Arms Race
Prosthetic Arm

Engineering Challenge

Final Report

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Discovery School

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PART I. Virtual Model – Accuracy & Precision

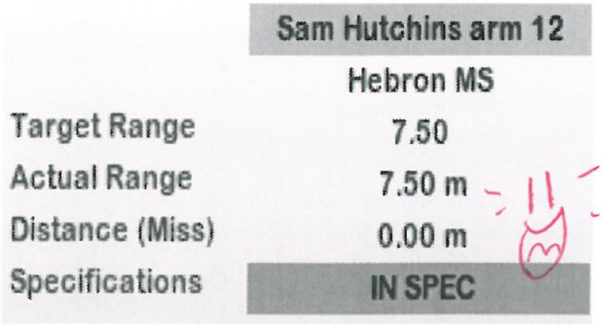
The Virtual model that I am using for the "Arms Race" competition is called:

"Sam Hutchins arm 12"

This graph shows my model's output speculations:

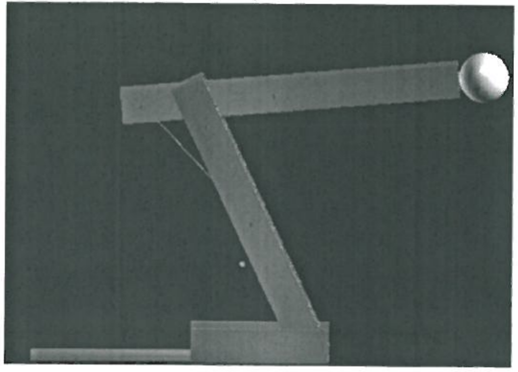
Design Inputs	Minimum	Maximum	Designed
Arm Length	150 mm	225 mm	225.0 mm
Arm Angle	45 deg	65 deg	65.0 deg
Forearm Length	200 mm	250 mm	250.0 mm
Pullback Angle	--	85 deg	85.0 deg
Forearm Tricep Handle Offset	15 mm	40 mm	40.0 mm
Arm Tricep Handle Offset	30 mm	100 mm	100.0 mm
Forearm Bicep Handle Offset	15 mm	60 mm	58.5 mm
Arm Bicep Handle Offset	15 mm	60 mm	20.0 mm
Total Material Length	--	2000	1373.2 mm
Number of Rubber Bands	--	3	3

My competition results are listed below:

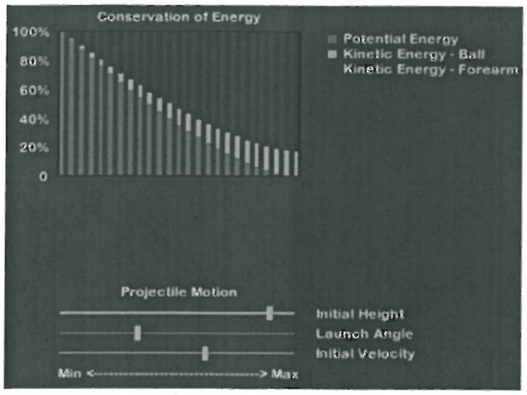


	Sam Hutchins arm 12
	Hebron MS
Target Range	7.50
Actual Range	7.50 m
Distance (Miss)	0.00 m
Specifications	IN SPEC

This is my Final Model:

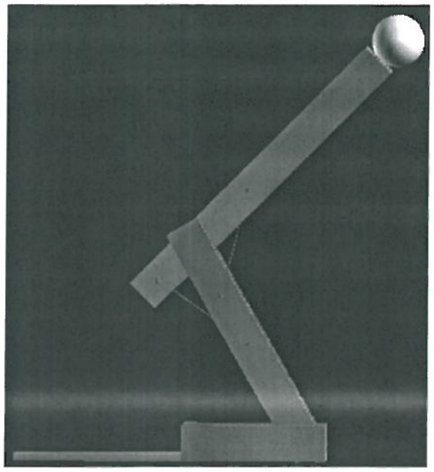


This is my Data Analysis:



PART II. Design Evolution

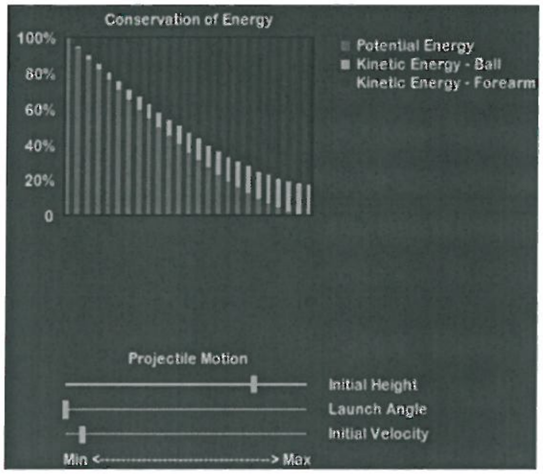
Model 1: “Sam Hutchins arm”



For this model I really did not know what I was doing. It was sort of my “mess up model”. I say this because I did not quite understand what everything meant and ~~did~~ this caused many issues. This one Mistake allowed me to be able to make better designs in the future.

