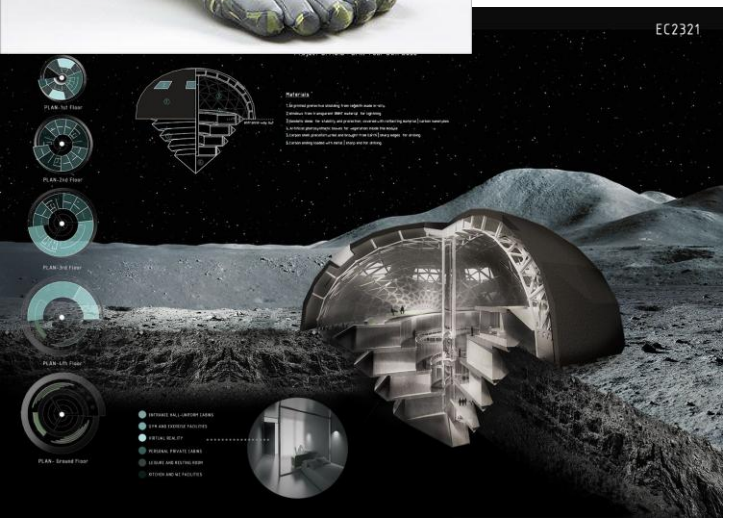
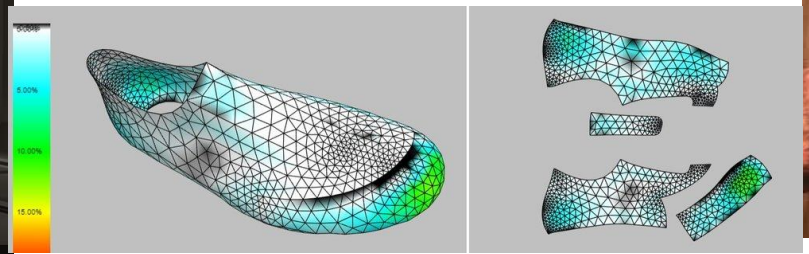
Lunar Habitat Shoes

Glenn Johnson

What kind of shoes are needed for the inside of the lunar habitats that will give good traction in **low gravity** without generating static electricity? What kind of flooring will be flexible yet durable and cleanable and provide good traction for the shoes?



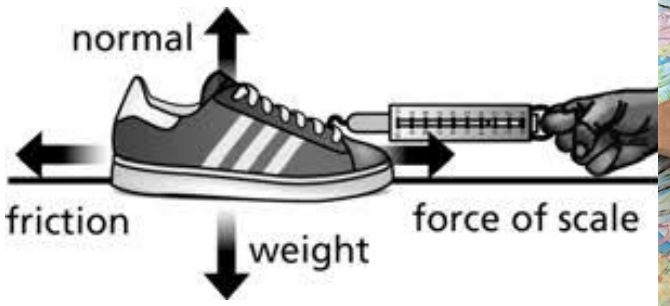


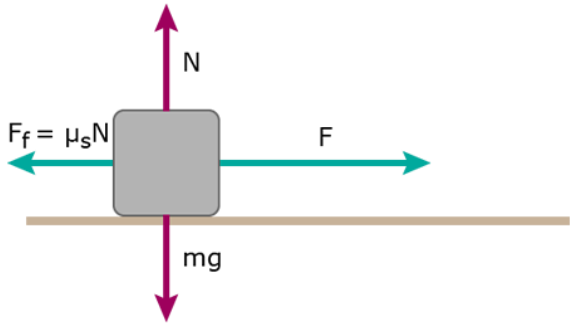
Why lunar habitat shoes?

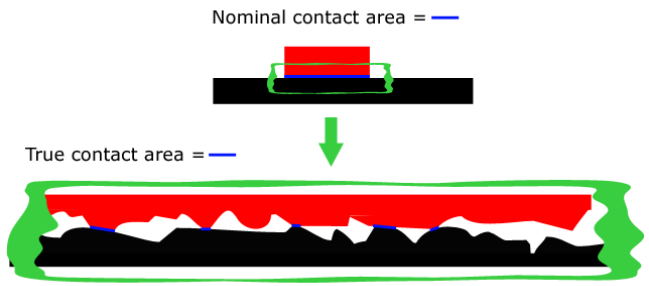
While on the moon, the astronauts will walk around in space suits with specialized work/hiking boots for their Lunar Space walks. However, when they come inside and remove their space suits, they will want (need) to wear more than socks while in their habitat. Less weight from the lower lunar gravity will also mean less friction. $F_f = \mu mg_{moon}$ where $g_{moon} = 1.62\ m/s^2$. This means that if you weigh 150 pounds on earth, you will only weigh around 25 lbs on the moon and that you will have only about 1/6th as much friction for pushing yourself around as you walk (or maybe bounce) around the lunar habitat. This will have some similarities to when you are trying to walk around in a pool where you have some buoyancy picking you up and having difficulty with friction to push you forward.

