“Arms Race”

Prosthetic Arm

Engineering Challenge

<u>FINAL REPORT</u>

By

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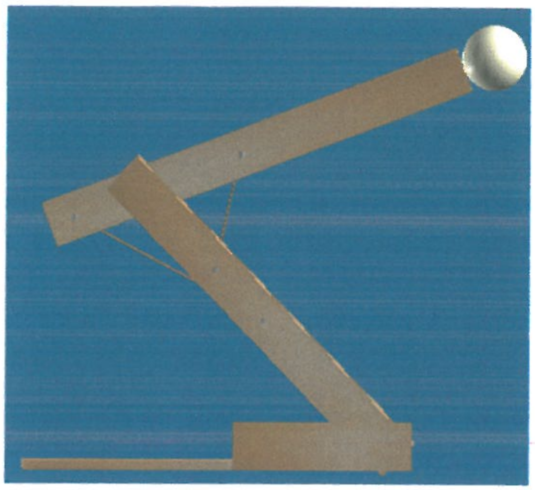
Discovery School

March, 2015

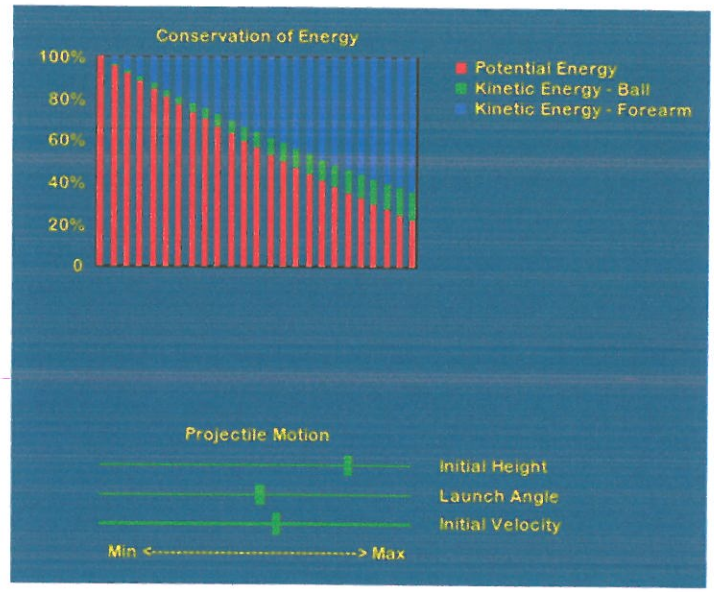
Part I. Virtual Model- Accuracy & Precision

My final model on WhiteBox was called "Eli 10"

