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Plug Retention Solution for Loose Wall Sockets Faced by Engineering Science Students

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1.0 Introduction

In spaces frequently used by Engineering Science students, power sockets often experience wear and tear. This leads to plugs tilting downwards and slipping out, disturbing the learning process, cutting power to essential devices and exposing live pins, creating a risk of electrical shock and fire. The purpose of this design report is to recommend a solution to this issue by outlining a comprehensive requirements framework and conducting testing and evaluations of potential designs.

1.1 The Opportunity

The device shall solve the problem of loose connections of plugs to wall sockets faced by Engineering Science students on campus and at residence. Specific locations include the following: Chestnut Residence, UofT Libraries frequented by Engineering Science Students, the EngSci Common Room, MyHall, McLennan Physical Laboratories, and Bahen Center for Information Technology.

1.2 Stakeholder Analysis and Background

A test of sockets around campus and in residence was conducted with 3 different types of plugs (refer to appendix E). For the bulkiest plug, 67 out of 123 connections were determined to be loose, indicating that the issue of loose plugs is present in places frequented by EngSci students.
The primary stakeholders are EngSci students, who experience connection issues.
A survey of 22 EngSci students conducted in the EngSci Common Room and Chestnut Residence reveal:

- 18/22 experienced connection issues weekly, with 9/22 encountering them daily
- 16/22 would prefer a solution with a volume and mass lower than that of a tennis ball (150cm^3 and 59.4g)
- When inquired about their priorities in a potential solution, top responses were:
    - Secure connection or similar (14/22)
    - Fast Deployment (12/22)
    - Durability for long-term use (10/22)

The Secondary stakeholders is the University of Toronto maintenance staff who mandate the solution to be non-damaging to campus infrastructure and residence as given by Chestnut Occupancy Agreement section 5.0 [20].

Furthermore, the Design Team's core values reflect sustainability, design for non-obsolescence, equal learning opportunities, low friction solutions and safety.

Overall, the stakeholders and design team values call for a secure, portable, low-friction, non-damaging, universal and safe way to charge devices. The need of the solution is to allow EngSci students to use any device uninterrupted in common locations.

2.0 Design Requirements

2.1 Complete Requirements Framework

Bringing all the above design team values, primary stakeholder values, secondary stakeholder needs, the following high-level objectives are obtained. These high-level objectives are able to be refined into a set of specific requirements that ensures that all the original stakeholder needs are met.

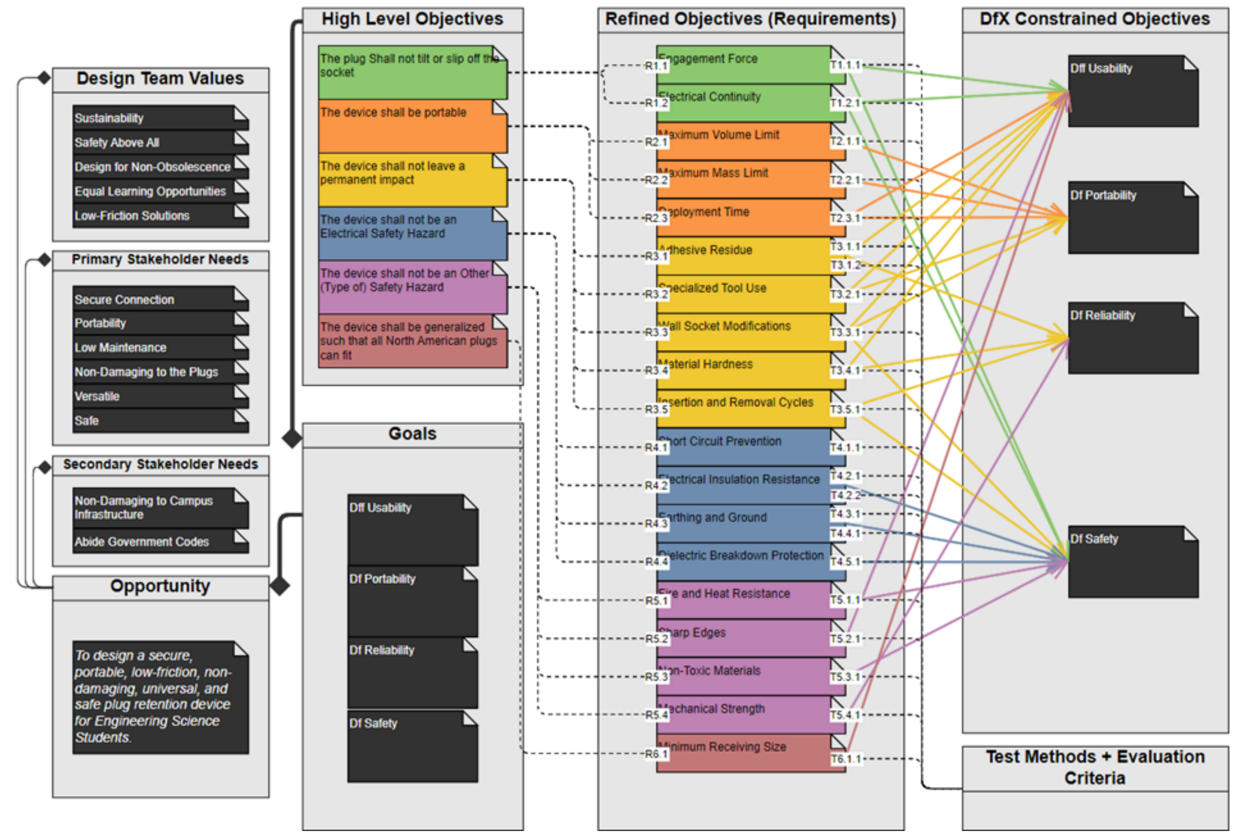


Figure 1: A high-level overview of the objectives and requirements for a successful design. Refer to Appendix B for a detailed requirements framework

2.1.1 Design for Usability

Objective 1: The device shall not tilt or slip off the socket
Engineering Science students need to power and charge their devices without interruptions. When the plug slips repetitively due to worn out sockets, it requires manual realignment to resume charging, distracting the students from their work. Moreover, the exposed live wires may lead to sparks and electric shocks that harm students. Both concerns are concerns that have been raised by the primary stakeholders,

where having a secure connection and being safe was their main concern. Moreover, our design team values align with a design that ensures that everyone has equal opportunity to learn and having a slipping plug distracts one from being productive.

Objective 3: The device shall not leave a permanent impact
A permanent solution cannot be applied inside the classroom by individuals as it damages university property.

Objective 6: The device shall be generalized such that most North American plugs can fit
On the basis of the research completed in Appendix B, we can determine that there is max size in the possible plug types that are used by Engineering Science Students at large. If the size that has been informed through our primary sources cannot be effectively accommodated, we do not meet the stakeholder requirements.

2.1.2 Design for Portability

Objective 2: The device shall be portable
There are multiple faulty wall sockets on campus and at home, thus, stakeholder analysis highlights the need for portability, enabling use across multiple locations.

2.1.3 Design for Reliability

This design space does not have a high-level objective as many objectives link to it.

2.1.4 Design for Safety

Objective 4: The device shall not be an Electrical Safety Hazard
Compliance with CSA C22.1 [26] and specific parts of CSA C22.2 [30] is required for legal sale in Canada. This prevents electrical shocks, which pose significant health risks and could lead to product recalls or government intervention.

Objective 5: The device shall not be an Other (Type of) Safety Hazard
Primary stakeholders prioritize safety, and the device must comply with Ontario's CEC enforcement of CSA C22.1 [26]. Non-compliance would prevent legal sales and endanger users, violating primary and secondary stakeholder needs.