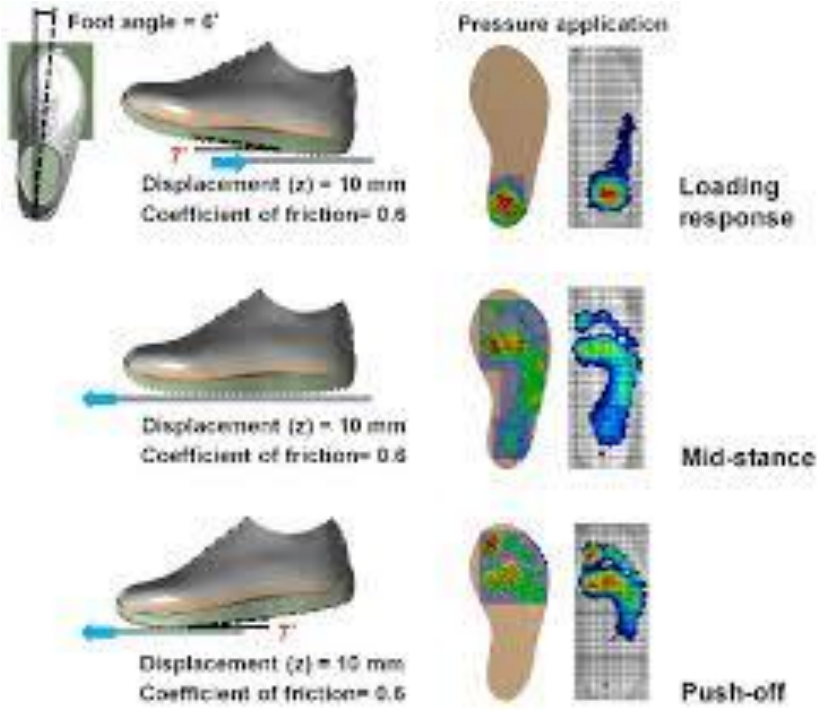
Because we expect it to be a very dry environment, it may be very prone to static electricity. This will be bad for any moon dust that gets inside with the space suits as the dust is more like shards of glass than rounded sand particles. Static electricity may make the dust cling to equipment, the walls, everything. Static electricity could also be an ignition source so things sent to the moon should also be as non-flammable as possible (similar to the Space Station).

This shoe may also be valuable in the Mars habitats that will be similar to the lunar habitats. The walking surface we use in the Lunar and Mars habitats would probably very similar to those used in the space craft that are rotated to simulate gravity for long missions like going to Mars. This just means there are a few specific places these shoes may have value.









Lunar Habitat Shoes

Problem:

The Lunar habitat will be a fairly unique location where NASA may need a specialized shoe to aid the astronauts in this new environment. Because of the 1/6th gravity you will also have 1/6th friction for walking around. Static electricity sparks can cause fires. Because the lunar dust is sharp like shards of glass, the floor needs to be easy to clean.

Objective:

Develop the shoes (upper and sole) the astronauts will wear in the lunar habitat and the inside surface material of the habitat they will walk on.

Shoes for the inside of the lunar habitat

- good traction
- light weight
- No spikes or sharp edges that could damage the walking surface or puncture the inflated habitat
- nonflammable materials
- must have some kind of arch support
- easy to put on and take off
- must not build up static electricity
- good insulation from the floor but minimizes sweaty feet
- arch support
- less padding so that bones are able to receive more shock despite low weight
- Choose a flexible, cleanable material for the floor of the habitats
- While these shoes may have many similarities to many existing shoes, I'm certain that no current shoe would fit all of the astronauts' Lunar habitat needs.

Options to consider

- zippers, Velcro, laces, elastic, buttons???
- like a scuba booty/ wrestling shoe, aqua sock, slippers, <u>more than a sandal</u>
- Leather, Nomex, beta cloth

If your school has a fashion design class or sewing classes, this would be a great project for collaboration.