That's right! Trial and Error! Sometimes the best way to learn how something works is to jump right in!

In the competition the ball went .5 meters and it missed by 7 meters



?

As you can see on the diagram That I less Kinetic Energy than Potential Energy which is not good because you want the most kinetic energy because it makes the “arm” faster when it is released.

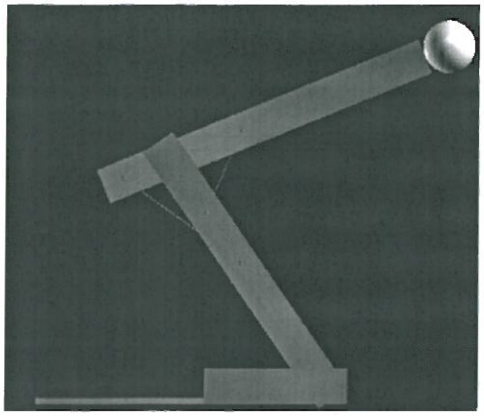
Also, there is not much kinetic energy for the ball.

What I want to do is make The Kinetic Energy more than Potential energy in my next design. ✓

Design outputs:

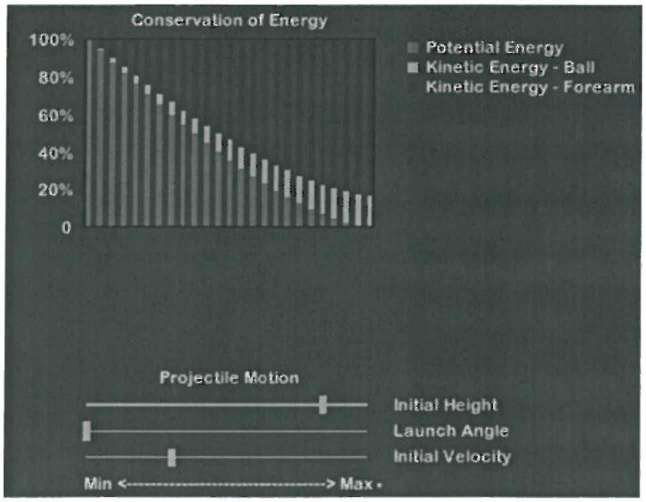
Design Inputs	Minimum	Maximum	Designed
Arm Length	150 mm	225 mm	185.0 mm
Arm Angle	45 deg	65 deg	60.0 deg
Forearm Length	200 mm	250 mm	235.0 mm
Pullback Angle	--	85 deg	45.0 deg
Forearm Tricep Handle Offset	15 mm	40 mm	35.0 mm
Arm Tricep Handle Offset	30 mm	100 mm	80.0 mm
Forearm Bicep Handle Offset	15 mm	60 mm	55.0 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

Model 2: "Sam Hutchins arm 4"



By this time I had become very frustrated on how to make the model hit the target. I thought and wondered if I had put all of the numbers in the middle of the minimum and maximum amounts it would be just right. As I had been before, I was wrong. Even though it did not hit the target it increased (this happened in my 3rd model).

In this model for example I increased my arm length as well as the Forearm length. I also decreased my arm angle to by 5 degrees. ✓



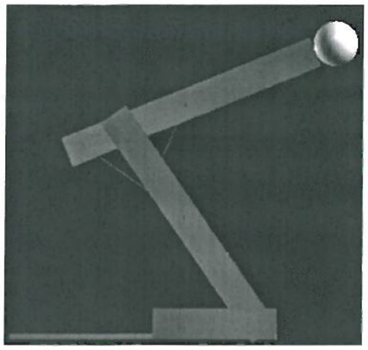
The model went 1.71 meters and missed by 5.79 meters. This model went 1.22 meters more than my first model. This showed me that the part I changed should keep the number I have it at

The velocity for my arm has increased but not by much. I need to create more Kinetic energy. ✓

Design outputs:

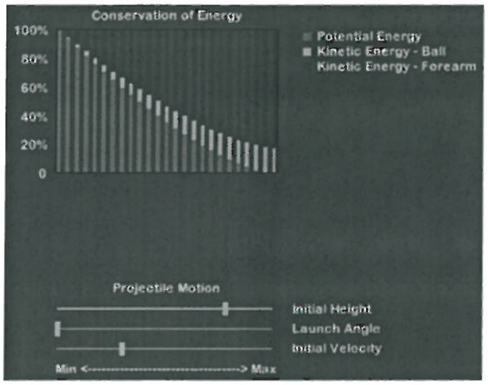
Design Inputs	Minimum	Maximum	Designed
Arm Length	150 mm	225 mm	220.0 mm
Arm Angle	45 deg	65 deg	55.0 deg
Forearm Length	200 mm	250 mm	245.0 mm
Pullback Angle	--	85 deg	68.0 deg
Forearm Tricep Handle Offset	15 mm	40 mm	35.0 mm
Arm Tricep Handle Offset	30 mm	100 mm	88.0 mm
Forearm Bicep Handle Offset	15 mm	60 mm	55.0 mm
Arm Bicep Handle Offset	15 mm	60 mm	45.0 mm
Total Material Length	--	2000	1353.2 mm
Number of Rubber Bands	--	3	2

Model 3: "Sam Hutchins 8 arm"



This model I decreased the forearm by 25 millimeters. Why? But, in model 6 and 7 I had gone through and maxed all of the measurements and then decreased and based on how far it went I would put the best number that I had tested. This is what I was doing with the Forearm in this situation.