2.2 Critical Requirements Framework

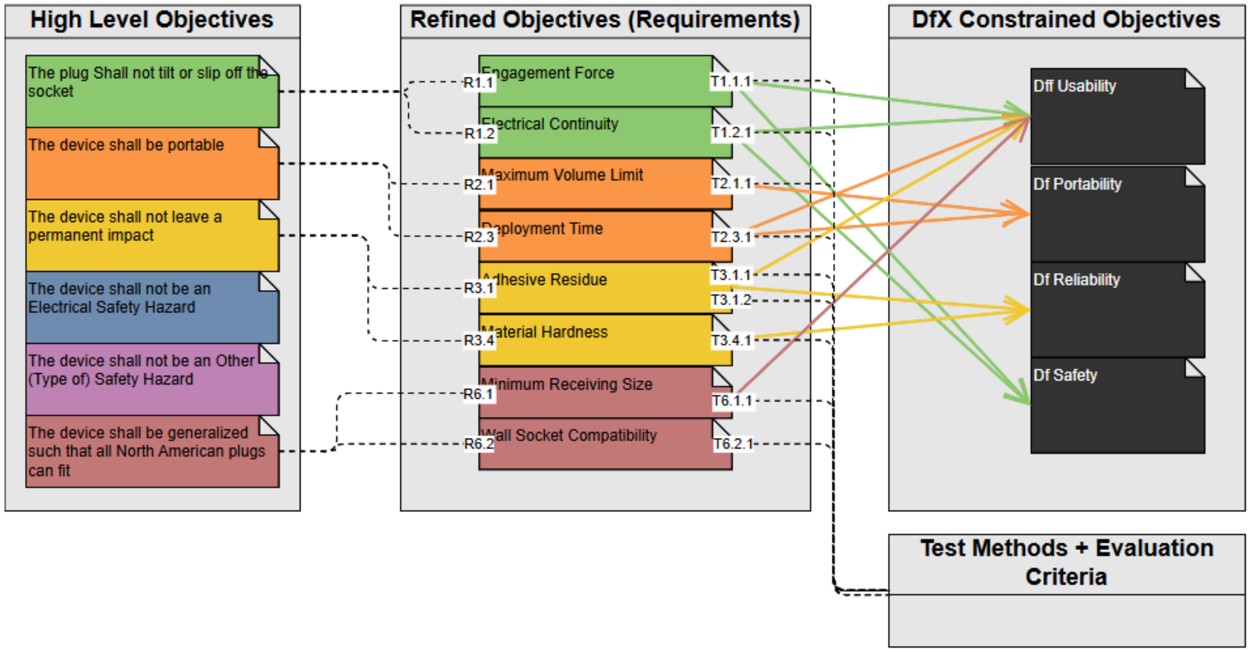


Figure 2: An overview of the High Level Objectives, the critical requirements and how they link to the goals.

2.2.1 - Critical Requirement Framework Introduction

The full requirement framework is too extensive to be evaluated and some requirements are more crucial to accomplishing the objectives and goals than others (refer to appendix B for the full requirement framework). Hence, critical requirements were selected. The first three below critical requirements must be passed for a design to be recommendable as when not met the stakeholder need is not met. The priority(ranked) is as they are presented in the document, going in order of higher to lower importance as per the justification below. The ranking is also reflected in pugh charts below. Refer to test cases below for evaluation criteria and test cases.

2.2.2 Engagement force

Engagement force is a key requirement to satisfying the plug shall not slip or tilt objective and the overall need of the solution to provide a secure connection between the plug and the socket.

2.2.3 Electrical Continuity

For a design to meet the safety requirements, it must satisfy the electrical continuity requirement, as the disruption of the flow of current leads to exposed live wires or leakage of current.

2.2.4 Damage to Wall Socket

The design, as informed by secondary stakeholders, must not damage the infrastructure facilitated by the University of Toronto.

2.2.5 Surface Compatibility

To make it portable, the solution must be compatible with various surfaces, allowing EngSci students to charge their devices in all of the spaces they frequent.

2.2.6 Plug Compatibility

The solution must accommodate a variety of different plugs. The objective shall be satisfied as the need is to provide all EngSci students with all devices a secure connection. From plug fitting data (refer to appendix E), it was also determined that larger, heavier plugs are also more prone to falling out and hence a device that can accommodate larger plugs is required.

2.2.7 Maximum Volume Limit

Of the 22 Engineering Science students asked, 16 said they would only consider a solution lighter than a tennis ball and one of the team values are low-friction solutions. Volume was chosen as a metric chosen over the mass, as the device has to fit in backpacks carried by EngSci students.The requirement is also a part of the portable objective.

2.2.8 Deployment Time

More than half of the Engineering Science students suggested they would need a fast deployment time and one of the team values is low-friction solutions. Both mandate the solution to be fast to deploy, making deployment time a key requirement.

2.2.9 Critical Requirements

Refined Objective	Criteria		Requirement
	Metric	Evaluation	
1 The device shall not cause the plug to slip			
R1.1 Engagement Force	Force [N]	The engagement force shall be within the allowable range. Refer to Appendix E for data on tight, well fitting, and loose use cases.	**T1.1.1** The device shall provide the plug an engagement force with the wall socket such that it is not too low to lead to slipping, and not too high to make it difficult to detach the plug. An engagement force of 10 N shall be provided to ensure secure plug retention based on UL 498 [10]. A maximum engagement force can be at 30N to ensure that the plug can be removed easily based on UL 498 [10].

R1.2 Electrical Continuity	Contact Resistance [mΩ]	The lower the contact the resistance the more suitable the design as resistive heating is reduced thereby reducing the risk of fire.	**T1.2.1** The device shall not affect the electrical continuity between the plug and the socket by maintaining a contact resistance below 10 mΩ between the wall socket and the plug pins based on IEC 60512-2-1 [11].
2 The device shall be portable			
R2.2 Maximum Volume Limit	Volume [cm^3]	The smaller the volume the more suitable the design as the user would be more inclined to use it if it was not bulky, it would appeal to the convenient need.	**T2.2.1** The device shall not have a volume larger than 150 cm^3.
R2.3 Deployment Time	Deployment Time [s]	The shorter the deployment time the more convenient it is to be used.	**T2.3.1** The device shall take no longer than 6s increase in deployment compared to using a typical plug-wall socket arrangement.
3 The device shall not leave a permanent impact			
R3.1 Adhesive Residue	*Visual Inspection*	The higher the adhesive scale test passed the less damaging the design is to the wall socket.	**T3.1.1** The device shall not leave residue after the removal of the device based on ASTM D3359 [3].
R3.4 Material Hardness	Shore Hardness [Shore A]	The design shall have a shore hardness not too low that it is prone to warping whilst not too hard that it cracks due to its brittle nature [31].	**T3.4.1** The material that is in contact with the plug or wall socket should have a Shore Hardness of less than 70A to prevent scratching and wear on the wall socket and plug based on ISO 868 [13]. Primary Stakeholder analysis identified that Engineering Science students expected a potential solution to serve them for at least 3 years and so softer materials are prone to breaking – there is indeed a balance that must be made.
6 The device shall be generalized such that all North American plugs can fit			
R6.1 Minimum Receiving Size	Length [cm]	The larger the plug analogue handled the more suitable the design.	**T6.1.1** The device shall be able to handle effectively a plug that has the minimum dimensions of 10.0cm by 7.50cm by 6.00cm as given by Appendix B.

R6.2 Wall Socket Compatibility	*Visual Inspection*	The more surfaces that a given device is able to fit to the more suitable the design.	**T 6.2.1** The device shall be able to fit over all plugs that Engineering Science students use, this means that the device shall: one, be able to fit around table-edge wall sockets, two fit onto flat wall sockets, and three around low-profile wall sockets.

3.0 Designs

3.1 Design 3 - Recommended Design: Magnetron

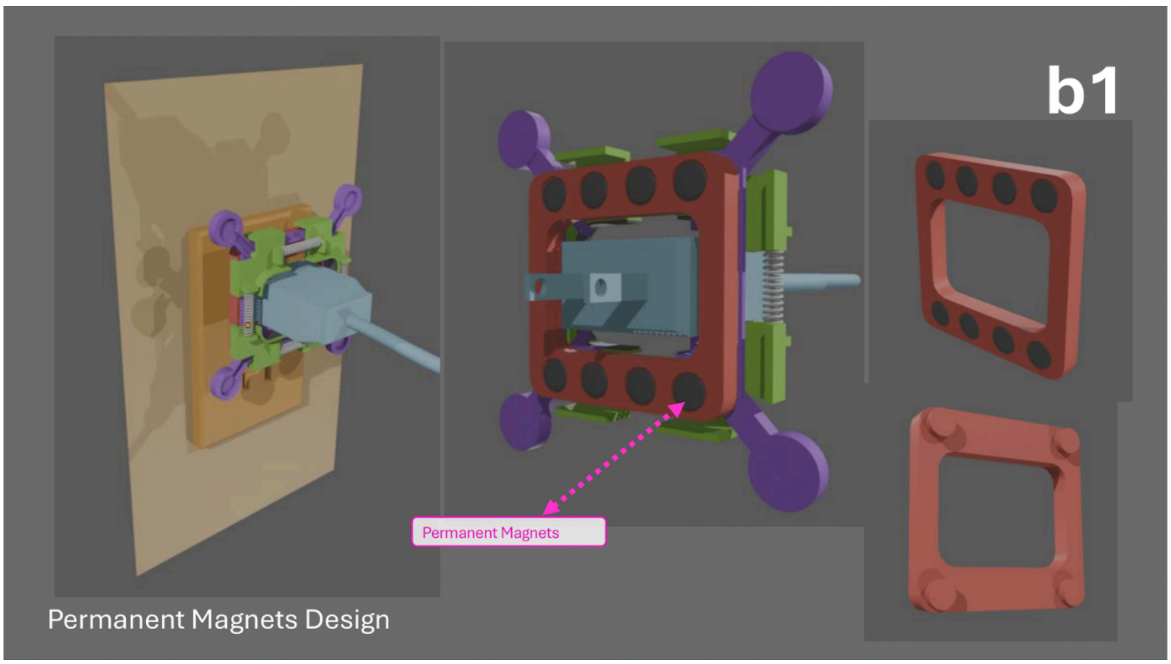


Figure 3: Demonstrates the Magnetron Design. The casing in which contains the permanent magnets is shown in, and the green bracket holds the plug.