Do not limit yourselves to these ideas. There are many other thoughts you can consider.

Aqua socks

Slippers with traction

Scuba booties

Zippers and laces

Roofing shoes for high incline, smooth surfaces with replaceable soles

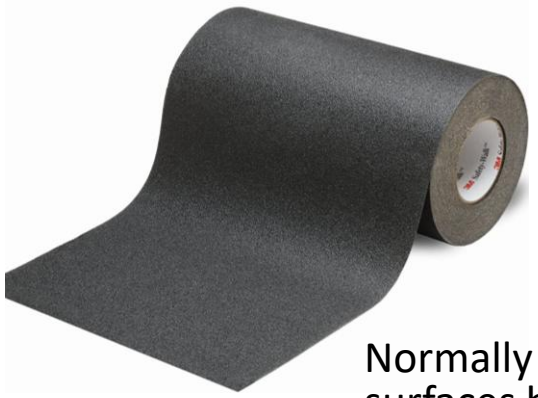
Boxing shoes

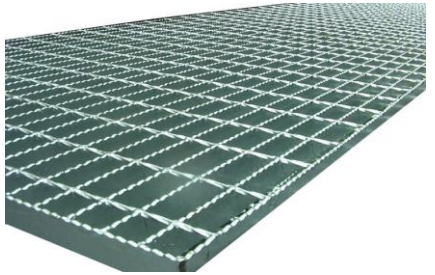
Moccasins

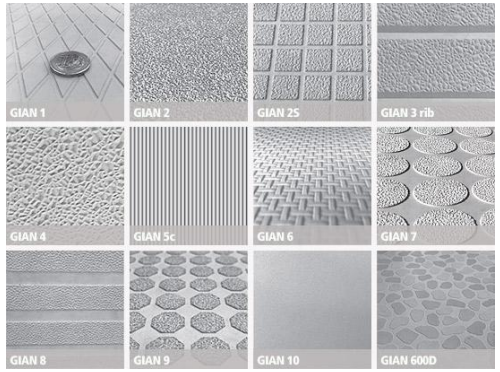
Rock Climbing shoes

Racing flats

Habitat interior walking surface





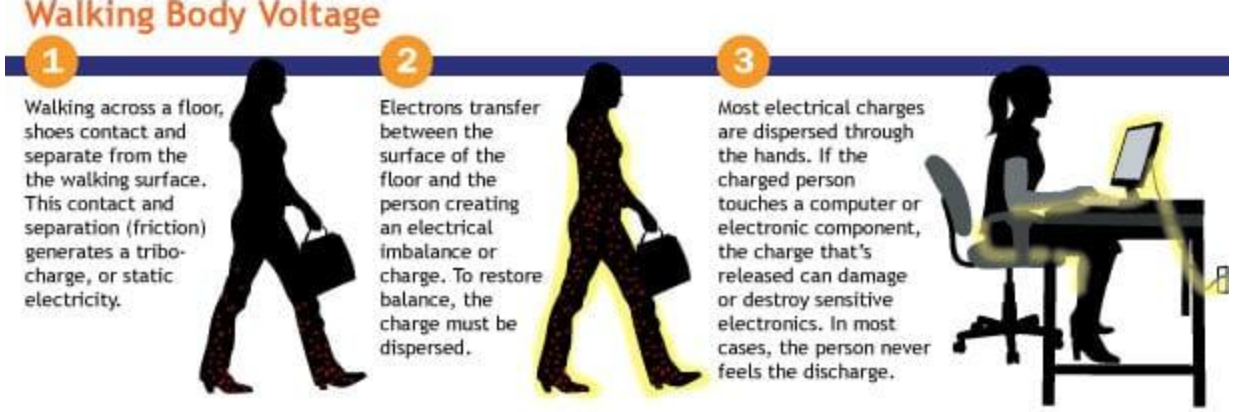


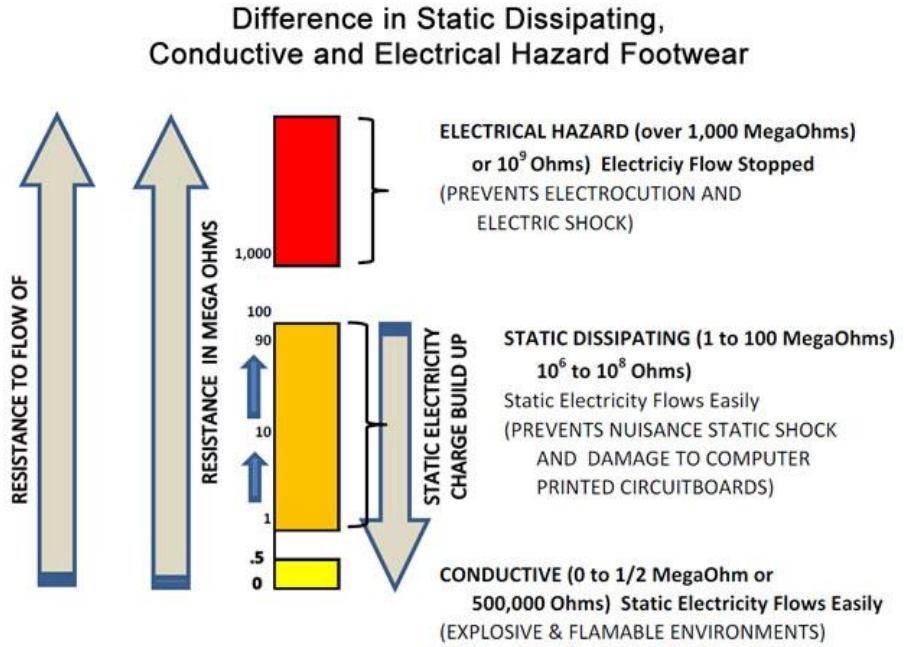
Normally when people are developing shoes they either have to design for many surfaces both inside and out or they design for a specific range of surfaces. In this case you can influence or determine the inside material for the lunar habitat. Assume the astronauts will rake the surface soil smooth and remove any big pointy rocks before they place the habitat on the ground and inflate it.

- durable so it won't wear out quickly or scratch off leaving dust and grit.
- easy to clean with brushes or vacuum cleaner. There may be something like a Roomba that will help control dust in the habitat.
- light weight so it doesn't add too much weight to the habitat
- nonflammable materials
- must not build up static electricity in conjunction with the shoe
- good insulation properties
- Will the surface be hot or cold for the people living in the habitat?