<u>This is my final model</u>



<u>This is my data analysis</u>



<u>These are my competition results</u>

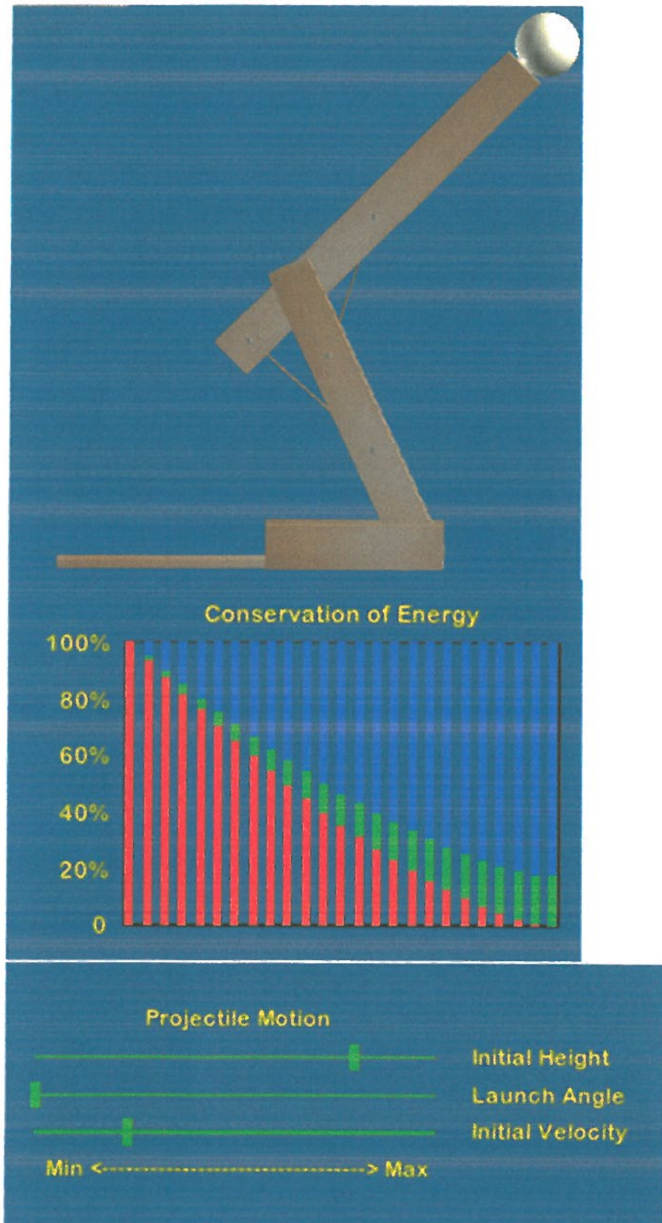
	Eli 10
	Hebron MS
Target Range	7.50
Actual Range	7.50 m
Distance (Miss)	0.00 m
Specifications	IN SPEC

<u>This is a table of my specs</u>

Design Inputs	Minimum	Maximum	Designed
Arm Length	150 mm	225 mm	225.0 mm
Arm Angle	45 deg	65 deg	46.0 deg
Forearm Length	200 mm	250 mm	250.0 mm
Pullback Angle	--	85 deg	69.2 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	60.0 mm
Arm Bicep Handle Offset	15 mm	60 mm	60.0 mm
Total Material Length	--	2000	1373.2 mm
Number of Rubber Bands	--	3	3

Part II. Design Evolution

Eli 1



To start out I decided to set everything to what I thought would work well and see how far it went.

How did you know/decide/hypothesize?

With it like this, it went only 1.7 meters. That is 5.8 meters from the target.

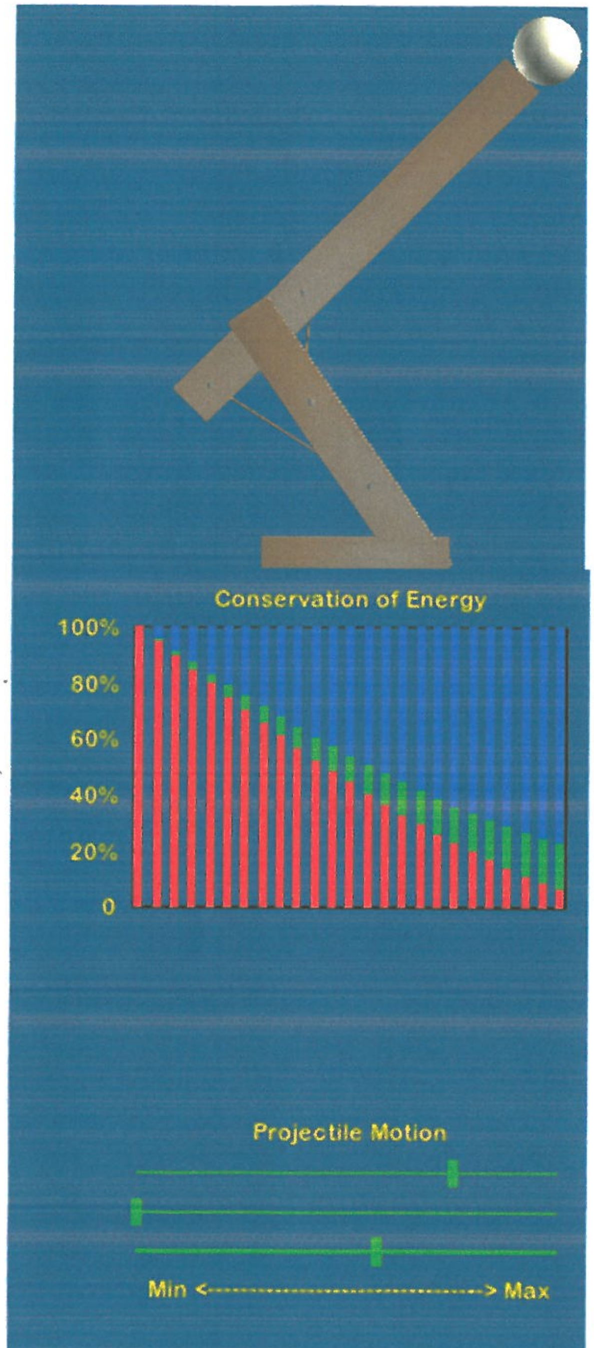
Looks like I need to change some values to make my kinetic energy go more horizontally to hit the target.