In this model the ball went 1.71 meters and missed 5.79 meters. This shows me that I should most likely max it out so maybe it would go farther. This also indicates that the forearm is not the problem.



Now there is a lot more Kinetic energy that will make the ball go farther when it is thrown.

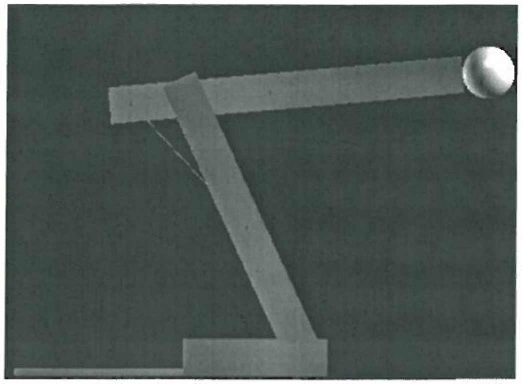
Now I will keep going up at little bits and decreasing by little amounts until I get to hit the target at 7.5 meters.

That's right. Reiterative design.

Design outputs:

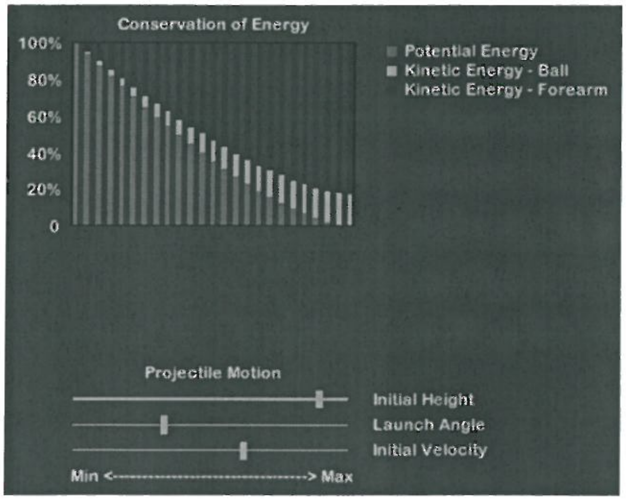
Design Inputs	Minimum	Maximum	Designed
Arm Length	150 mm	225 mm	220.0 mm
Arm Angle	45 deg	65 deg	55.0 deg
Forearm Length	200 mm	250 mm	220.0 mm
Pullback Angle	--	85 deg	68.0 deg
Forearm Tricep Handle Offset	15 mm	40 mm	35.0 mm
Arm Tricep Handle Offset	30 mm	100 mm	88.0 mm
Forearm Bicep Handle Offset	15 mm	60 mm	55.0 mm
Arm Bicep Handle Offset	15 mm	60 mm	45.0 mm
Total Material Length	--	2000	1303.2 mm
Number of Rubber Bands	--	3	2

Model 4: “Sam Hutchins arm 12”



This model which is my final model hit the target at 7.5 Meters. In this model I had maxed the Arm length as well as making the arm angle maximum. Also I maxed the forearm length and the Forearm angle. This and a few other factors allowed the arm to hit the target.

The ball hit the target dead on and did not miss at all.