Static Electricity

- We should expect that the temperature and humidity on the lunar base will probably be similar to that on the ISS—70 degrees F and around 40% humidity. That is fairly dry and will allow significant static electric build up. Computers and electronics can be damaged by static electricity generated by walking across the room. Static electric sparks can also be cause fires if they happen in flammable materials. As much as NASA works to prevent fires by using nonflammable materials, there will always be some materials like plastic bags, paper, and even hair from people. Some of this can be controlled by choosing materials for the floor and the shoes. This may take a little searching and some testing.





What kind of sole do you want to make?

TPU or ninja flex for 3D printers give you lots of options to print out a flexible sole that fits your ideas.

Something else?

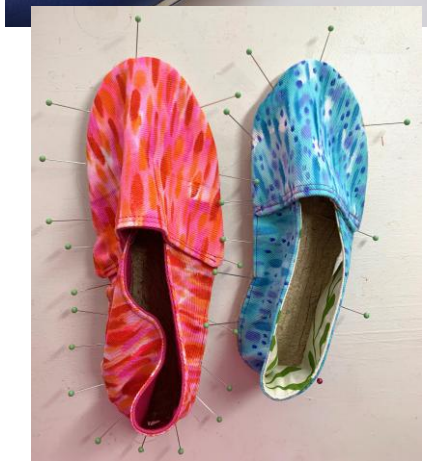
These are the replaceable soles for roofing shoes that Velcro onto the bottom of the work boot.

Steal from an existing shoe—purchase from the internet or take it off another pair of shoes

I do not expect you to make the shoes out of the same materials as would be used on the moon nor will they be exactly like the ones that fly. **You should be able to demonstrate some of your ideas with your prototype and tell the materials that should be used.**