My launch angle is at the very minimum, so I will set the pullback angle to a higher value to see if that helps.

Specifications

Design Inputs	Minimum	Maximum	Designed
Arm Length	150 mm	225 mm	185.0 mm
Arm Angle	45 deg	65 deg	65.0 deg
Forearm Length	200 mm	250 mm	235.0 mm
Pullback Angle	--	85 deg	45.0 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	60.0 mm
Arm Bicep Handle Offset	15 mm	60 mm	40.0 mm
Total Material Length	--	2000	1263.2 mm
Number of Rubber Bands	--	3	2

Eli 3



On the second model I changed my arm length and angle. I upped my forearm length and changed the offsets on the rubber bands. I did however forget to change the arm angle☹.

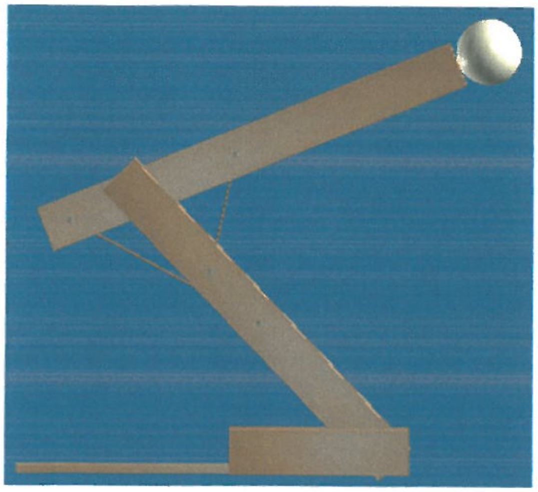
I saw a change in the energy graph which made it lower but the arm threw ball farther, but I was still 4.96 mm off.

For the next model I will skip a lot of steps to the near end because most of the others are like this.

Design Specifications

Design Inputs	Minimum	Maximum	Designed
Arm Length	150 mm	225 mm	175.0 mm
Arm Angle	45 deg	65 deg	55.0 deg
Forearm Length	200 mm	250 mm	250.0 mm
Pullback Angle	--	85 deg	45.0 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	30.0 mm
Arm Bicep Handle Offset	15 mm	60 mm	45.0 mm
Total Material Length	--	2000	1273.2 mm
Number of Rubber Bands	--	3	3