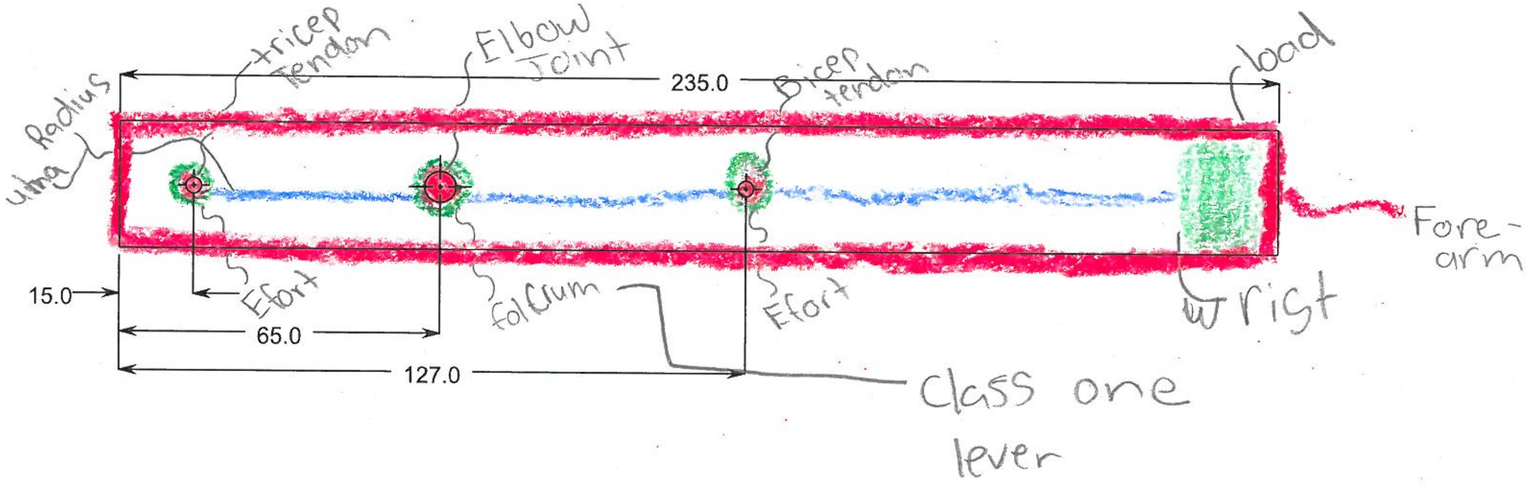
Now my Launch angle has increased as well as my initial velocity this allowed me Kinetic energy to increase and allowed the ball to hit the target. ✓

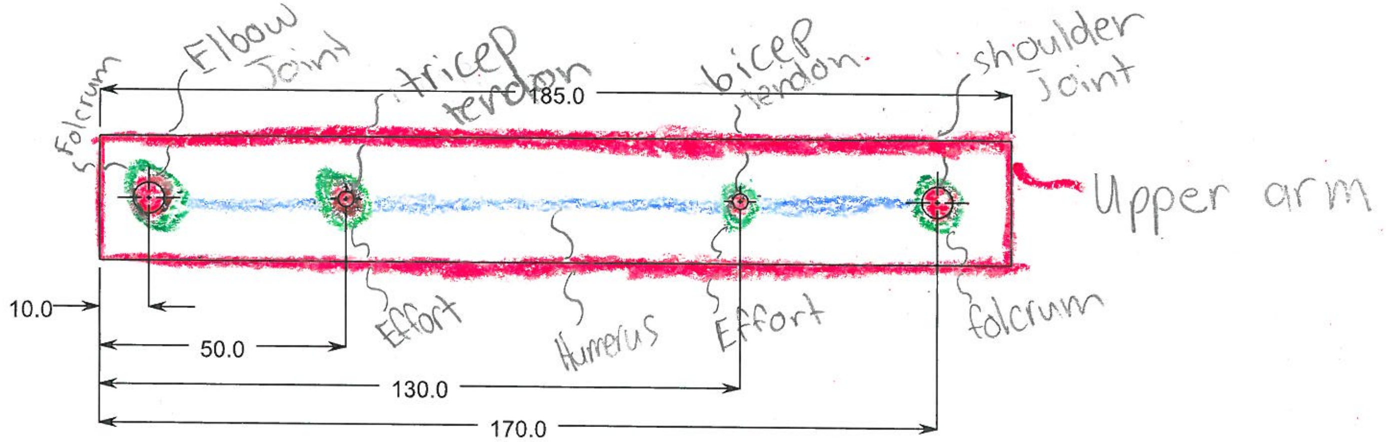
Design outputs:

Design Inputs	Minimum	Maximum	Designed
Arm Length	150 mm	225 mm	225.0 mm
Arm Angle	45 deg	65 deg	65.0 deg
Forearm Length	200 mm	250 mm	250.0 mm
Pullback Angle	--	85 deg	85.0 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	58.5 mm
Arm Bicep Handle Offset	15 mm	60 mm	20.0 mm
Total Material Length	--	2000	1373.2 mm
Number of Rubber Bands	--	3	3

Sam H.

V. Schematic Blueprint:





Looks great!

Notes: Cut two arms and two forearms

Sam Hutchins arm 12

VI. Prototype Model:

Not Written

✓

VII. Refinement of Model:

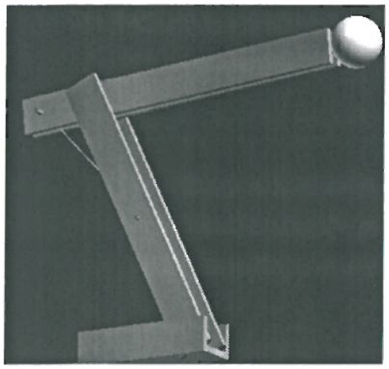
Throughout the project I have done many modifications to the model of the arm. For example I have changed the number of rubber bands on the tricep and bicep as well as changing the size of the rubber bands, I also have changed the pullback angle and the arm angle. ✓

Change 1:

The first modification I made was, changing the amount of rubber bands from two being on the tricep to three being on the tricep and having no bicep muscle. I did this because I was not hitting the target and I figured if I put more force going forward than the ball would go further. I did that and that what led to my bicep breaking so many times because there was no force stopping the tricep and the rod kept hitting the wood and it broke. ✓

Design Inputs	Minimum	Maximum	Designed
Arm Length	150 mm	225 mm	225.0 mm
Arm Angle	45 deg	65 deg	65.0 deg
Forearm Length	200 mm	250 mm	250.0 mm
Pullback Angle	--	85 deg	85.0 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	58.5 mm
Arm Bicep Handle Offset	15 mm	60 mm	20.0 mm
Total Material Length	--	2000	1373.2 mm
Number of Rubber Bands	--	3	4

(I could not set the bicep rubber band to zero that is why it says there are 4 rubber bands.) ✓



This is a picture of the model online without any bicep rubber bands and only tricep rubber bands.