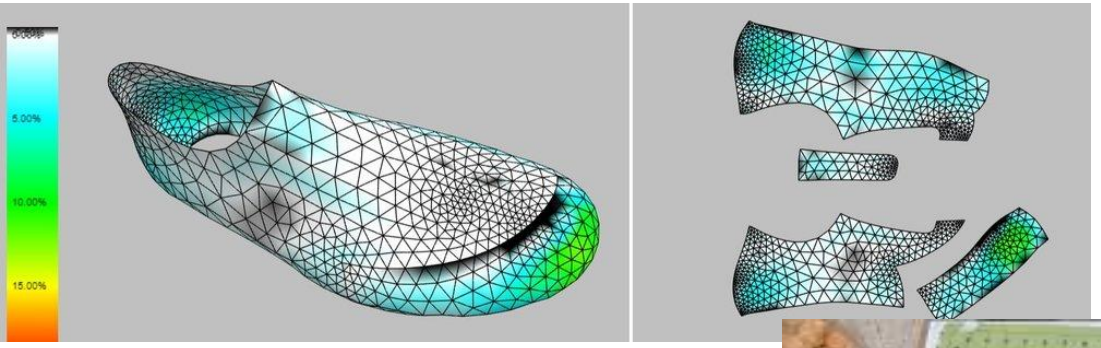
Shoe Goo can be used to make a flexible sole for your shoe with good traction

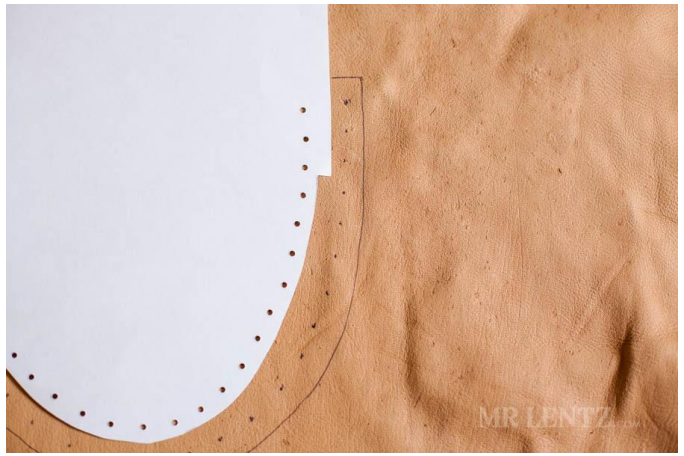
I put some silicone caulking on some cling wrap and put it on the cold waffle iron and let it cure into the waffle shape. No need to close the waffle lid. You could also make a mold with a 3D printer and make the sole out of silicone caulking or Shoe Goo. Many options for how to make the sole of your shoe.

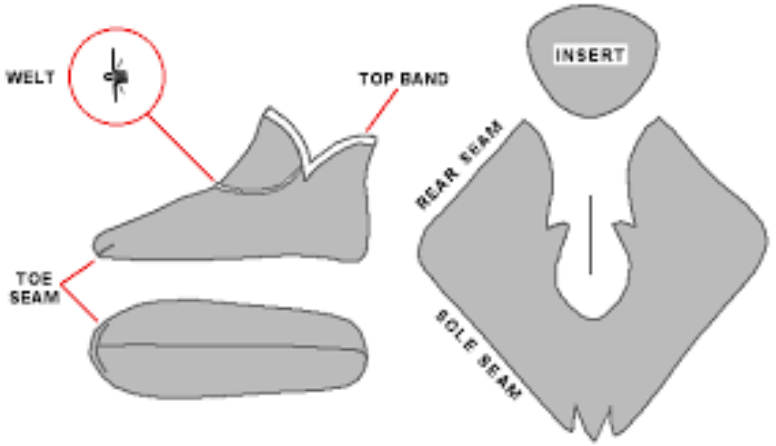


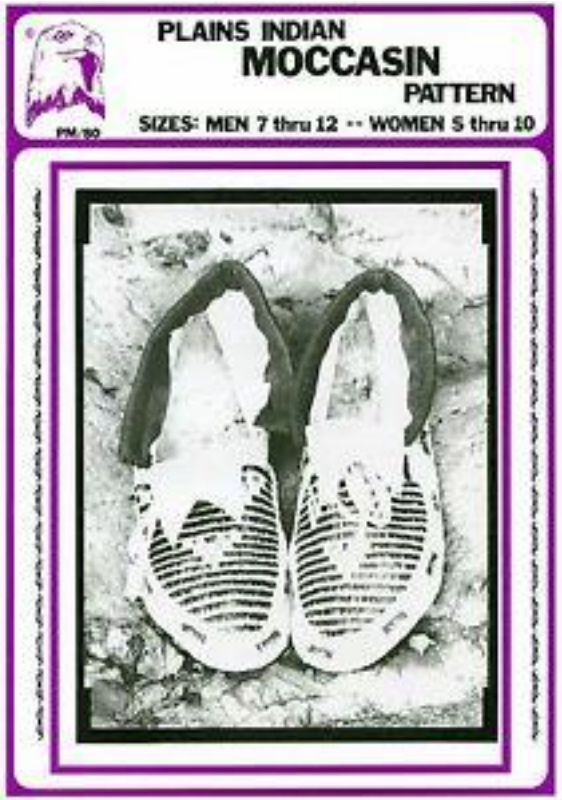
There are several shoe kits available on the Internet so you can make your own shoe with your style. You can start with their pattern and make your own sole. There are many options for how to make shoes you can wear and test out.

