University of California, San Diego

Department of Mechanical and Aerospace Engineering

MAE 156A Fundamental Principles of Mechanical Design I

Winter 2024

Individual Component Analysis

Research Area: Connectors

01 March 2024

Team 29: Neubo Inc's Neublox

Nicholas Sudi

Team Members: Max Lee, Aaron Marshall, Wenhan Tang

Background Information:

Our sponsor, Dr Dylan Drotman, tasked us to design a pneumatic circuit block which is an educational kit that explains circuit components such as logic gates, capacitors, and resistors to teach children (particularly 7-12-year-olds) how they work without the use of electrical components. Our team will make blocks that are easy to connect such as legos while including soft components that are less harmful and using pneumatics to depict the logic or current of the circuit.

I will be focusing on the connections between the blocks explained above. Since we have to connect different blocks that let air pass through to form a circuit, the project requires us to investigate possible connections between such blocks. I will investigate the parameters of good connections (intractability and reliability) as well as the different kinds of connections that can be used.

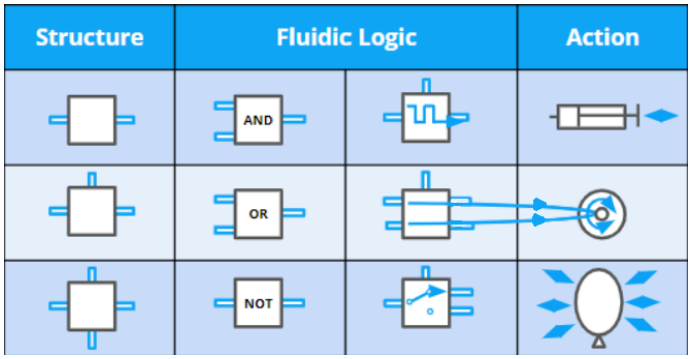


Figure 1: A chart provided to us by our sponsor illustrating desired components.

Functional Requirements:

The connectors should be able to withstand a certain amount of load:

- It should withstand holding up multiple blocks at the same time, when the blocks fall, or even when parents come to help. According to P. E. de Winter's Article, 7 to 12-year-old kids have a pushing around 354 to 610 N or an average force of 484 N while sitting down. In that sense, I can estimate the bending moment and stress that the connection should withstand.

Fatigue (connect and disconnect):

- The components will disconnect and connect a lot so it has to withstand a lot of cycles over time

Air-sealed:

- The range of pressure is around 15 psi from my other groupmate and the papers on logic gate designs

Secondary Considerations:

- Should be easy to use/intuitive for children

Information Gathering Approach:

- Keywords used:
    - Tube connectors (explained more in findings)
    - Grip strength of children & forces by children (Appendix
    - Magnets strength, ratings
- Contacts:
    - Professor Michael Tolley and Allyson Chen: In-Person Interview (Appendix
    - Dr. Saurabh Jadhav (PhD related to pneumatics circuits and Ansys Expertise)

Detailed Description of findings:

	Custom		Ready to Buy		
	Magnets	Lego	Luer locks	Barb adapters	Push to connect
Cost per comp.	$ 0.63	$ 0.03	$6.02	$0.893	
Connection	Intuitive	Intuitive	Tedious	Most effort	Slightly intuitive
Pros	Audible click	Click	Easy to disconnect	Best seal	Easy to connect
Cons	Less Seal Small coercive force	Less Seal	Deformed under long use	Hard to disconnect	Require more hands

Table 1: Comparison chart on different types of component connectors

A lot of keywords regarding tube connectors for air resulted in common connectors for tubes such as barb adapters, push-to-connect, and luer locks. Barb adapters are friction fitted with a taper on its diameter, it stretches the tube such that it creates a tight seal as shown in Figure 2a. It is inserted with a diameter smaller than the Inner Diameter (ID) of the tube while gradually getting bigger than the ID. Especially for softer tubes like silicone tubes, this deformed the tube to accommodate for the bigger diameter tight seal. Dr Dylan Drotman explained that the deformation could create fatigue over time and that it would reduce the seal over time. From using it and as suggested by Professor Michael Tolley, this is the hardest to take out as the friction generated by the rubber plastic fit. From The Engineering Toolbox, rubber and plastic fit has a high friction coefficient of 0.7.