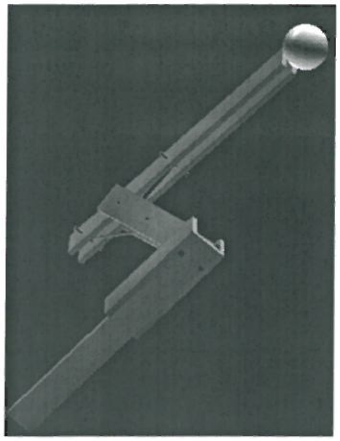
After a few more tests with the rubber bands like this I decided to take them off and have the rubber bands like they were because when they were like this they kept breaking the model.

Change 2:

After the previous change were I put three tricep rubber bands on I decided to change the size of the rubber bands. I had learned from my last mistake that I needed a bicep rubber band so I doubled a 30 rubber band (the smallest) and put it as the bicep so it would surely it would not break again. Then I doubled two 33 rubber bands and put them on as the triceps. This allowed my model to go farther than it had gone before but it did not hit the target. It missed by 1 meter. ✓

Design Inputs	Minimum	Maximum	Designed
Arm Length	150 mm	225 mm	225.0 mm
Arm Angle	45 deg	65 deg	65.0 deg
Forearm Length	200 mm	250 mm	250.0 mm
Pullback Angle	--	85 deg	95.1 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	58.5 mm
Arm Bicep Handle Offset	15 mm	60 mm	20.0 mm
Total Material Length	--	2000	1373.2 mm
Number of Rubber Bands	--	3	3

(For some reason the angle on the virtual design went up 10 degrees.)



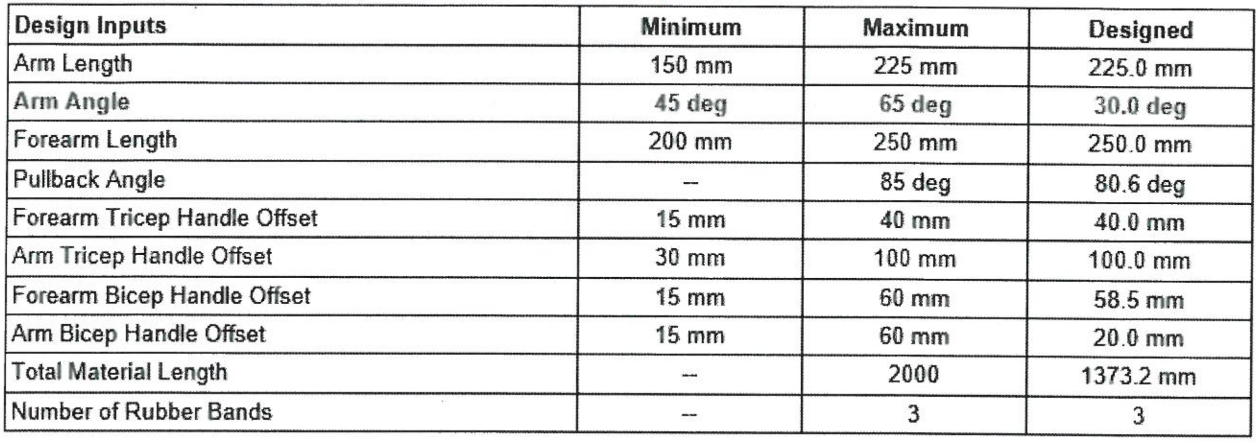
This shows a picture of the model with 1 bicep rubber band that is 30 and 2 tricep rubber bands that are 33.

I had no problems with this model other than it not hitting the target.

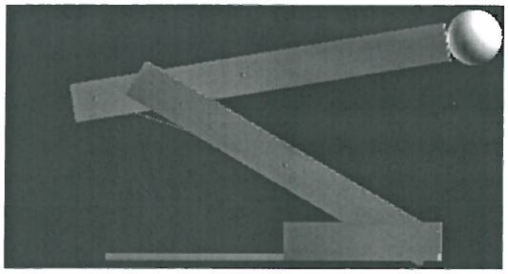
Change 3:

I then asked Mr. Franklin if we could have our our arm angle longer than the virtual design said it could be he said it was all right so I then thought about changing the the arm angle thinking it would go all the way. I thought it would hit the target so I did and all it did was go up really high and come straight back down and hit hardly went anywhere. It only went 1.5 meters and it was a bust.