The Magnetron design has permanent magnets surrounding the plug which interacts with the Ferum metal within the wall socket, generating an engagement force. It attaches to the plug through a spring loaded bracketing mechanism. Refer to the working mechanism detailed in the video [1] at 1:15s here.

3.2 Overarching Design Process

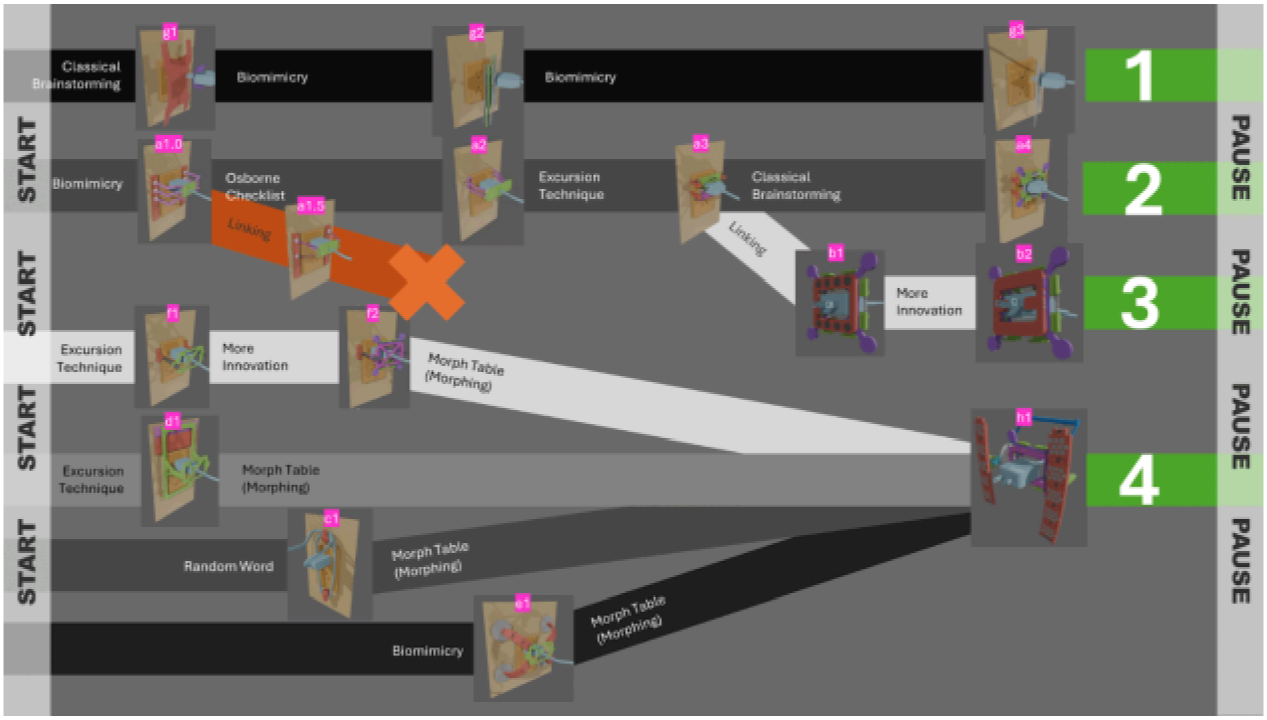


Figure 4: This figure shows the designs that the Design Team generated and further iterated upon until obtaining 4 designs that met all critical requirements.

To tackle the issue of pugs slipping out of power sockets, a variety of design concepts were generated using various methods that include biomimicry, classical brainstorming, morphological analysis and more. Multiple tools were applied for each design iteration but only the tools that worked best and the designs they lead to are shown in figure 4. The general design procedure was as follows: A design was generated with a diverging technique. Later, it was analyzed against the critical requirements. If it failed any of the critical requirements, the design would be iterated in an attempt to improve its lowest metric. Once the team couldn't come up with another iteration, the design was discarded if it didn't meet the first 3 critical requirements or the design became one of the top 4.

3.3 Design 1: Nanotape

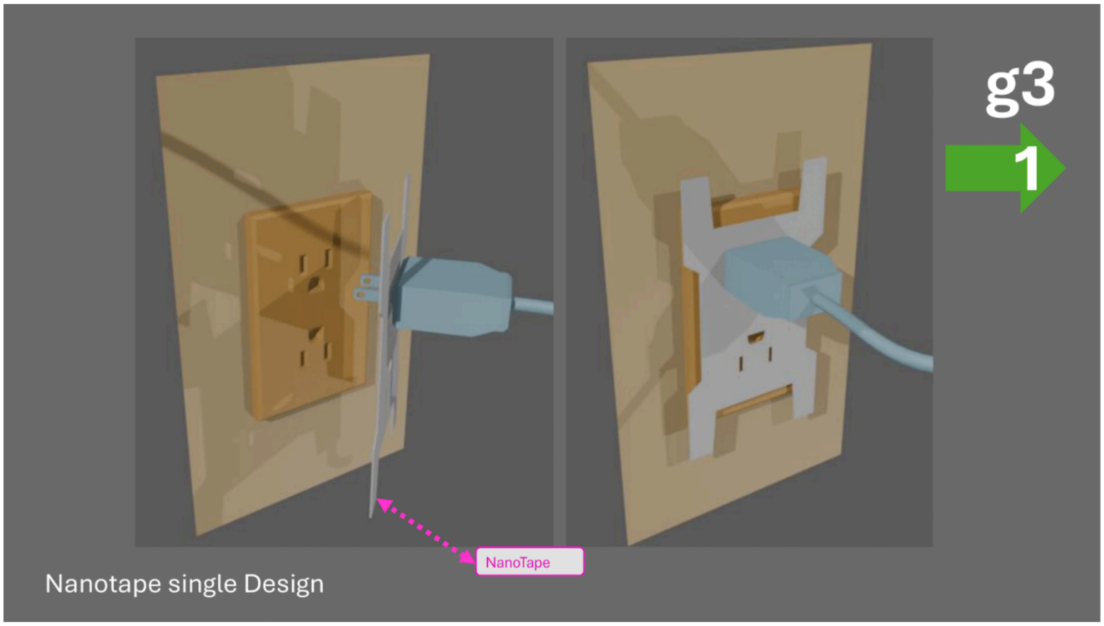


Figure 5: Demonstrates the nanotape design. Left side is before application, the right side is after attachment.

The nanotape design involves a single layer of nanotape deployed between the plug and the socket, it provides the engagement force between the two, and can easily be detached. Refer to video [1] for key design considerations here.

3.4 Design 2: Spring Clamps

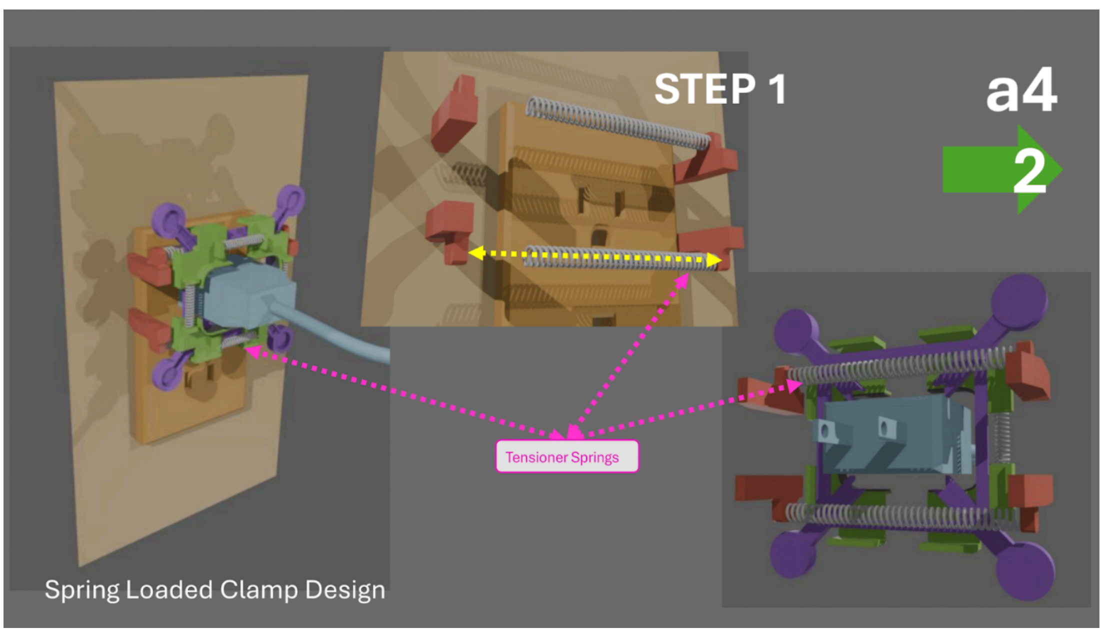


Figure 6: Demonstrates the Spring Clamps design and the Spring Loading mechanism.