Eli 9

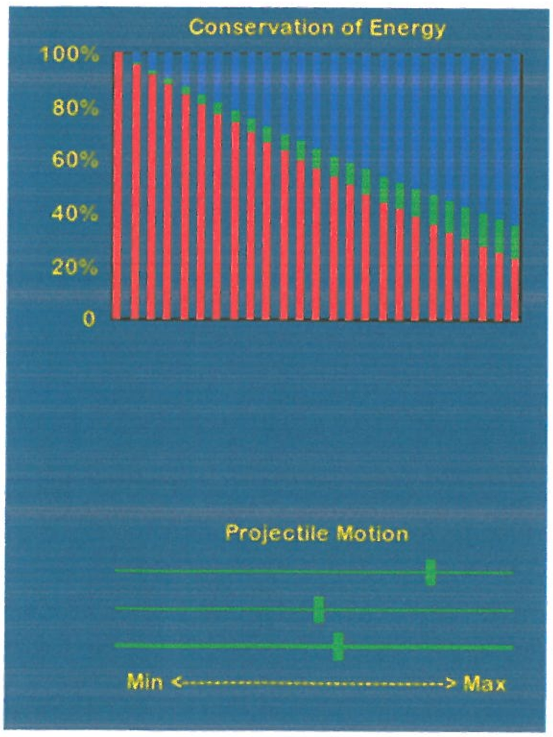


This is my second to last model and it goes much further than all previous models.

In this on I changed almost everything. Were the others not working? Did you essentially start over, or modify previous ones incrementally?

It seemed to work well even though the energy graph showed it would do worse. The projectile motion graph shows the launch angle (middle) to be about halfway between the min and max.

To perfect it I will need to tweak just a few things to get it from 7.34 to 7.50.



Design Specifications

Design Inputs	Minimum	Maximum	Designed
Arm Length	150 mm	225 mm	225.0 mm
Arm Angle	45 deg	65 deg	46.0 deg
Forearm Length	200 mm	250 mm	250.0 mm
Pullback Angle	--	85 deg	68.0 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	60.0 mm
Arm Bicep Handle Offset	15 mm	60 mm	60.0 mm
Total Material Length	--	2000	1373.2 mm
Number of Rubber Bands	--	3	3

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.

$\sqrt{\frac{2 \cdot .07}{.00175}}$ V = 8.9 m/s

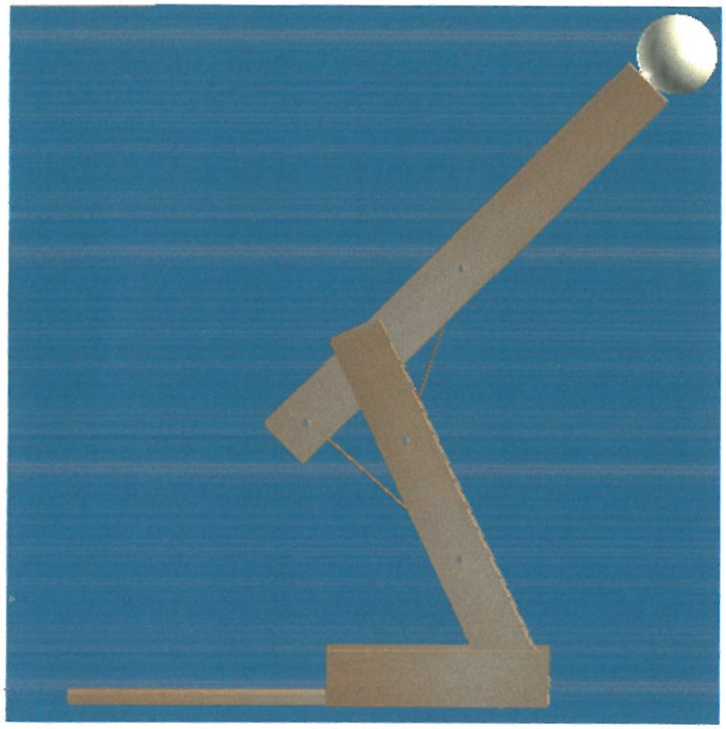
Excellent!

