to the rubber band. The energy is then stored in the stretched rubber band until the arm is released. The work done by the rubber bands (muscles) is equal to the change in potential energy between the pullback and launch position.

$$Work = PE_i - PE_f$$

In general, the potential energy of a spring is:

$$PE = \frac{1}{2}kx^2$$

Where k is a spring constant associated with the rubber band and x is the stretched length of the rubber band minus the relaxed length of the rubber band.

We can also add a variable N to the equation to accommodate more than one rubber band:

$$PE = \frac{1}{2}Nkx^2$$

Using the values in the table, the potential energy stored in the triceps muscle at the pullback position is calculated as follows.

$$PE_t = \frac{1}{2} * 1 * 35.0 * 0.0359^2 = 0.02\ Joules$$

Since the triceps and biceps muscles oppose one another, the total potential energy at the pullback position is the potential energy of the triceps muscle minus the potential energy of the biceps muscle. Since the biceps muscle is loose at the pullback position, its potential energy is zero. So the total potential energy at the pullback position is just that of the triceps muscle.

$$PE_{pullback} = PE_t - PE_b = 0.02 - 0.0 = 0.02\ Joules$$

At the launch position (or just a moment before launch), both the triceps and biceps muscles are loose. Therefore, there is no potential energy in the system at the launch position.

$$PE_{launch} = PE_t - PE_b = 0.0 - 0.0 = 0.0\ Joules$$

And the total work done by the muscles between the pullback and launch position is therefore calculated as follows:

$$Work = PE_{pullback} - PE_{launch} = 0.02 - 0.0 = 0.02\ Joules$$

Potential Energy & Work

Calculate the work done by your prosthetic arm and the potential energy of the bicep and tricep muscles by referencing the information on the left.

Be sure to show your math.

Work $PE_i - PE_f$

$PE = \frac{1}{2}kx^2$

k = spring constant

x = stretch (pullback)

$PE_T = \frac{1}{2}Nkx^2$

N = # of rubber bands

$PE_T = \frac{1}{2}(2)(30)(0.039522^2)$

0.05 Joules = PE_T

$PE_B = \frac{1}{2}(30)(0^2)$

PE_B = 0 Joules

0.05 - 0 = work

0.05 = work

Work =

0.05 Joules

All moving objects have kinetic energy. Just like potential energy, there are many forms of kinetic energy like vibrational (the energy due to vibrational motion), rotational (the energy due to rotational motion), and translation (the energy due to movement along a straight line). For our prosthetic arm, the work done by the rubber bands will cause the forearm and ball to move. Thus these two components will have kinetic energy.

The kinetic energy of the ball with mass *m* and velocity *v* is defined as:

$$KE = \frac{1}{2}mv^2$$

The prosthetic arm also has kinetic energy and we should actually take this into account. However, to simplify the problem we will neglect the kinetic energy associated with the rotating arm and assume that all of the system's kinetic energy is from the ball. Thus, we will assume that the total kinetic energy in the system at a given time is as follows:

$$KE = \frac{1}{2}mv^2$$

As before, we need to calculate the kinetic energy in the system at the pullback position and the launch position. At the pullback position (just before the arm is released) the ball and forearm are motionless (or velocity is zero). Thus, there is no kinetic energy in the system at the pullback position.

$$KE_{pullback} = 0.0\ Joules$$

At the launch position, the ball and forearm are moving, so some of the system's energy is in the form of kinetic energy. And since we know that this total kinetic energy is equal to the work done by the rubber bands, we can utilize the following formula:

$$Work = KE_f - KE_i$$

Since the initial (pullback) kinetic energy is zero, this formula reduces to the following:

$$Work = \frac{1}{2}mv^2$$

In other words, the work done by the rubber bands is equal to the total kinetic energy in the system. Energy is conserved.

Now rearrange the terms to isolate velocity:

$$v = \sqrt{\frac{2 * Work}{m}}$$

We have already calculated the work done by the rubber bands and the mass (m) of the ball is given. So we can now calculate the velocity of the ball when it leaves the hand.

$$v = \sqrt{\frac{2 * Work}{m}} = \sqrt{\frac{2 * 0.02}{0.00175}}$$

$$v = 4.78\ m/s$$

Kinetic Energy & Velocity

Calculate the work done by your prosthetic arm and the potential energy of the bicep and tricep muscles by referencing the information on the left.