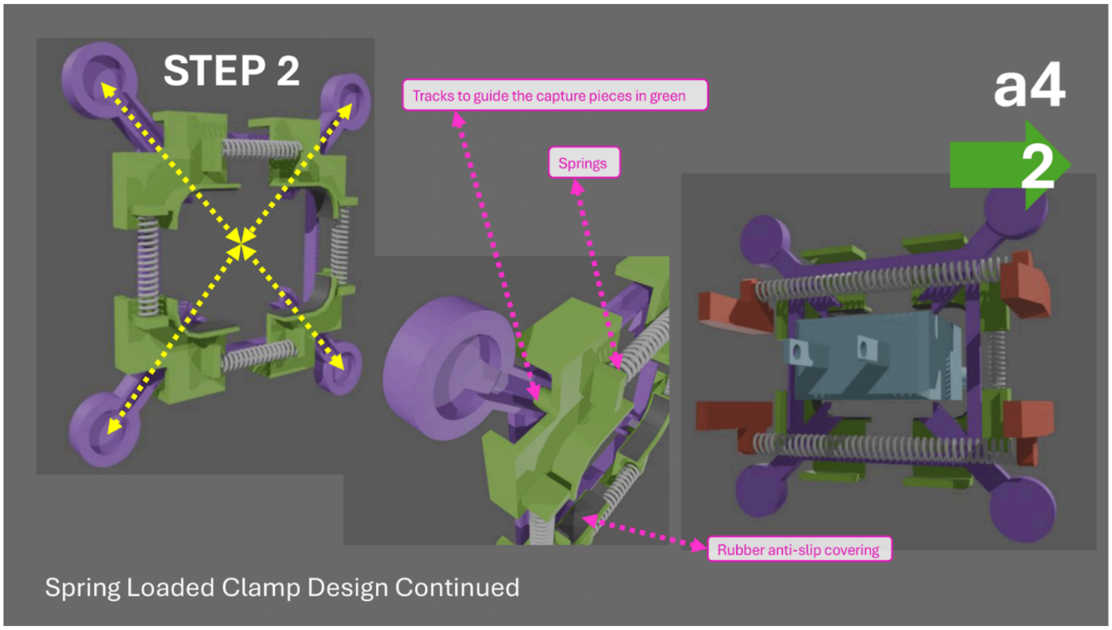


Figure 7: Demonstrates the bracketing mechanism used to attach the device to the plug.

The Spring Clamps work by holding the plug while its claws attach to the ends of the socket. Friction between the claws and the ends of the wall socket prohibits the plug from being removed. Refer to video [1] at 0:27 for key design considerations here.

3.5 Design 4: Octopi Suction

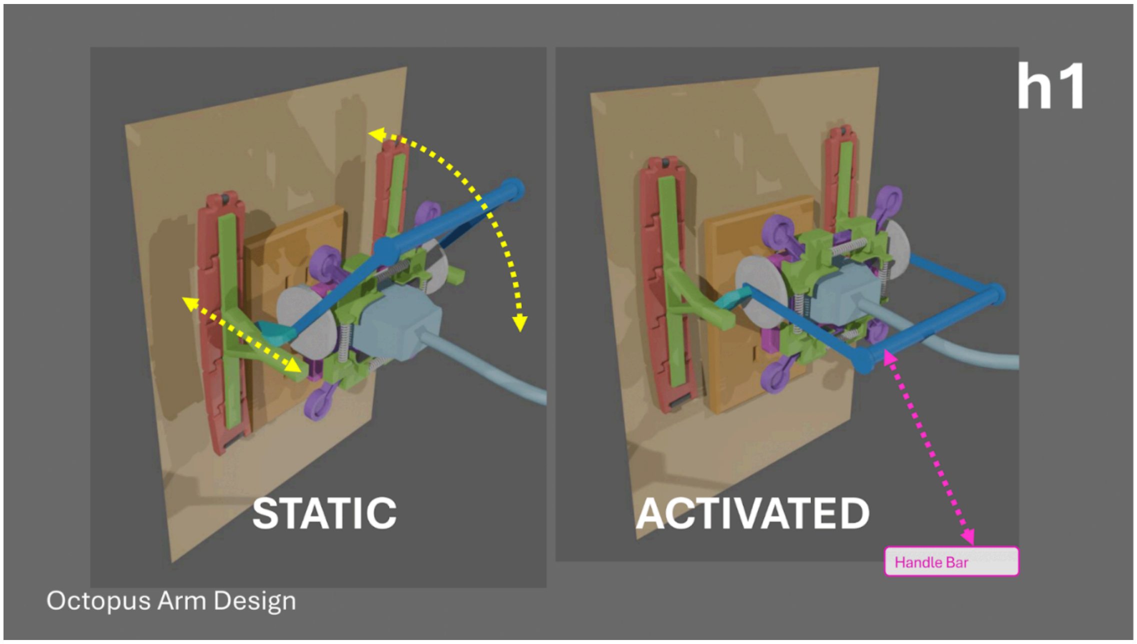


Figure 8: Demonstrates the Octopi Suction Design. Left side is static, and the right side is when activated.

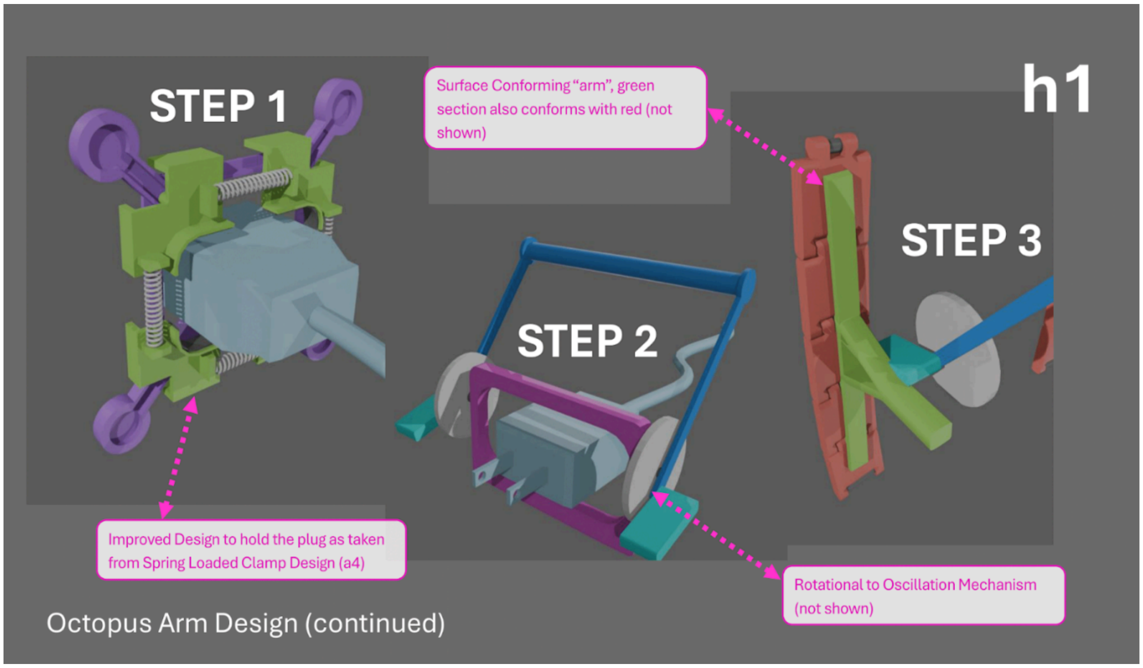


Figure 9: Demonstrates the mechanism of the Octopi Suction Design.