Velocity =

8.9 m/s

Part VII. Refinement of Model

Trial 1



To start out I built the real model exactly like the computer model to see how it worked.✓

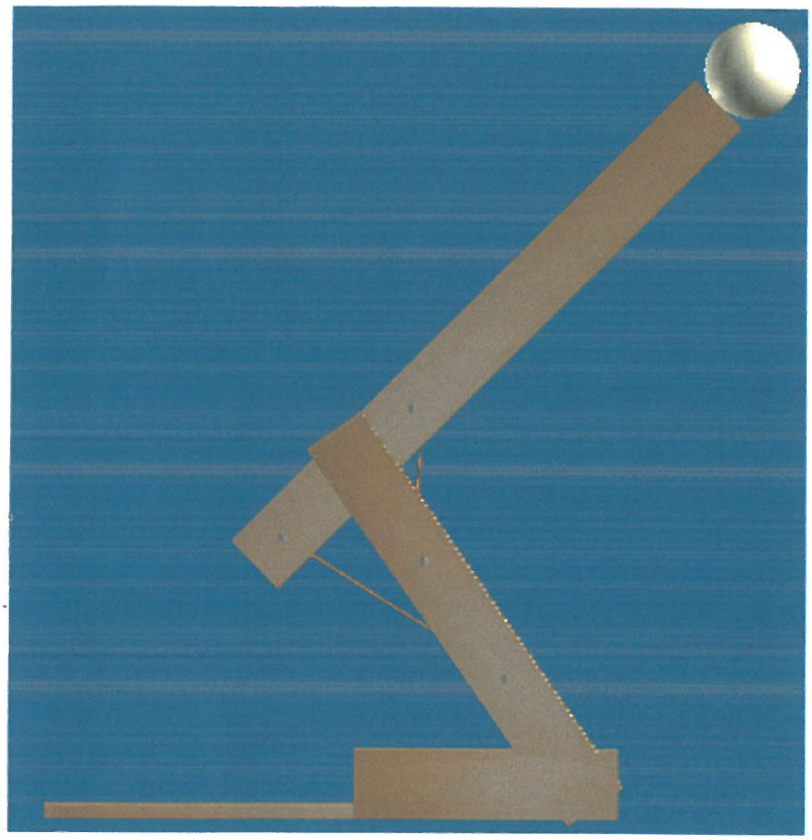
I didn't work out and all. It went about 3 meters.

Then I noticed the bicep rubber band didn't stop the arm from hitting the wood so I took off the bicep completely. ✓

NOW

1	2	3	4	5	6	7	7.5

Trial 2



On this trial I took off the bicep rubber band and saw how far it would go.

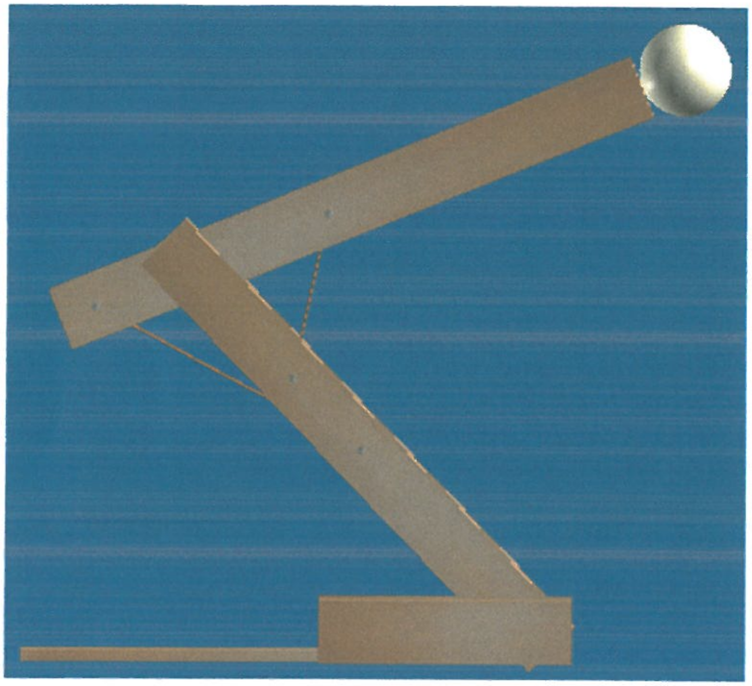
This time it went farther at about 5.25 meters, but was still 2.25 meters off.

I thought about way to modify the rubber bands and looked at other models that were built.