(That's why they restricted it!)

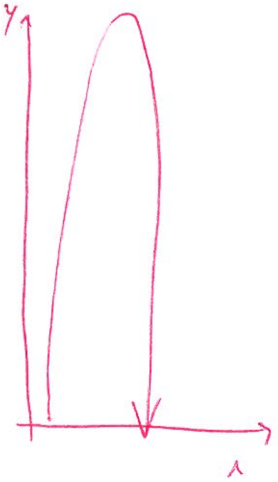


Design Inputs	Minimum	Maximum	Designed
Arm Length	150 mm	225 mm	225.0 mm
Arm Angle	45 deg	65 deg	30.0 deg
Forearm Length	200 mm	250 mm	250.0 mm
Pullback Angle	--	85 deg	80.6 deg
Forearm Tricep Handle Offset	15 mm	40 mm	40.0 mm
Arm Tricep Handle Offset	30 mm	100 mm	100.0 mm
Forearm Bicep Handle Offset	15 mm	60 mm	58.5 mm
Arm Bicep Handle Offset	15 mm	60 mm	20.0 mm
Total Material Length	--	2000	1373.2 mm
Number of Rubber Bands	--	3	3



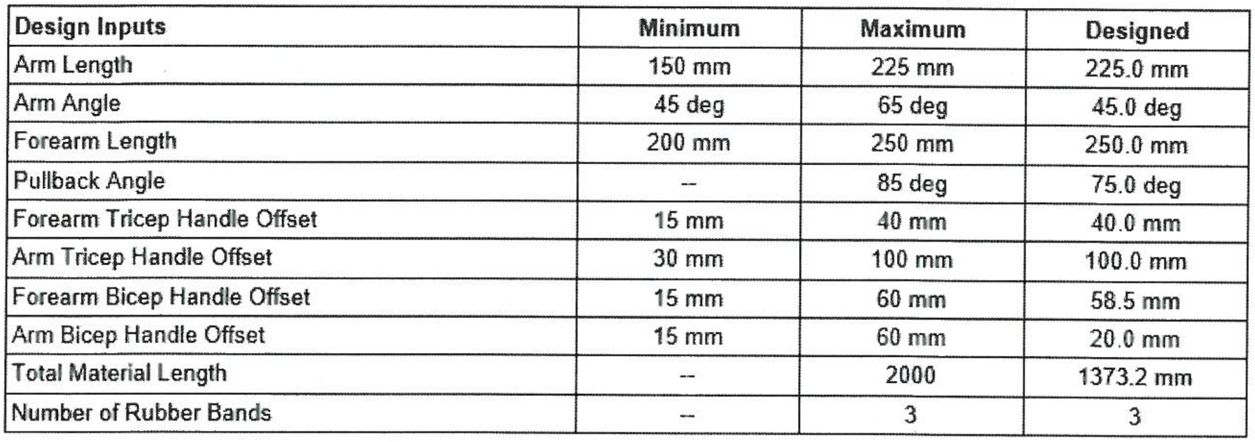
This is a picture of the model arm angle all the way (30 degree).

I had no problem with this model other than it had a huge parabola but it hardly went any distance.

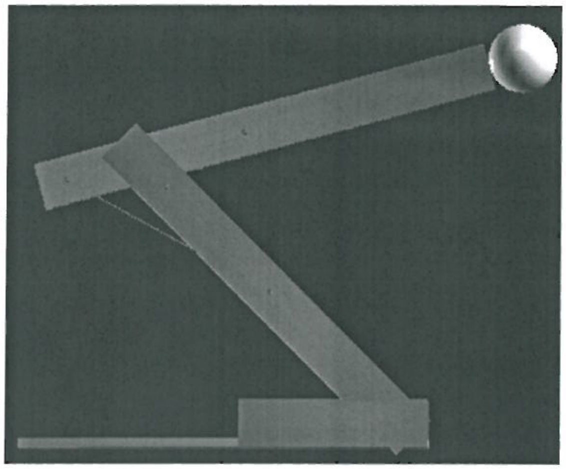


Final model change:

For my final model I had a pullback of 75 degrees and an arm angle of 45 degrees. This is the best change I made because it is more consistent and it always is really close to the target I have to shoot. ✓



Design Inputs	Minimum	Maximum	Designed
Arm Length	150 mm	225 mm	225.0 mm
Arm Angle	45 deg	65 deg	45.0 deg
Forearm Length	200 mm	250 mm	250.0 mm
Pullback Angle	--	85 deg	75.0 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	58.5 mm
Arm Bicep Handle Offset	15 mm	60 mm	20.0 mm
Total Material Length	--	2000	1373.2 mm
Number of Rubber Bands	--	3	3



This is a picture of the final model that I have.

This is the best model that I have and it has zero problems besides it does not hit 7.5 meters exactly.