Octopi Suction mechanism fits around the plug tightly utilising the plug bracket. Then, the arms (shown in red) are placed against the surface near the socket, and provide the force to stick the suction cups against the surface, the blue level arm is lowered. Refer to the video [1] at 1:40 for key design considerations here.

4.0 Justifying the Recommended Design

4.1 Initial Analysis - Pairwise Comparison

	Magnetron	Octopi Suction	Spring Clamps	Nanotape	Total
Magnetron	-	0	1	1	2
Octopi Suction	0	-	1	1	2
Spring Clamps	0	0	-	1	1
Nanotape	0	0	0	-	0

The pairwise comparison reveals that the Octopi Suction and Magnetron designs are closely tied in performance. This indicates that further analysis is necessary to determine which design is ultimately superior.

Moreover, the close ties may also indicate that the design space was explored sufficiently and that no significantly better designs were missed.

4.2 Further Analysis

4.2.1 Measurement Matrix

Critical Metrics	Relevant Requirements	Unit	Magnetron	Octopi Suction	Spring Clamps	Nanotape
Engagement Force	R1.1 Engagement Force	Newtons	15	14	20	10
Electrical Continuity	R1.2 Electrical Continuity	Boolean	Flush Mount	Flush Mount	Flush Mount	Non-Flush Mount
Damage to Wall Socket	R3.1 Adhesive Residues	Boolean	No	No	No	Yes
	R3.4 Material Hardness	Shore Hardness	90A [22]	60A [23]	83D []	5A [25]
Wall Socket Compatibility	R6.2 Wall Socket Compatibility	Proportion	30/32	25/32	19/32	28/32
Minimum Plug Receiving Size	R6.1 Minimum Receiving Size	Proportion	7/8	7/8	7/8	8/8
Maximum Volume Limit	R2.1 Maximum Volume Limit	Cubic Centimeters	98	149	136	49
Deployment Time	R2.3 Deployment Time	Seconds	2.267	4.200	5.567	3.300

4.2.2 Data and Data Collection Procedure

4.2.2.1 Engagement Force Testing

This test involved using a force gauge to pull two wooden blocks apart which were connected based on a similar analogue to the candidate designs whilst measuring the maximum force till disengagement. See video at 2:29 for Nanotape here and at 2:43 for Magnetron here.

Refer to Appendix A1.0, section A1.1 for complete data.

4.2.2.2 Electrical Continuity

It is important to note that electrical continuity is assessed based on whether the plug is mounted flush, as an alternative to measuring the resistance. Since the evaluation focuses on a relative comparison of designs, the flush or non-flush criterion was chosen as a simpler and effective metric.

4.2.2.3 Adhesive Residue

Since this is a relative comparison, simply stating “yes” or “no” was sufficient to populate the Pugh charts as given in further sections.

4.2.2.4 Material Hardness

Wall sockets are typically composed of ABS (at the low end of hardness) and Nylon [21] (at the high end of hardness) plastics. This means that the surface in contact with the device will have a shore hardness of between 79D (ABS) [25] and 95D (Nylon) [25], this means any material used in any design that is higher or close to this will result in wear on the wall sockets.

4.2.2.5 Wall Socket Compatibility Testing

Wooden blocks were made of the maximum dimension of the designs by taking information from the CAD models and with reference to the maximum volume of the design. Afterwards, locations that had a loose fit for all types of plugs (refer to Appendix E) were visited and tested on whether the centre of the wooden blocks could be fit flush with the sockets. Refer to video [1] at 2:24 here.

Refer to Appendix A1.0, section A1.2 for complete data.

4.2.2.6 Minimum Plug Receiving Size

The volume of reference plugs was estimated and compared to the Minimum Receiving Size. While nanotape could accommodate all designs, the others were not able to accommodate reference design 8 in Appendix D.

4.2.2.7 Deployment Time Testing

Designs were not prototyped in their completeness, however, proxies were made to simulate the connection. After, each member on the team, starting with a distance of 30 cm between the prototype plug and socket, would at a relaxed pace connect the plug and socket. This was repeated by each team member 3 times for each design. Data is tabulated below. See deployment time proxy test in video [1] for Nanotape at 2:13 here and Magnetron at 2:21 here.

Refer to Appendix A1.0, section A1.3 for complete data.

4.2.2.8 Maximum Volume of Device

The maximum volume of each of the designs was found by taking the maximum edge dimension of the design in each axis and finding the volume by taking the product of the three values.

4.2.3 Strengths and Limitations of Data Collection

4.2.3.1 Deployment Time Testing

Deployment time was tested for only 3 people and 3 trials. The proxy test was conducted with two wooden blocks instead with a plug and wall socket. For a thorough test, with various plugs, more trials and more people, results may differ, however, the proxy remains a good approximation to the time it would take to use the design as the mechanism is the same. Refer to video [1] at 2:13 here.

4.2.3.2 Wall Socket Compatibility Testing

The wall socket compatibility test was low fidelity as it did not account for different materials around the sockets, the orientation of the socket or the geometry of the surface around the socket. It was tested by comparing the size of the proposed design and the wall socket. Hence, the data overestimates the compatibility of the designs, however, it gives a relative representation of how compatible the devices are. In reality, the ratios may differ but the team is able to conclude that the Spring Clamps Mechanism is by far the least compatible.

4.2.3.3 Engagement Force Testing

Engagement Force testing was conducted between wooden blocks with a spring scale. The scale was from 0 to 15 kilograms, while all the designs had an engagement force of 10 - 20 N (1 - 2 kg), introducing a high level of uncertainty to what force the detachment happened at (refer to video [1] at 2:43 here). The prototypes were proxy tests, for example, nanotape was replaced with velcro. Combining the two drawbacks of the testing listed above, the team is not confident in the exact results, specifically for nanotape. However, with the exclusion of nanotape, the team can say with certainty that all designs meet the engagement force requirement.

4.3 Final Analysis

4.3.1 Pugh Chart with Datum as Status Quo

Here, the status Quo refers to the absence of any such design, only the plug is used.

Rank	Critical Metrics	Status Quo	Magnetron	Octopi Suction	Spring Clamps	Nanotape
1	Engagement Force	Same	Better	Better	Better	Better
1	Electrical Continuity	Same	Same	Same	Same	Worse
1	Damage to Wall Socket	Same	Same	Same	Worse	Worse
2	Wall Socket Compatibility	Same	Same	Same	Worse	Same
2	Minimum Plug Receiving Size	Same	Same	Same	Same	Same
3	Maximum Volume Limit	Same	Worse	Worse	Worse	Worse
3	Deployment Time	Same	Same	Worse	Worse	Same

4.3.2 Pugh Chart with Datum as Magnetron

Rank	**Critical Metrics**	Magnetron	Octopi Suction	Spring Clamps	Nanotape
1	Engagement Force	Same	Worse	Better	Worse
1	Electrical Continuity	Same	Same	Same	Worse
1	Damage to Wall Socket	Same	Same	Same	Worse
2	Wall Socket Compatibility	Same	Worse	Worse	Worse
2	Minimum Plug Receiving Size	Same	Same	Same	Better
3	Maximum Volume Limit	Same	Worse	Worse	Better
3	Deployment Time	Same	Worse	Worse	Worse

4.3.3 Pugh Chart with Datum as Octopi Suction

Rank	**Critical Metrics**	Magnetron	Octopi Suction	Spring Clamps	Nanotape
1	Engagement Force	Better	Same	Better	Worse
1	Electrical Continuity	Same	Same	Same	Worse
1	Damage to Wall Socket	Same	Same	Worse	Worse
2	Wall Socket Compatibility	Same	Same	Same	Better
2	Minimum Plug Receiving Size	Better	Same	Worse	Better
3	Maximum Volume Limit	Better	Same	Better	Better
3	Deployment Time	Better	Same	Worse	Better

4.3.4 Pugh Chart with Datum as Spring Clamps

Rank	**Critical Metrics**	Magnetron	Octopi Suction	Spring Clamps	Nanotape
1	Engagement Force	Worse	Worse	Same	Worse
1	Electrical Continuity	Same	Same	Same	Worse
1	Damage to Wall Socket	Better	Better	Same	Worse
2	Wall Socket Compatibility	Better	Better	Same	Better
2	Minimum Plug Receiving Size	Same	Same	Same	Better
3	Maximum Volume Limit	Better	Worse	Same	Better
3	Deployment Time	Better	Better	Same	Better

4.3.5 Pugh Chart with Datum as Nanotape

Rank	**Critical Metrics**	Magnetron	Octopi Suction	Spring Clamps	Nanotape
1	Engagement Force	Better	Better	Better	Same
1	Electrical Continuity	Better	Better	Better	Same
1	Damage to Wall Socket	Better	Better	Better	Same
2	Wall Socket Compatibility	Better	Worse	Worse	Same
2	Minimum Plug Receiving Size	Worse	Worse	Worse	Same
3	Maximum Volume Limit	Worse	Worse	Worse	Same
3	Deployment Time	Better	Worse	Worse	Same

4.3.6 Design Decisions and Final Analysis

Analysis of the Pugh Charts indicates that all four designs outperform the Status Quo (defined as the absence of devices to connect a plug to the wall socket). Each design provides a higher engagement force, resolves issues related to slipping and tilting wall sockets, and ensures safety and portability. This therefore means simply continuing on with the Status Quo would not resolve the stakeholders' needs.