NOW

|	|	|	|	|	|	|	|
1	2	3	4	5	6	7	7.5

Trial 3 (Final)



For the last trial I used modifications to make the ball go farther.

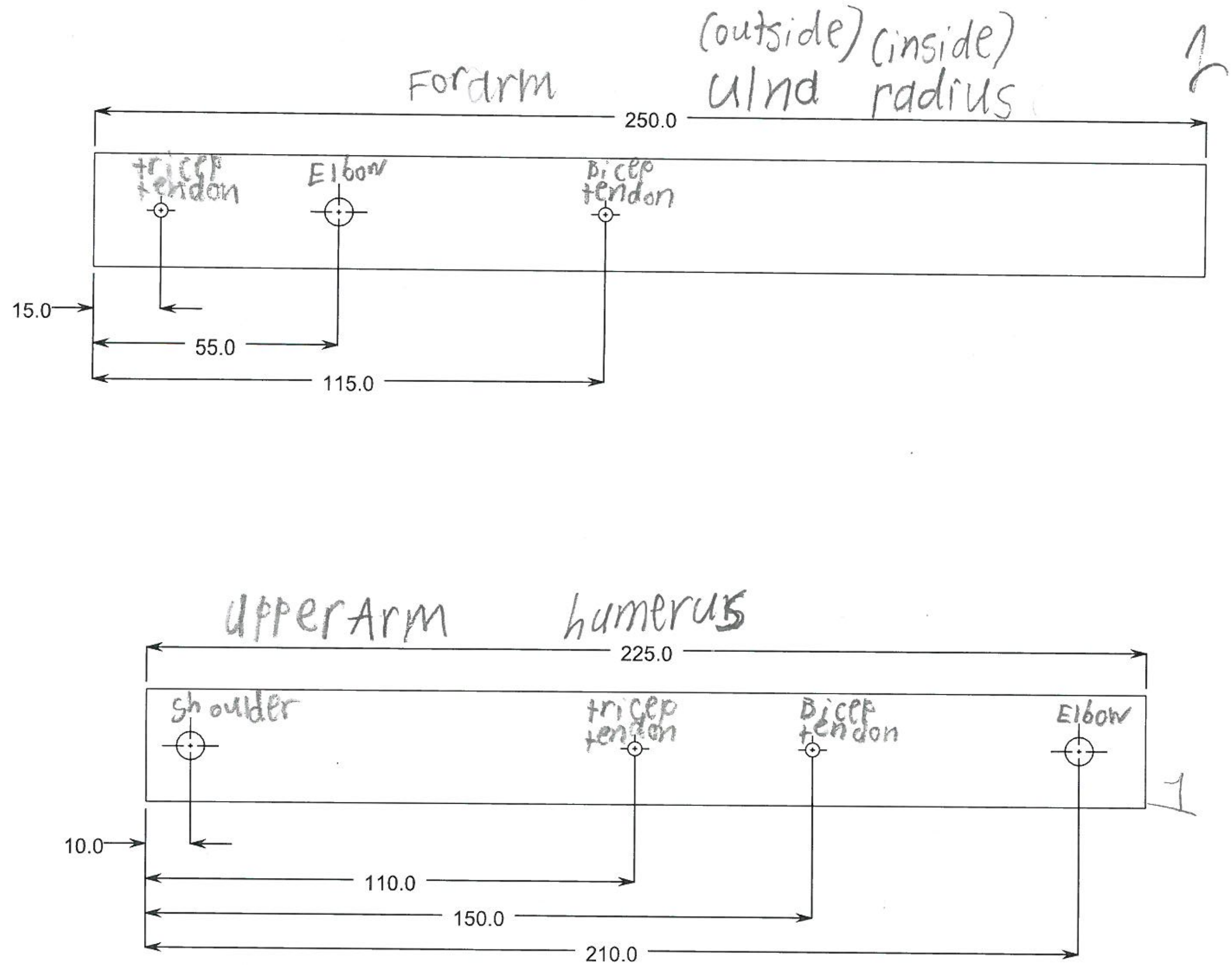
I incorporated two different techniques, twisting the rubber bands to make them shorter and folding another rubber band over the bar to make it like two.