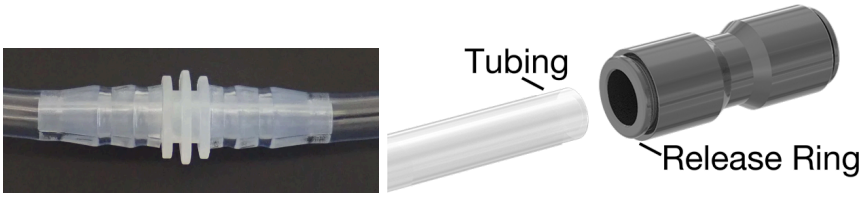


Figure 2: Connector examples: (a) barb adapters (b) luer locks (c) push-to-connect fittings

The second type of connector is a luer lock. As shown in Figure 2b, it fits with another connector that has threads. This looks more intuitive but does take longer to assemble with extra guidance for the kids. From the McMasterr table specifications, the maximum pressure is 40 psi. It withstands less than the barb adapters which might result in a less tight seal in higher pressure.

The third type of connector is a push-to-connect adapters. The section view of the push-to-connect show that the adapter clamped using steel lock claws. It then seals effectively using an o-ring. To release, the release sleeve is pressed and the tube is pulled out. Among these connectors, the push-to-connect adapter is the most intuitive out of the three. It has an audible

click that signify when it is released. We also experienced that the claws could be stuck when the tubes are harder such that it damaged the outer diameter of the tube.

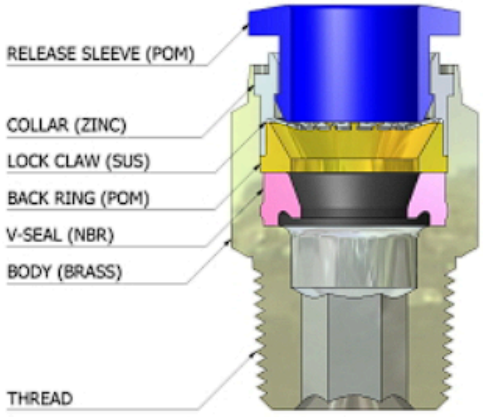


Figure 3: Push-to-connect fittings section view

Looking at the cons of these connectors, two types of custom-design connectors are part of the consideration. Our sponsor suggested using magnets which is intuitive and not difficult to disassemble. The force of a D42 (commonly used) ⅛ inch diameter magnet is 3.7 pounds which is significantly smaller than children's pulling strength as referenced earlier. We should consider a stronger magnet or more magnets. Additionally, this will provide less seal.

Lastly, lego connectors were used in normal Lego mindstorm kits, these pin connectors are snap-fitted which is intuitive for kids and easy to disconnect and connect. Unfortunately, this does not have a tight seal.

I learned from this Individual Component Analysis that we need to design adapters that are easy to connect but also have a tight seal. Allyson Chen suggested we can always include O-rings in our design to include a tight seal. I will follow the design process from the YouTube video of Tarkka to select o-rings from the catalog. The appendix also shows the calculation that my design calculation should be able to handle stress against children's forces.

References:

P. E. de Winter , L. P. A. Steenbekkers & J.J. Houtkamp (1994) Pushing and pulling forces exerted by children, International Journal for Consumer and Product Safety, 1:4, 243-258, DOI: 10.1080/09298349408945742 https://www.tandfonline.com/doi/epdf/10.1080/09298349408945742?needAccess=true

Plastic Quick-Turn Tube Coupling: *Sockets, for 1/8" Barbed Tube ID, Polypropylene*. (2024). McMaster-Carr. https://www.mcmaster.com/51525K293/

Push-to-Connect Tube Fitting for Air: *Adapter, for 1/4" Tube OD x 6 mm Tube OD.* (2024). McMaster-Carr. https://www.mcmaster.com/5779k258/