Comparative analysis within the Pugh Charts shows that the Magnetron design consistently achieves superior performance. It is identified as the optimal choice, as it is associated with the highest number of "worse" ratings (highlighted in green), indicating that other designs perform less favorably in the seven critical metrics. Although Magnetron is slightly inferior to Spring Clamps in the most important metric - engagement force - both meet the requirement for this metric. Given the high uncertainty in engagement force testing, this difference is considered less significant compared to Magnetron's overall superiority in other, be it less important, critical metrics.

Another reason for the recommendation of the Magnetron was the fact that it was the quickest to apply of the designs, making it a low-friction solution. In combination with being a safe, sustainable, and non-obsolescent solution, the Magnetron reflects the team values well.

While the Nanotape design accommodates more plugs and is smaller, these features are secondary to the primary stakeholder priorities of engagement force and electrical continuity. Testing indicates that while Nanotape's engagement force is barely compliant with the requirement,and its design prevents a flush connection between the plug and socket, raising concerns about electrical continuity.

5.0 Key Design Decisions of Magnetron

5.1 Permanent Magnets

The team converged on the use of permanent magnets as opposed to electromagnets for two reasons. Firstly, electromagnets were significantly more complex and outside of the scope of first year EngSci students. Secondly, electromagnets are highly dependent on the power drawn from the socket, meaning that the device would perform differently depending on what device was powered. While permanent magnets are, too, affected it to a much lesser extent. For these 2 reasons the team elected to proceed with permanent magnets. The last reason for proceeding with magnets was that it represented the teams value for low-friction solutions.

5.2 Plug Bracket

One of the critical requirements was the minimum receiving size - the larger the plug that a design could accommodate, the better. For this reason, the plug bracket as utilised in the Spring Clamp design was carried over to Magnetron as it allowed it to be compatible with plugs of any shape, volume and mass. It also contains rubber coatings that ensure that the plug does not slip out from the device itself thereby ensuring that the critical metric of engagement force is met.

5.3 Minimal Design

Another critical design was maximum volume limit, which arose from the primary stakeholder analysis. To create a design less than the volume of a tennis ball, mini-permanent magnets were chosen over larger magnets. Another reason to proceed with 8 mini-permanent magnets was to maximize the area over which the magnetic force was applied and increase the number of sockets the design could be deployed on.

6.0 Conclusion

Based on the analysis and comparisons above, the Magnetron Mechanism is the recommended solution to address the problem of plugs tilting and falling out of worn-out sockets. It was determined to be the superior design solution, meeting the first three critical requirements and outperforming other designs in the remaining five.

While it is a clear leader in the analysis, the proxy tests of the Magnetron Mechanism against the critical metrics provides only an approximation of its actual performance. As such, we are unable to confidently recommend this solution as a market-ready product at this stage. However, the design team strongly recommends that this design be prioritized for further development, as it demonstrates the highest potential among all evaluated options to fully meet stakeholder needs. Advancing this design through additional development and rigorous testing of a fully developed prototype (using Appendix C test cases) would enable the verification of its performance across all critical metrics (thereby all requirements given in Appendix B) and ensure that it would be able to meet stakeholder needs.

7.0 Source Extracts

Some reference numbers do not exist in this document, this is because these numbers are taken by sources that are maintained in the design brief (appendix I).

[01] Ayan Ali. Praxis I Supplemental Video. (Dec. 2, 2024). Accessed: Dec. 2, 2024. [Online Video]

[02] "Printer Power Cord for HP Officejet Pro 4500 6600 4650 4630 5255 6962 8600 8710 7740/Envy 5055 5530/Deskjet 2652 3755/Photosmart 7520 6520/All-in-One/Canon Pixma 2 Prong Replacement Cable(6Ft) : Amazon.ca: Electronics." Amazon.ca. Accessed: Oct. 11, 2024. [Online]. Available: SHORTENED URL

[03] "Cablelera North American Power Cord Extension, NEMA 5-15P to C19, 8', 14 AWG, 15A, 125V (ZWACPFAC-08) : Amazon.ca: Electronics." Amazon.ca. Accessed: Oct. 11, 2024. [Online]. Available: SHORTENED URL

[04] "UNIVERSAL MULTI-OUTLET AMERICAN, CANADA 15 AMPERE-125 VOLT PLUG ADAPTER, TYPE B, 2 POLE-3 WIRE GROUNDING (2P+E). IVORY." International Configurations, Inc. - CORDSETS, CORD SET, DETACHABLE CORDSETS, IEC60320, IEC320, IEC60309, IEC309, PLUGS, OUTLETS, SOCKETS, PLUG ADAPTERS, RECEPTACLES, OUTLET STRIPS, POWER STRIPS - International Configurations, Inc. Accessed: Oct. 11, 2024. [Online]. Available: https://internationalconfig.com/icc6.asp?item=30250-NS

[05] "Genuine Apple 5W USB Power Adapter Charger Wall Plug Cube for iPhone." Ebay. Accessed: Oct. 11, 2024. [Online]. Available: https://www.ebay.ca/itm/195428617212

[06] "Multi Plug Outlet Extender, TESSAN Mini Wall Plug Expander with 3 Electrical Outlet, 3 USB Outlet Plug, Cube Multiple Plug Outlet Splitter for Travel, Home, Office, Cruise Ship, Dorm Room Essentials." Amazon. Accessed: Oct. 11, 2024. [Online]. Available: SHORTENED URL

[07] "Universal Travel Adapter, All in One Plug Adapter with USB C, Worldwide Power Adapter USB Type C Port, International Wall Charger Foldable Plug Converter Outlet for Europe EU UK AUS (Type G/C/I/A)." Amazon.com. Accessed: Oct. 11, 2024. [Online]. Available: SHORTENED URL

[08] "12V LED Strip Power Supply, 2A 24W Power Adapter, 12V Power Supply for LED Strip Lights Security Camera DVD Player, AC 100-240V to DC 12V Transformer, US Plug (2 Pack) : Amazon.ca: Tools & Home Improvement." Amazon.ca. Accessed: Oct. 11, 2024. [Online]. Available: SHORTENED URL

[09] "Amazon.com: Unidapt Multi Plug Outlet Extender, 3 Outlet Wall Adapt er, Multiple Outlet Splitter, Grounded Wall Tap Power Plug Expander for Cruise Ship Home Office Dorm Essentials,

2-Pack : Tools & Home Improvement.” Amazon.com. Accessed: Oct. 11, 2024. [Online]. Available: SHORTENED URL

[10] “UL 498, Standard for Safety for Attachment Plugs and Receptacles.” 114 Retention of Plugs Test Pg. 117, 15th Ed, Underwriters Laboratories, Northbrook, IL, USA, 2020. Accessed: Oct. 13, 2024. [Online]. Available: SHORTENED URL

114 Retention of Plugs Test

114.1 The contacts of the receptacles illustrated in Figures C1.1, C1.5, C1.6, C1.9, and C1.10 shall be capable of holding an attachment plug so that a force of 3 – 15 lbf (13 – 67 N) is required to withdraw the plug when tested as described in this Section.

Exception: A receptacle that has provision for locking the plug in place after the blades have been inserted in the female contacts need not be subjected to this test.

114.2 Each device is to be subjected to ten conditioning cycles of insertion and withdrawal of a standard solid-blade attachment plug of a type with which the device is intended for use and that has American National Standard detent holes in rigidly mounted blades, following which the plug is to be fully reinserted into the device. A pull of 3 lbf (13 N) in a direction perpendicular to the plane of the face of the receptacle and tending to withdraw the plug from the device is then to be applied to the plug for 1 minute. The results are unacceptable if there is any displacement of the plug.