This final adjustment landed the ball in a range of 7.5 to 8.5. Luckily I have found the exact angle to pull it to for 7.5 meters.

Why? what effect did that have?

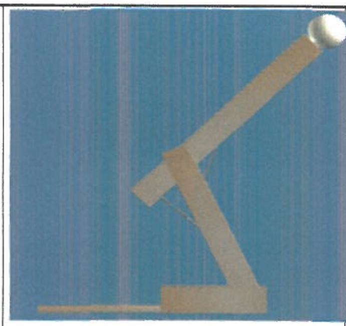
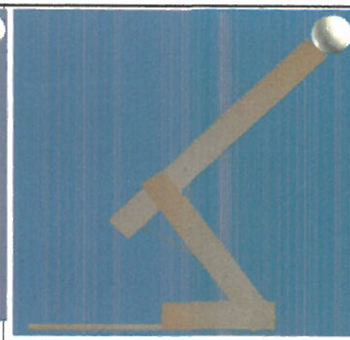
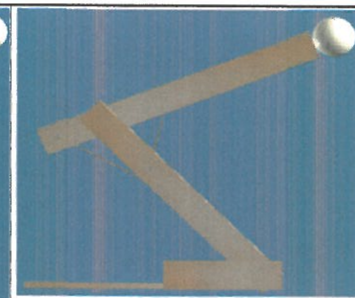
NOW!!!