Shoe patterns









Tutorial for making a shoe pattern
https://www.youtube.com/watch?v=huL9Fg4zXN4

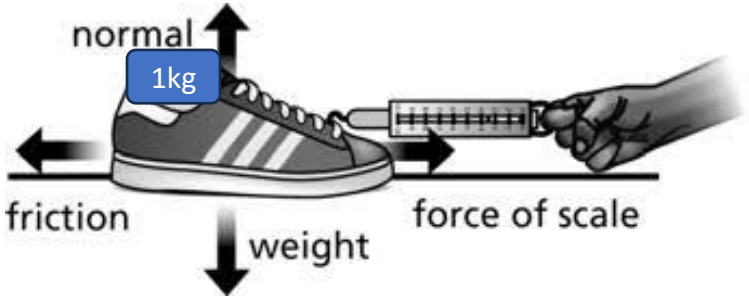
Testing-- This would be a great time to talk to a Physics teacher at your school.

- Just like the shoes you are wearing today give you more or less traction on different surfaces, the flooring material you choose for the inside of the habitat will provide a specific amount of friction for your shoe.
- I want your team to measure the coefficient of friction (kinetic and static) between your shoe sole and the material you choose for the floor when there is 1 kg of weight sitting on the ankle of the shoe spreader.

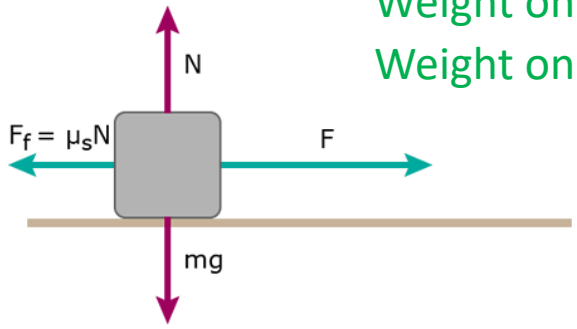
1. Place your shoe on the appropriate flooring sample.
2. Install a shoe spreader that has a heal.
3. Place 1 kg of weight on the ankle of the shoe spreader.
4. Use some kind of force measuring tool (spring scale, digital scale,…) to measure horizontal force of friction while shoe is being pulled across the flooring material.

- How much force does it take to start the shoe moving?
  - Static friction—force required to start the shoe to move
- How much force does it take to pull the shoe once it is moving?
  - Kinetic friction—force required to keep the shoe moving at a constant rate (not accelerating)
- We are mostly interested in the static friction since we are hoping the astronauts are not sliding around.
- Is there a difference between forward or backward forces (could be due to the type of tread you put on the bottom of the shoe. What about side forces?
- Your team should also have information about how the shoe feels and functions by having a team mate wear the shoe for a day.
  - Zipper, velocro, laces, … do they work the way you want?
  - Does it look the way you want a shoe to look?
  - Do your feet get hot or cold?
  - There may be other types of testing that would also be appropriate, but this is a good starting point.

Friction on Earth
Friction on the moon



Weight on the Earth
Weight on the moon



This testing could be treated just like the friction experiment you may have done in your physics class.

https://www.youtube.com/watch?v=fo_pmp5rtzo

Shoe spreader

I built some shoes with a kit

1.

2.

3.

4.

5.

7.

6.

8.