114.3 The receptacle is then to be subjected to the regular overload and temperature tests, following which the entire procedure described above is to be repeated. In the repeated test, the results are unacceptable if the plug is displaced by the 3 lbf (13 N) pull, but it is required that the cap be withdrawn when the pull is increased to 15 lbf (67 N). If the device is intended to accommodate either a 2- or 3-wire plug, the entire procedure described above is to be performed with a 2-wire plug, after which a 3-wire plug inserted into the device is required to be withdrawn by a 15 lbf (67 N) pull.

[11] “IEC 60512-2-1:2002. Connectors for electronic equipment.” Tests and measurements - Part 2-1: Electrical continuity and contact resistance tests - Test 2a: Contact resistance - Millivolt level method, 5 Requirements, Pg 7 International Electrotechnical Commission, 2002. Accessed: Oct. 13, 2024. [Online]. Available: SHORTENED URL

5 Requirements

The value of the contact resistance shall not exceed, for any measurement, the value specified in the detail specification.

The contact resistance measurement with d.c. shall be the average of the two readings obtained with forward and reverse current.

Use of the following equation will ensure that the calculated resistance is always correct:

$$R = \frac{|V_{mf} - V_{mr}|}{|I_f| + |I_r|}$$

NOTE In the equation, the sign of the voltage measurements must be included.

where

R is the resistance;

V_{mf} is the measured forward voltage;

V_{mr} is the measured reverse voltage;

I_f is the forward current;

I_r is the reverse current.

NOTE Any deviation from the standard test procedure should be clearly indicated in the test report.

[12] "ASTM D3359-20. Standard Test Methods for Measuring Adhesion by Tape Test." ASTM International, 2020. Section 4 Test Methods, Page 2. Accessed: Oct. 13, 2024. [Online]. Available: https://cdn.standards.iteh.ai/samples/112953/22ddb3d5fb0948ed9acd68d9f2dded63/ASTM-D3359-22.pdf

4. Summary of Test Methods

4.1 *Test Method A*—An X-cut is made through the film to the substrate, pressure-sensitive tape is applied over the cut and then removed, and adhesion is assessed qualitatively on a 0 to 5 scale.

[13] "ISO 868:2003. Plastics and ebonite - Determination of indentation hardness by means of a durometer (Shore hardness)." International Organization for Standardization, 2003. Accessed: Oct. 13, 2024. [Online]. Available: https://cdn.standards.iteh.ai/samples/34804/a84cf1ebb91149e39513cc01c9e01050/ISO-868-2003.pdf

8 Procedure

8.1 Place the test specimen on a hard, horizontal, plane surface. Hold the durometer in a vertical position with the point of the indenter (4.2) at least 9 mm from any edge of the test specimen. Apply the presser foot (4.1) to the test specimen as rapidly as possible, without shock, keeping the foot parallel to the surface of the test specimen. Apply just sufficient pressure to obtain firm contact between presser foot and test specimen.

NOTE Better reproducibility may be obtained by using either a durometer stand or a weight centred on the axis of the indenter, or both, to apply the presser foot to the test specimen. Recommended masses are 1 kg for the type A durometer and 5 kg for the type D durometer.

Read the scale of the indicating device (4.3) after 15 s ± 1s. If an instantaneous reading is specified, read the scale within 1 s after the presser foot is in firm contact with the test specimen, unless the durometer has a maximum indicator, in which case the maximum reading shall be taken.

[14] "A GUIDE TO PRODUCTS & TEST METHODS." CLASSIFIED SURFACES & RECOGNISED COURTS. Accessed: Oct. 13, 2024. [Online]. Available: https://www.itftennis.com/media/4420/2023-technical-booklet.pdf

Test balls

A high-specification ball is required for court testing to reduce the effect of ball properties on the measurement of surface characteristics (see Table 1).

Type of ball	Pressurised
Mass	57.6 ± 0.3 g
Diameter	6.60 ± 0.05 cm (2.598 ± 0.020 inches)
Forward deformation	0.64 ± 0.04 cm (0.252 ± 0.016 inches)
Return deformation	0.94 ± 0.14 cm (0.370 ± 0.055 inches)
Rebound	141 ± 1 cm (55.5 ± 0.4 inches)
Woven cloth	55 ± 5% wool, 45 ± 5% nylon

Table 1. Ball specification for surface testing.

[15] "Toxic substances list - Canada.ca." Canada.ca. Accessed: Oct. 13, 2024. [Online]. Available: https://www.canada.ca/en/environment-climate-change/services/CE environmental-protection-act-registry/substances-list/toxic.html

Toxic substances list: schedule 1

Updated Schedule 1 as of May 12, 2021

1. Chlorobiphenyls that have the molecular formula $C_{12}H_{(10-n)}Cl_n$ in which "n" is greater than 2
2. Dodecachloropentacyclo [5.3.0.0^{2,6}.0^{3,9}.0^{4,8}] decane (Mirex)
3. Polybrominated biphenyls that have the molecular formula $C_{12}H_{(10-n)}Br_n$ in which "n" is greater than 2
4. Chlorofluorocarbon: totally halogenated chlorofluorocarbons that have the molecular formula $C_nCl_xF_{(2n+2-x)}$
5. Polychlorinated terphenyls that have a molecular formula $C_{18}H_{(14-n)}Cl_n$ in which "n" is greater than 2
6. Asbestos
7. Lead
8. Mercury and its compounds
9. Vinyl chloride
10. Bromochlorodifluoromethane that has the molecular formula CF_2BrCl
11. Bromotrifluoromethane that has the molecular formula CF_3Br
12. Dibromotetrafluoroethane that has the molecular formula $C_2F_4Br_2$
13. Fuel containing toxic substances that are dangerous goods within the meaning of section 2 of the Transportation of Dangerous Goods Act, 1992 and that

    (a) are neither normal components of the fuel nor additives designed to improve the characteristics or the performance of the fuel or

    (b) are normal components of the fuel or additives designed to improve the characteristics or performance of the fuels, but are present in quantities or concentrations greater than those generally accepted by industry standards
14. Dibenzo-para-dioxin that has the molecular formula of $C_{12}H_8O_2$
15. Dibenzofuran that has the molecular formula $C_{12}H_8O$
16. Polychlorinated dibenzo-para-dioxins that have the molecular formula $C_{12}H_{(8-n)}O_2Cl_n$in which "n" is greater than 2
17. Polychlorinated dibenzofurans that have the molecular formula $C_{12}H_{(8-n)}OCl_n$ in which "n" is greater than 2
18. Tetrachloromethane (carbon tetrachloride) CCl_4
19. 1,1,1-trichloroethane (methyl chloroform) CCl_3-CH_3
20. Bromofluorocarbons other than those set out in items 10 to 12
21. Hydrobromofluorocarbons that have the molecular formula $C_nH_xF_yBr_{(2n+2-x-y)}$ in which $0<n\leq3$
22. Methyl bromide
23. Bis(chloromethyl) ether that has the molecular formula $C_2H_4Cl_2O$
24. Chloromethyl methyl ether that has the molecular formula C_2H_5ClO

List has been truncated as it is 200 items long, see above link for the full list.

[20] Home - Chestnut Residence at University of Toronto. Accessed: Oct. 13, 2024. [Online]. Available: https://chestnut.utoronto.ca/wp-content/uploads/2024-25-Occupancy-Agreement.pdf

UNIVERSITY OF TORONTO | **Chestnut Residence** Spaces & Experiences

Meal Plan fees are available on the Food Services website - Meal Plans - Food Services at University of Toronto (utoronto.ca)

FACILITIES

5.0 Responsibility for Resident's Room

The Resident agrees to pay for all missing items, damages, or cleaning caused to the premises by the Resident or guest(s) during the term of this Agreement. The Resident agrees to not make any alterations, additions, or change in any way to the premises.

5.1 Responsibility for Shared Unit Facilities

All residents occupying a room or unit are jointly and severally responsible for items missing from, cleaning to, or damages caused to, the Shared Unit Facilities within the room or unit, which include, but are not necessarily limited to, the bathroom and living space.

5.2 Responsibility for Common Areas

All residents are jointly and severally responsible for items missing from, cleaning to, or damages caused to, the areas accessible by all residents, which include, but are not necessarily limited to lounges, stairwells, kitchenettes, laundry rooms, and hallways (hereinafter called the "Common Areas"). The Residence Life Office may, in its sole and absolute discretion, assign liability for missing items, cleaning, or damages caused to the Common Areas to residents occupying specific rooms, floors, or buildings.

5.3 Access & Entry

The Resident must produce their room key card for inspection by Security upon entering Chestnut Residence.