Be sure to show your math.

$KE = \frac{1}{2}mv^2$

m = mass

v = velocity

$KE = \frac{1}{2}(1.75)v^2$

$Work = KE_f - 0$

$2 \cdot 0.05 = \frac{1}{2}(0.00175)v^2 \cdot 2$

$\frac{2 \cdot 0.05}{0.00175} = \frac{1.75v^2 \cdot 2}{0.00175}$

$v = \sqrt{\frac{2 \cdot 0.05}{0.00175}}$

v = 7.56

Velocity =

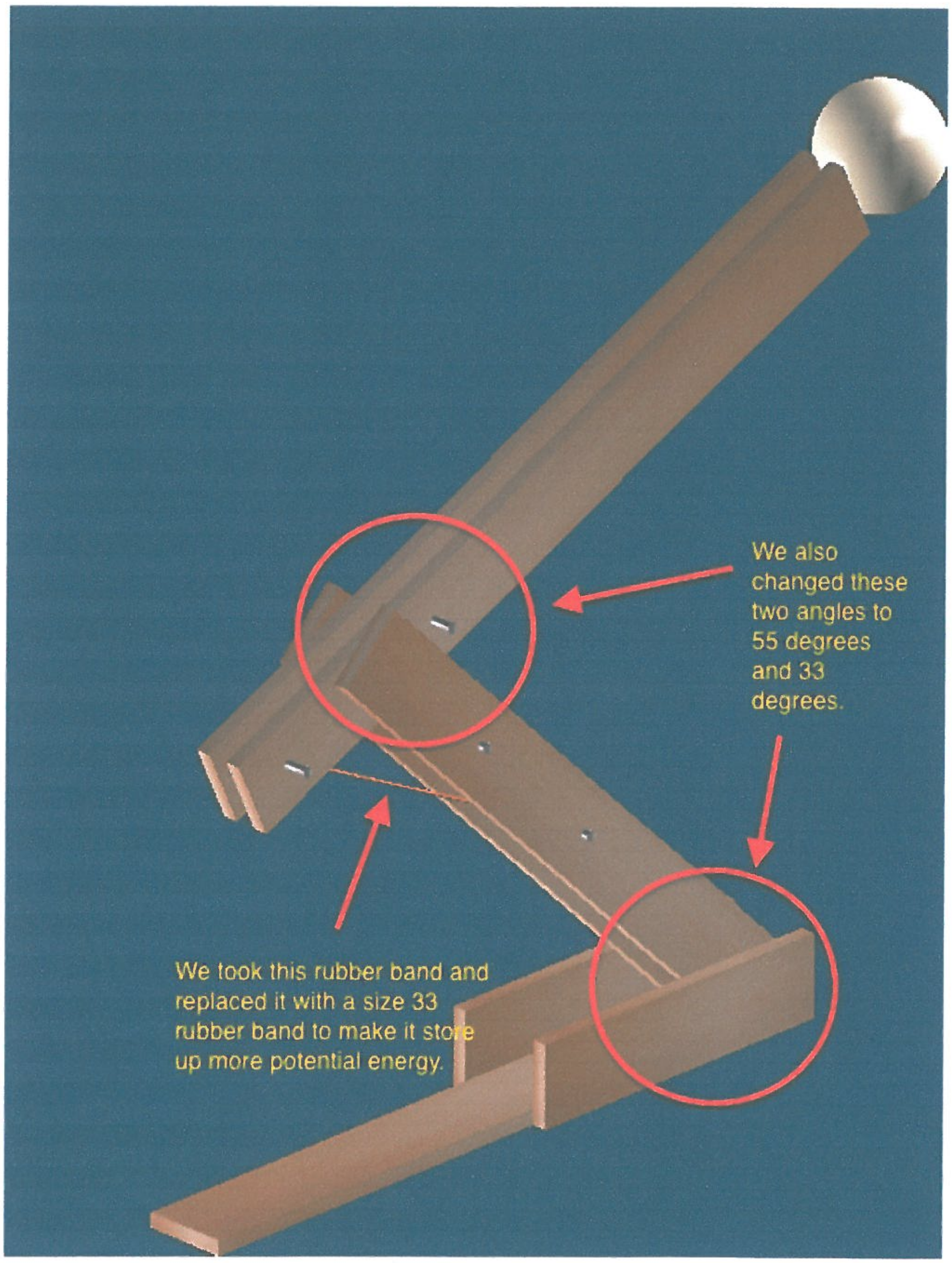
7.56 m/s

Refinement of Model:

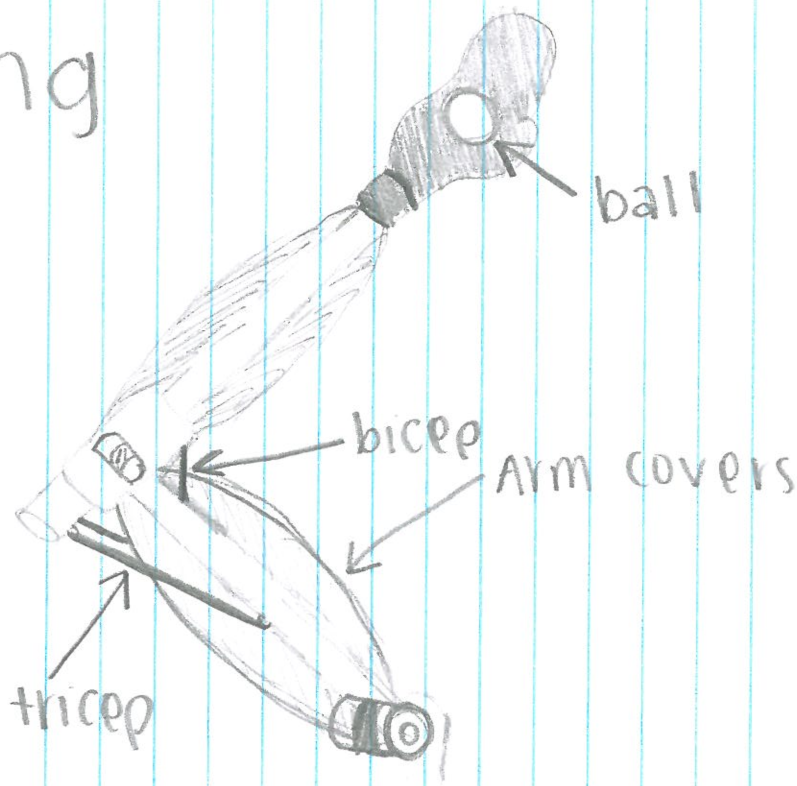
We have done a bunch of things to change our model.

These are including changing the rubber band size and then twisting it to store more potential energy.

We also changed the angles to 55 degrees and about 33 degrees.



Concept Drawing



Ballistics Prediction:

Based on what we have thrown during class period launches and based on our math, we think that our ball will go at least 4.5 meters.

Lever Identification:

Our lever is a 3rd class lever.

Post-Analysis and Reflection

During our project we had tons of difficulties.

While in the engineering process on the computer we had trouble getting everything by just trial and error, this was when we were not partners yet. Doing this each of us kept getting less than two meters so we decided to put our heads together. This is where we put each of our good ideas together.

Then when we moved in to the building process we built our arm backwards. We decided just to keep it that way since it didn't affect our distance. We had a few people comment on the way our arm was built backwards so we decided to move our launching point a little back because of the "unfairness."

In the launching process, we snapped our arm exactly four times on the same piece of balsa wood When snapped we decided to ask Mr. Franklin why it kept snapping. He explained that it might have been snapping because our rubber bands were too little to be handling that angle that we had measured. He also explained that the Tricep muscles were too strong because our metal wire kept smacking up against the wood. We thought these contributed to the continuous breaking of our arm. To solve this problem we decided to go to the scrap box and get an extra. This was because our arm looked rough.

Also during the process of building our arm we had a ton of absences. So, each day we didn't know what we were doing because either one person was gone or the other. We decided to use our own time at home to Face Time and talk to each other so we could get the job done. But, that was also a problem because every day one of s would have something going on. But we were proactive and decided to get the job done.

All of these difficulties held us back but we think that we came up with a great outcome in the end.