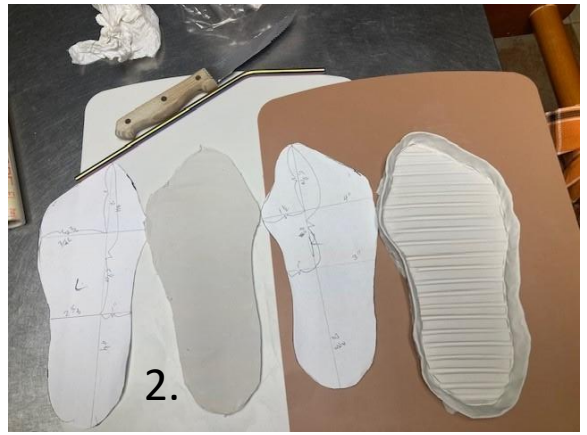
This kit came with the soles, insoles and a pattern. I supplied the leather, tools and grommets. It took me around 5 or 6 hours to make them—less than a day. My wife wears them and says they are pretty good.

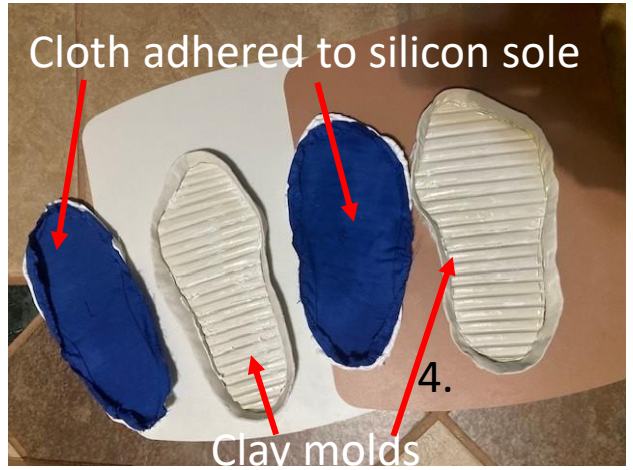
Although these shoes might be ok on the moon, I think the soles are thicker and heavier than what they need to be. I think students could come up with a better sole and there could be a better pattern for the upper. Leather is a good material for the upper but there are plenty of other options that could be good. I suspect some people might come up with more interesting colors that fit their style.

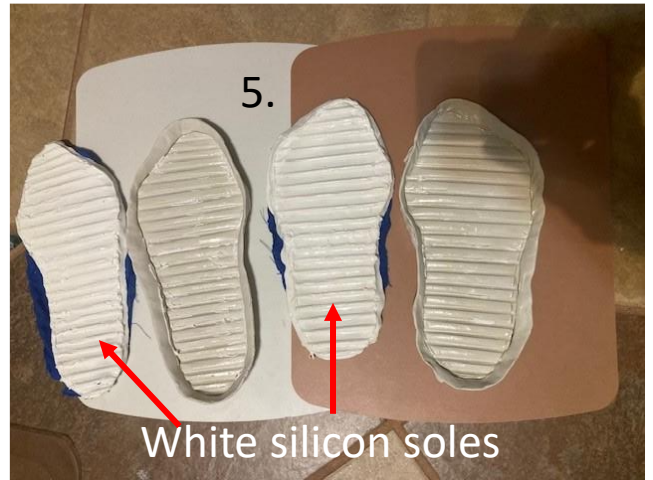
I did this to explore how long and difficult it is to make a pair of shoes—not too bad. I made a few mistakes but I just pulled out the lacing and did it again.

Different shoe problem

- I have a friend who has funky feet. She can't find shoes that fit her so I decided to try to make a pare of shoes that might work better for her. I started with tracing her feet on some paper and then working from the sole up.
- I cut out some cloth for the inside of the shoe with about ½" of extra all the way around so I will have something I can sew to.
- I stitched the edges of the cloth so the edges stand up instead of laying flat (visible in 3.)
- I want to use silicon caulking as my attempt at a sole. I don't know if it will last very long but it is available and not a bad beginning.
- I will make a mold out of clay using the paper foot prints and use a metal straw to make the tread for the sole.
- I used olive oil as a releasing agent between the silicon and the clay. I tried to remove some of the excess oil with a paper towel. Next time I think I would maybe use a spray on Pam so there isn't little pools of oil in the mold. A fine powder may also work.
- By pressing the cloth into the wet silicon, I'm hoping to get good adhesion between the cloth and the silicon sole. Time will tell.
- This sole mold could be much better if it was designed in CAD and 3D printed but this will work for me to test out the molding process.