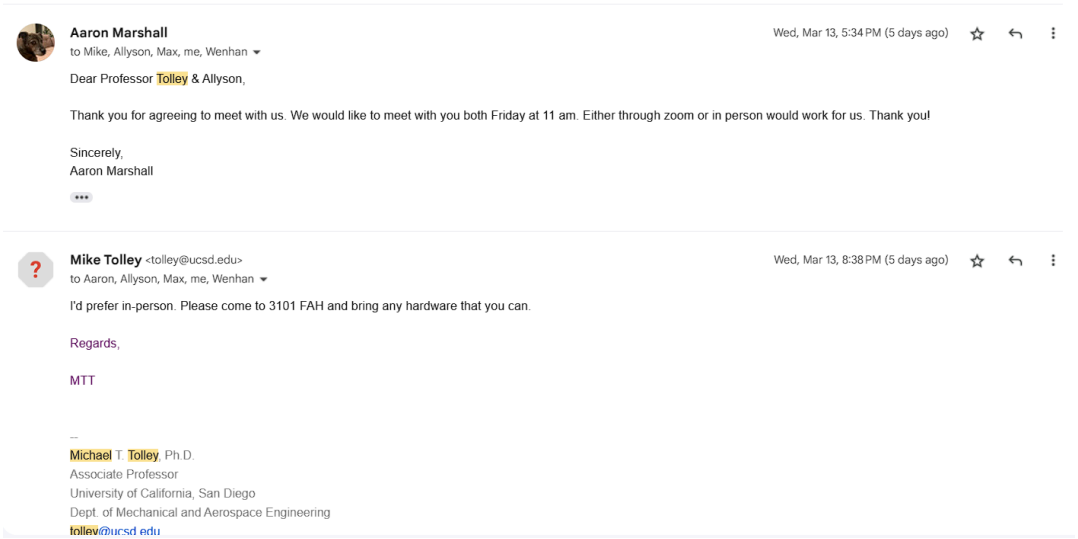
Plastic Barbed Tube Fitting for Air and Water: *Easy-View Connector for 1/8" Tube ID.* (2024). McMaster-Carr. https://www.mcmaster.com/5117K43/

Push to Connect Fittings-PC. (2024). *Idealer.* https://www.ideal-bell.com/products/push-to-connect-fittings/

Friction - Friction Coefficients and Calculator. (2024). *The Engineering Toolbox.* https://www.engineeringtoolbox.com/friction-coefficients-d_778.html

Tarkka. (2024). How to Select, Design, and Install O-Ring Seals. *YouTube.* https://youtu.be/BOP15Xymens?si=nxByljE5vtEFeYa-

Appendix:



Aaron Marshall Wed, Mar 13, 5:34 PM (5 days ago)
to Mike, Allyson, Max, me, Wenhan

Dear Professor Tolley & Allyson,

Thank you for agreeing to meet with us. We would like to meet with you both Friday at 11 am. Either through zoom or in person would work for us. Thank you!

Sincerely,
Aaron Marshall

Mike Tolley <tolley@ucsd.edu> Wed, Mar 13, 8:38 PM (5 days ago)
to Aaron, Allyson, Max, me, Wenhan

I'd prefer in-person. Please come to 3101 FAH and bring any hardware that you can.

Regards,

MTT

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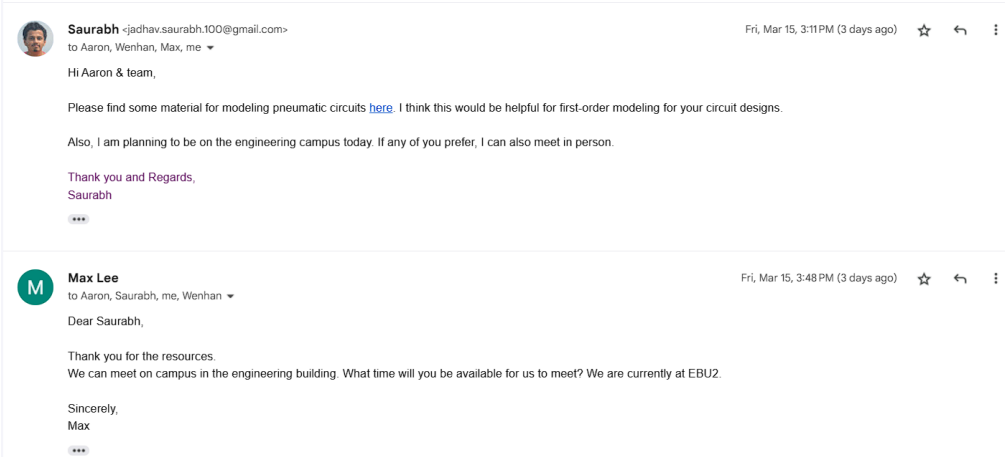
Michael T. Tolley, Ph.D.
Associate Professor
University of California, San Diego
Dept. of Mechanical and Aerospace Engineering
tolley@ucsd.edu