VIII. Ballistics Predictions:

These are my final models outputs:

Design Inputs	Minimum	Maximum	Designed
Arm Length	150 mm	225 mm	225.0 mm
Arm Angle	45 deg	65 deg	65.0 deg
Forearm Length	200 mm	250 mm	250.0 mm
Pullback Angle	--	85 deg	85.0 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	58.5 mm
Arm Bicep Handle Offset	15 mm	60 mm	20.0 mm
Total Material Length	--	2000	1373.2 mm
Number of Rubber Bands	--	3	3

Projectile:

Practice (does not count): 7.00 Meters

Test 1: 7.25 Meters

Test 2: 7.45Meters

Test 3: 7.35 Meters

That's pretty consistent!

Average: 7.35 Meters

I can tell from these test that I am not consistent but it is good enough for the actual test. If I were to get one of these numbers in the actual trajectory test I would get full points. So I can conclude, even though I did not hit the target I will succeed on the test.

IX. Actual Trajectory:

Not Written

✓

X. Post Analysis & Reflection:

Throughout the construction and planning of my "Arm" there were many difficulties including the arm breaking during testing, cutting the wood in incorrect places, and the design not hitting the target. Also, there were occasions when the ball did not come close to hitting the target because of air resistance of the ball or the rubber bands not having enough tension to allow the ball to go farther. In the design stages I would have too much potential energy as opposed to kinetic energy. These are some of the few problems I came across in the designing, construction, and testing for my "Prosthetic Arm".

When I had started the design of my "Arm" I really did not know what was what and what it did. This led to my first mistake because I thought I had went 7.5 Meters (which is how far I had to through the ball) hut it was actually the opponent that went against me. By this time I had already started building my arm and had started building the bicep. Once I had realized this it was too late I had already drilled the holes and the only thing I could do was go back to the designing stage and make the ball hit 7.5 meters.

Already building?! Really? oh no!

After I had Perfected my online design it was back to building. Since I had only had limited pieces of wood I had to make do of what I had and what I had to do was use the piece of wood I had (thankfully they were the same size in length) already drilled the holes in for my bicep. Everything was working out all my wholes were not close to the ones I had already drilled but one. They were 5 centimeters away from each other and I feared that when I drilled the new hole the wood would crack between the two holes. I drilled it anyways, and what happens it cracks. I was trying to find a solution and Mr. Franklin suggested that I put glue in the whole that I did not use. So I took his advice and I did that. It worked!

That Mr. Franklin sounds like a smart guy...

The next challenge that I faced was my bicep (on my "arm") braking 3 times. The first time it had happened I just made a new one, the second time I glued it back together, the third time that it had happened I realized that the metal piece, where the triceps rubber bands connected, was bashing into the bicep. What I did was make the metal piece shorter. This would allow the metal piece not to hit the bicep. Another incident was when the base, which acted like the shoulder, the wing nut, which held the bicep on the base, had worn its way through the piece of wood. This time I just made another base.

Yep.

If the physical design does not match the virtual design perfectly then it would not have the same outcome because n the virtual design the conditions are most likely no wind or not precipitation. When we are at school there will be air conditioning and it could factor in to where the ball will go. Also, if your holes in your arm are off a little bit to it "identical" piece the metal rod will be slanted. Some concepts one can learn from this is that to always check multiple times that you are correct before you do something. Look at my example, I thought my ball had hit 7.5 meters but actually I did not read it correctly. Also, someone can learn how to learn from their mistakes because through the mistakes that I had made I was able to fix my problems. For example, my arm's bicep kept braking in the same place and I realized that the metal rod was hitting it.

Through my mistakes I was able to create my prosthetic arm prototype.

Great work, Sam. !!