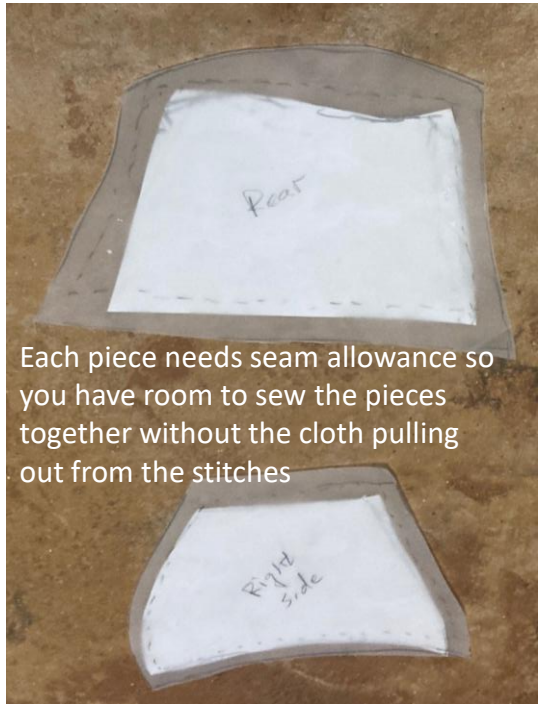


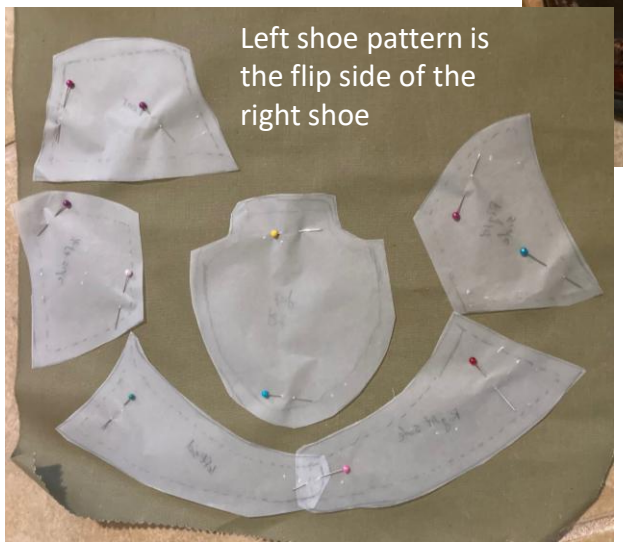


Patterning a Shoe

I'm putting a some extra effort into showing the shoe making process because I haven't done it before and I think that most engineering or science teachers have not gone through making patterns for sewing projects before.

1. To make a pattern, I started with a shoe that I thought I could work with and cut out a paper pattern for each part of the shoe.
2. Then I used tracing paper to add extra cloth for the seam allowance. (I need room to have cloth for sewing together).
3. The only part that I made very different was the front of the shoe that needed to be wider to account for my friend's wider foot.
4. The difference between a left and right shoe is flipping the pattern over. I patterned the right shoe and labeled it on the top. To make the same pieces for the left shoe, I flipped them over which is why these names are backward through the tracing paper.
5. I like working with free materials for my prototypes. I don't care what the first prototype looks like as long as is shows functionality. This green cloth is not what I want but it was free and will work as a first demonstration of the idea.





Ugly Shoe coming together

1. Pin pieces together with strait pins to hold them in place and get the curvatures needed for the cloth. I really liked getting some more practice on the sewing machine. Although there are techniques to learn, it isn't that hard especially if you have a parent or friend to help out.
2. Once I had the upper portion sewn together by machine, I had to hand stitch the sole onto the upper. For one shoe, I did a whip stitch and then came back around to tighten it up with a running stitch. But on the next shoe I ended up doing two running stitches—one to get it together and then a second to tighten it up.

Finished ugly prototype

The sole is really flexible and thin so I found a pair of flip flops that were bigger than my friend's foot and cut them down to fit inside as the insole.

After my friend tries them on and tells me what is good and what is bad, I will make another pair with some of that knowledge along with what I learned about making the shoe.
I think the next one will have

- a double thickness of cloth to make it more rigid.
- Softer insoles.
- Maybe a cardboard heal cup
- More grommets for shoe strings
- All one color
- Fold over the edges of the cloth for a nicer seam

It doesn't bother me that this version of the shoe is ugly since I intend for it to be part of the design process. The next one will look better and the next will be even better. Prototypes are research for a better version. (Let's see if my friend agrees :o)))