Figure A.1: Email screenshot before our in-person interview with Professor Michael Tolley and Allyson Chen

Summary: We discussed our projects and went through different individual component analyses. Allyson suggested using O-rings instead of barb adapters and referred me to a datasheet.



Saurabh <jadhav.saurabh.100@gmail.com> Fri, Mar 15, 3:11 PM (3 days ago)
to Aaron, Wenhan, Max, me

Hi Aaron & team,

Please find some material for modeling pneumatic circuits here. I think this would be helpful for first-order modeling for your circuit designs.

Also, I am planning to be on the engineering campus today. If any of you prefer, I can also meet in person.

Thank you and Regards,
Saurabh

Max Lee Fri, Mar 15, 3:48 PM (3 days ago)
to Aaron, Saurabh, me, Wenhan

Dear Saurabh,

Thank you for the resources.
We can meet on campus in the engineering building. What time will you be available for us to meet? We are currently at EBU2.

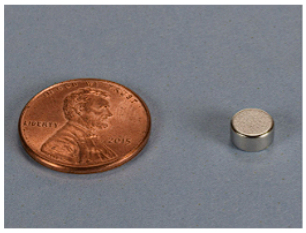
Sincerely,
Max

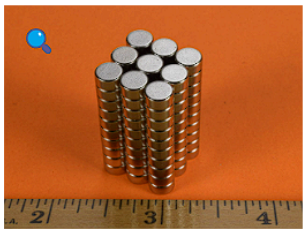
Figure A.2: Email screenshot before the in-person interview with Dr. Jadhav

Summary: We discussed our project and reflected on the pressure simulation required for membranes to move up and down

roducts › Neodymium Magnets › Disc Magnets & Cylinder Magnets › D42 - Neodymium Disc Magnet

D42 - Neodymium Disc Magnet





Description | Technical | Downloads | Video

Dimensions: 1/4" dia. x 1/8" thick
Tolerances: ±0.004" x ±0.004"
Material: NdFeB, Grade N42
Plating/Coating: Ni-Cu-Ni (nickel)
Magnetization Direction: Axial (Poles on Flat Ends)
Weight: 0.0266 oz. (0.754 g)
Pull Force, Case 1: 2.30 lbs
Pull Force, Case 2: 3.71 lbs
Surface Field: 4667 Gauss
Max Operating Temp: 176°F (80°C)
Brmax: 13,200 Gauss
BHmax: 42 MGOe

This is one of our most popular sizes. This is a great size for general purpose hanging and a wide variety of magnetic applications.

This size is also available in grade N52 as part number D42-N52, in grade N52 with black nickel plating as part number D42B-N52 , in grade N42 with black epoxy coating as part number D42E , and diametrically magnetized as part number D42DIA.

Price: $0.34

Click image to open expanded view

LEGO Technic Mindstorm NXT Black Friction Pin Connector Part 2780 (Quantity 300)

Visit the LEGO Store

4.8 ★★★★★ 172 ratings | Search this page

Amazon's Choice Overall Pick

50+ bought in past month

Best Price on Amazon

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“Pushing and pulling forces exerted by children”

Summary: The study investigated different forces children can exert while standing and sitting. The paper involves testing children with different heights, ages, and body masses to look into consideration. Pushing force of 484 N average from boys and girls. Some considerations from the study include the paper investigated a bigger age group (4 to 12 years) instead of (7 to 12 years) as intended and the sitting and standing study might not be best representative to the kinds of toys because it involves just one directional force while the components involve pulling and pushing