XI. Concept Drawing

Sam Hutchins

Key

🟨 = prosthetic covers

🟪 = Shoulder Joint

🟥 = Hand

🟥 = elbow joint

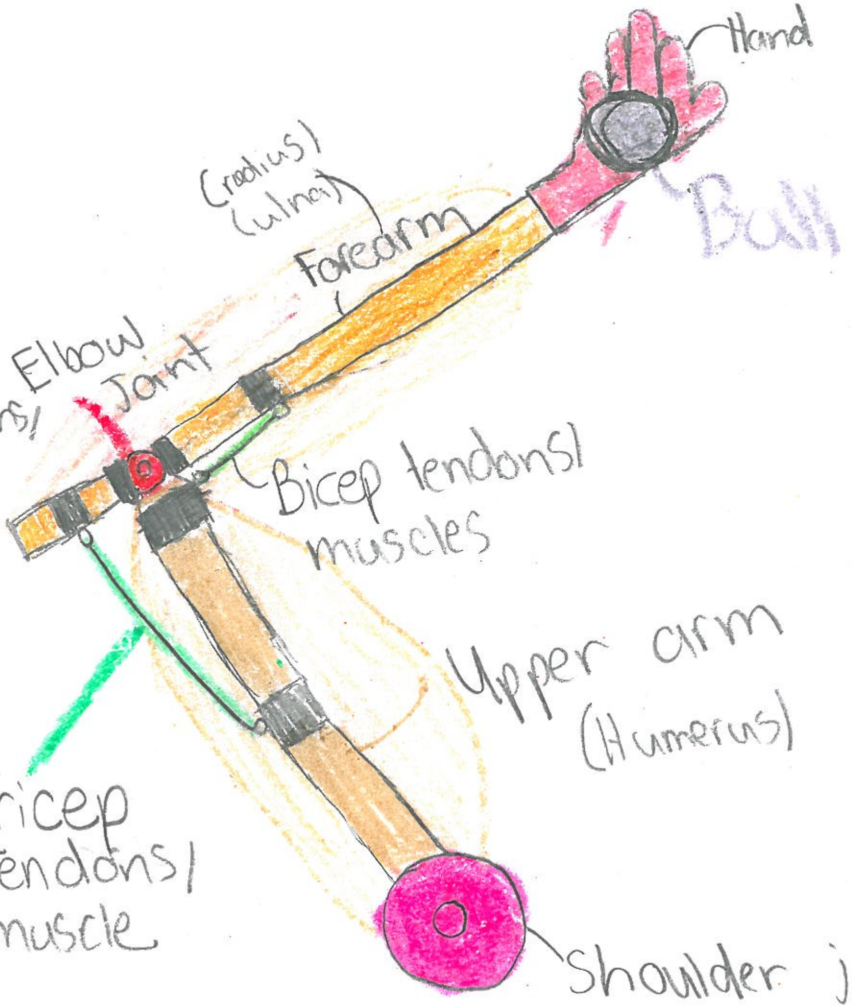
🟨 = Upper arm (Humerus

🟩 = Tricep tendons/ muscle

🟩 = Bicep tendons/ muscle

⬜ = Ball

🟧 = Forearm (radious + Ulna)



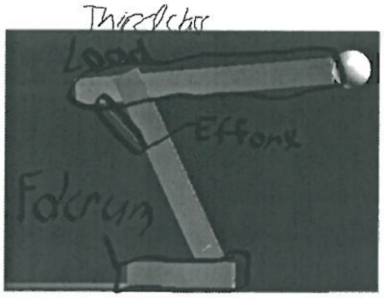
Awesome!

XII. Lever Identification:

In the model of my “Arm” there are two levers each a different class of lever. There are three classes of levers and each consist of a fulcrum, load, and a effort. The fulcrum is the point where the lever rests or pivots. The load is the weight that the lever is moving and uses the effort and the fulcrum to move it. The effort is the point where the lever is given energy and creates it to move. ✓

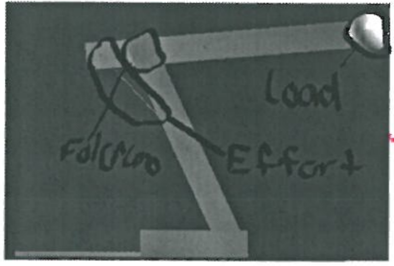
So ~~the~~ one of the levers found in the arm/prototype is a third class lever and that is a lever that has the fulcrum on the opposite end of the load and the effort in the middle of the two. I know that from the base/shoulder, of the arm/prototype, to the forearm that the shoulder is the fulcrum, the tricep rubber bands are the effort and the forearm is the load. Even though there is one lever in the arm it does not mean that there is not another one at work.

Third class



The second lever is a first class lever. A first class lever is like a seesaw and it has a fulcrum in the middle and the load on one side as well as the effort on the other side. I know that this is a first class lever because at the end of the bicep there is a hole and you had to put a crew in it to keep it attached. This would make it the pivot point because it is also the resting point. The effort is at the one of the ends and I know that it is the effort because it is creating tension and allowing the load to propel. At the opposite end of the effort there is the load, which is the Ping-Pong ball, and it is the load because it is the weight the effort is moving.

First Class



Good labeling

In conclusion, there are two levers in the prototype. A third class lever and a first class lever. Each of these levers consist of a fulcrum, load, and effort. Without these simple machines the ball would not go anywhere and stay in the arms hand. These are the levers within the prototype of the arm I had constructed.

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.

Tricep:

x= Streched - relaxed

relaxed= 7.0 cm stretched= [illegible] cm

x= 130 = [illegible] mm

$PE = \frac{1}{2}NKx^2$ $1000\overline{)44.73}$

$PE = \frac{1}{2}(2)\cdot(35)\cdot(.049)^2$

PE = .07 joules

$PE_{pullback} = 0.07 - 0 = 0.07$

PE launch = 0

Work = 0.07 - 0 = 0.07

Great!

Work =

0.07 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.

$KE = 1/2\, mv^2$

Work = KE final − KE initial

KE initial = 0

Work = KE final = 1/2 = 1/2 mv^2

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

$mv^2 = 2 \cdot work$

$v^2 = \frac{2 \cdot work}{m}$

$V = \sqrt{\frac{2 \cdot work}{m}}$

$V = \sqrt{\frac{2 \cdot .07}{0.00175}}$

mass of Ball in Kilo

V = 8.94 m/s

Very nice!

Velocity =

8.94 m/s