1	2	3	4	5	6	7	7.5	8



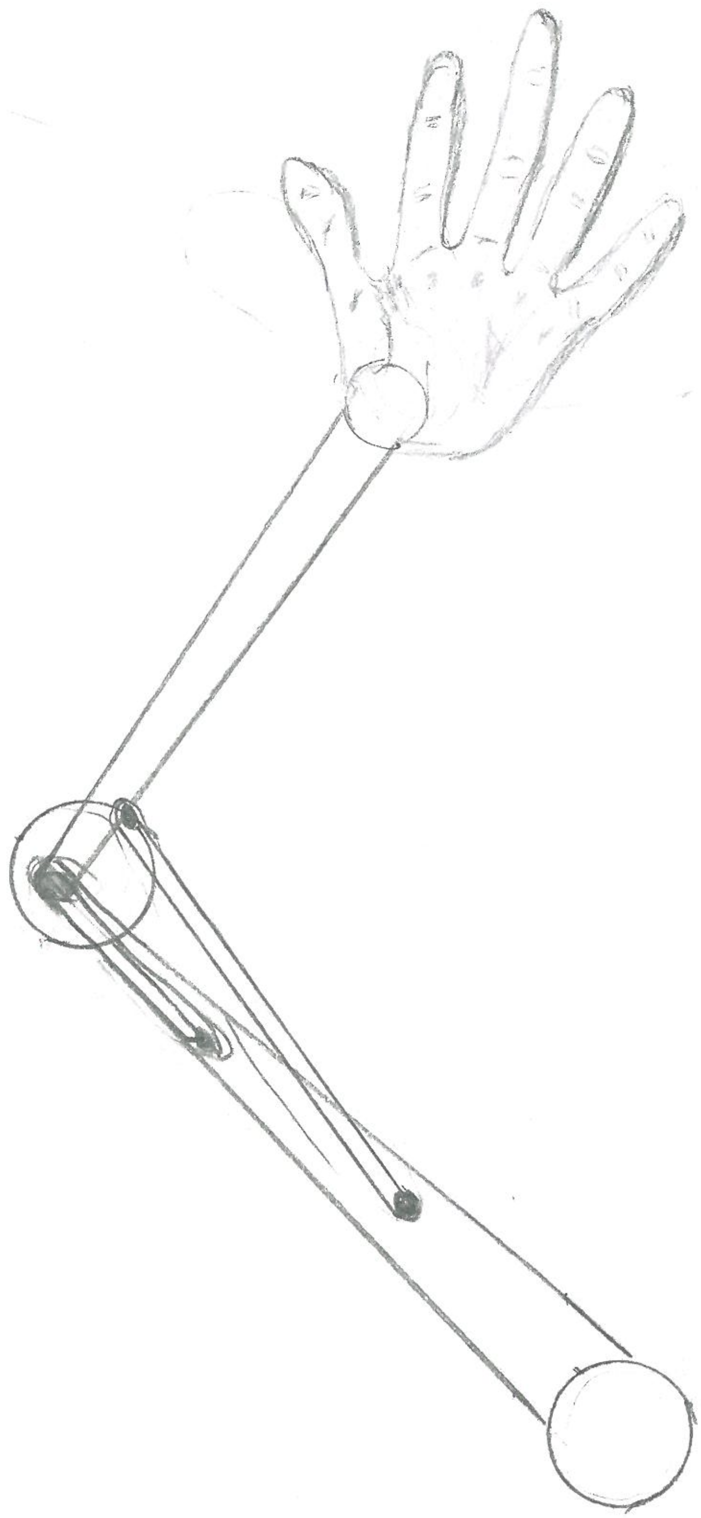
Eli Marks

Notes: Cut two arms and two forearms

				
Name	Eli 1	Eli 3	Eli 9	
Structure - Arm length	185 mm	175 mm	225 mm	
Structure - Arm Angle	65 deg	55 deg	46 deg	
Structure - Forarm length	235 mm	250 mm	259 mm	
Structure - Pullback Angle	45 deg	45 deg	68 deg	
Tricep - Forearm	40 mm	40 mm	40 mm	
Tricep - Arm	100 mm	100 mm	100 mm	
Bicep - Forearm	60 mm	30 mm	60 mm	
Bicep - Arm	40 mm	45 mm	60 mm	
Actual Range	1.7 m	4.96 m	7.34 m	
Distance (Miss)	5.8 m	2.54 m	.16 m	

I like the summary!

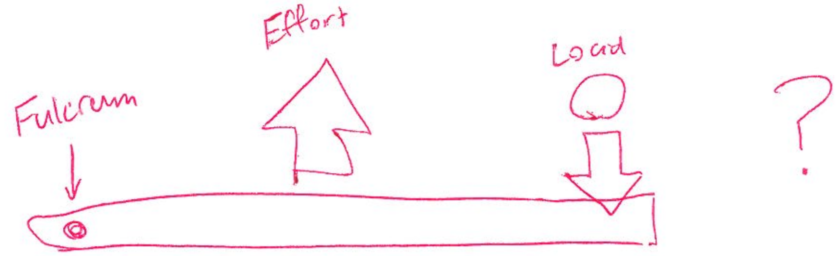
XI. Concept drawing



XII. Lever Identification

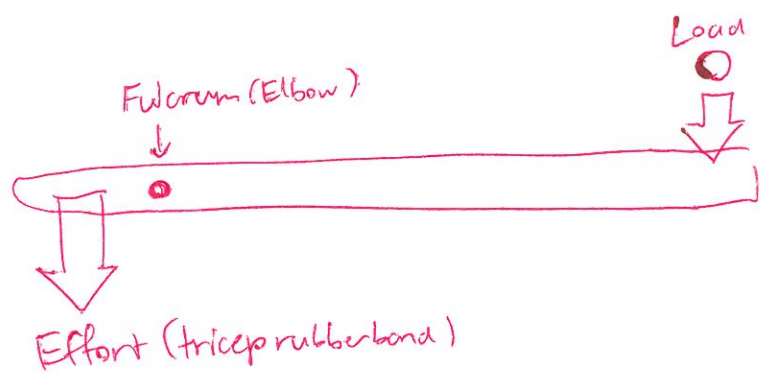
My arm is a lever because it has a load, effort, and a fulcrum. Furthermore, it is a 3^{rd} class lever because the load is on the end, the effort is in the middle, and the fulcrum is on the other end.

So...



What is pulling "up?"

Rubber band is pulling down (tricep)



Effor - Fulcrum - Load = 1st Class Lever