[21] "Plug socket material:Abs vs. polycarbonate." Yin Long Electric. Accessed: Dec. 2, 2024. [Online]. Available: https://elonelec.com/plug-socket-material/

[22] "What is neodymium? Definitions and examples - club Z! Tutoring." Club Z! Tutoring. Accessed: Dec. 2, 2024. [Online]. Available: https://clubztutoring.com/ed-resources/science/what-is-neodymium/#:~:text=*%20Neodymium%20is%20a%20soft%20metal,is%20attracted%20to%20magnetic%20fields.

[23] "Vacuum suction cups | schmalz." Vakuumtechnik: Automation, Handhabung, Spannen | Schmalz. Accessed: Dec. 2, 2024. [Online]. Available: https://www.schmalz.com/en-ca/vacuum-technology-for-automation/vacuum-components/vacuum-suction-cups/

[24] "Rubber materials: Shore A versus shore D." Rubber-Cal – Rubber Flooring, Sheet Rubber, Rubber Mats, and Doormats. Accessed: Dec. 2, 2024. [Online]. Available: https://rubbercal.com/shore-a-vs-shore-d#:~:text=Sheets%20of%20rubber%20are%20available,require%20a%20lot%20of%20compression.

[25] "Shore Hardness for Plastics and Rubbers: Shore A and Shore D | Xometry Pro." Xometry Pro. Accessed: Dec. 2, 2024. [Online]. Available: https://xometry.pro/en/articles/shore-hardness-for-plastics-and-rubbers/

A1.0 Appendix A: Data for Proxy Tests

A1.1 Engagement Force Testing Data

Design	Trial Number	Force till Disengagement	Average	Adjusted Value	Adjusted Value Method
Magnetron	1	7.3 N	7.4 N	14.8 N	A singular magnet roughly 4 times larger than 1 of the 8 magnets in the design was used and hence final value is adjusted by a factor of 2.
	2	6.9 N			
	3	7.5 N			
	4	7.6 N			
	5	7.7 N			
Octopi Suction	1	13 N	14 N	14 N	There was no need for an adjustment.
	2	15 N			
	3	16 N			
	4	13 N			
	5	14 N			
Spring Clamps	1	22 N	20. N	20. N	There was no need for an adjustment.
	2	12 N			
	3	23 N			
	4	22 N			
	5	21 N			
Nanotape	1	9 N	9.7 N	10 N	Velcro was a rough proxy so the final value is rounded to one significant figure.
	2	10. 5N			
	3	9.5 N			
	4	10 N			
	5	9.5 N			

A1.2 Wall Socket Compatibility Testing Data

Socket Number	Location	Magnetron	Octopi Suction	Spring Clamps	Nanotape
1	Gerstein Library 1st Floor Inner Library	Fits	Fits	Doesn't Fit	Fits
2	Gerstein Library 1st Floor Inner Library	Fits	Fits	Doesn't Fit	Fits
3	Gerstein Library 1st Floor Inner Library	Fits	Fits	Doesn't Fit	Fits
4	Gerstein Library Basement Floor	Fits	Fits	Doesn't Fit	Fits
5	Gerstein Library Basement Floor	Fits	Doesn't Fit	Doesn't Fit	Doesn't Fit

6	EngSci Common Room	Fits	Fits	Fits	Fits
7	EngSci Common Room	Fits	Fits	Fits	Fits
8	Bahen Centre First Floor	Fits	Doesn’t Fit	Doesn’t Fit	Fits
9	Bahen Centre First Floor	Fits	Doesn’t Fit	Doesn’t Fit	Fits
10	Robarts Library 6th Floor	Fits	Fits	Fits	Fits
11	Robarts Library 4th Floor	Fits	Doesn’t Fit	Fits	Fits
12	Robarts Library 7th Floor	Fits	Doesn’t Fit	Fits	Fits
13	18th Floor Chestnut Residence	Fits	Fits	Doesn’t Fit	Fits
14	18th Floor Chestnut Residence	Fits	Fits	Doesn’t Fit	Fits
15	18th Floor Chestnut Residence	Fits	Fits	Fits	Fits
16	15th Floor Chestnut Residence	Fits	Fits	Fits	Fits
17	15th Floor Chestnut Residence	Fits	Fits	Fits	Fits
18	15th Floor Chestnut Residence	Fits	Fits	Fits	Fits
19	28th Floor Chestnut Residence	Fits	Fits	Fits	Fits
20	28th Floor Chestnut Residence	Fits	Fits	Fits	Fits
21	28th Floor Chestnut Residence	Fits	Fits	Fits	Fits
22	28th Floor Chestnut Residence	Fits	Fits	Fits	Fits
23	27th Floor Chestnut Residence	Fits	Fits	Fits	Fits
24	27th Floor Chestnut Residence	Fits	Fits	Fits	Fits
25	MyHall 1st Floor	Doesn’t Fit	Doesn’t Fit	Doesn’t Fit	Doesn’t Fit
26	MyHall 4th Floor	Fits	Fits	Fits	Fits
27	MyHall 4th Floor	Fits	Fits	Fits	Fits
28	102 McLennan Physical Laboratories	Fits	Fits	Fits	Fits
29	102 McLennan Physical Laboratories	Fits	Fits	Fits	Fits
30	102 McLennan Physical Laboratories	Fits	Doesn’t Fit	Doesn’t Fit	Doesn’t Fit
31	102 McLennan Physical Laboratories	Fits	Fits	Doesn’t Fit	Fits
32	126 McLennan Physical Laboratories	Doesn’t Fit	Fits	Doesn’t Fit	Doesn’t Fit

A1.3 Deployment Time Testing Data

Design	Trial Number	Aleksandr	Ahmad	Ayan	Trail Average	Group Average
	1	2.2	2.5	1.8	2.2	
	2	1.9	2.6	2.4	2.3	
Magnetron	3	1.8	2.4	2.6	2.3	2.267
	1	5.5	5.0	3.5	4.7	
	2	4.2	3.5	3.6	3.7	

4.200

	3	4.3	4.3	4.0	4.2	
Spring Clamps	1	6.0	5.7	4.8	5.5	5.567
	2	6.4	5.3	4.9	5.5	
	3	6.4	5.6	4.8	5.7	
Nanotape	1	3.0	2.7	3.4	3.0	3.300
	2	3.6	3.9	3.2	3.6	
	3	3.3	3.6	3.0	3.3	
Status Quo	1	2.1	2.2	2.4	2.2	2.286
	2	2.4	2.0	2.3	2.2	
	3	2.3	2.5	2.4	2.4	

B1.0 Appendix B: Complete Requirements Framework

Refined Objective	Criteria		Requirement
	Metric	Evaluation	
1 The device shall not cause the plug to slip			
R1.1 Engagement Force	Force [N] Force [N] Force [N]	The engagement force shall be balanced in the middle of the range, the more suitable the balance the more suitable the design. Engagement force can change based on the tightness of the plug and so an engagement force that meets R1.1 for all use cases is best, refer to Appendix E for data on tight, well fitting, and loose use cases.	**T1.1.1** The device shall provide the plug an engagement force with the wall socket such that it is not too low to lead to slipping, and not too high to make it difficult to detach the plug. An engagement force of 13 N shall be provided to ensure secure plug retention based on UL 498 [10]. A maximum engagement force can be at 67N to ensure that the plug can be removed easily based on UL 498 [10].
R1.2 Electrical Continuity	Contact Resistance [mΩ]	The lower the contact the resistance the more suitable the design as resistive heating is reduced thereby reducing the risk of fire.	**T1.2.1** The device shall not affect the electrical continuity between the plug and the socket by maintaining a contact resistance below 10 mΩ between the wall socket and the plug pins based on IEC 60512-2-1 [11] which indicated a low electrical continuity and general market values for North American Plugs.
2 The device shall be portable			
R2.1 Maximum Mass Limit	Mass [g]	The lower the weight the more suitable the design as the user would be more inclined to use it as it would	**T2.1.1** The device shall weigh no more than 60g to allow for the device to carry easily as suggested by primary

		not weigh them down, it would appeal to the convenient need.	stakeholder needs through questioning Engineering Science Students.
R2.2 Maximum Volume Limit	Volume [cm^3]	The smaller the volume the more suitable the design as the user would be more inclined to use it if it was not bulky, it would appeal to the convenient need.	**T2.2.1** The device shall not have a volume larger than 150 cm^3.
R2.3 Deployment Time	Deployment Time [s]	The shorter the time the more suitable the design as the user would be more inclined to use it if it did not take time to setup, it would appeal to the convenient need.	**T2.3.1** The device shall take no longer than 5s increase in deployment compared to using a typical plug-wall socket arrangement. It shall also add no more than 5s in removal time compared to a typical plug-wall-socket arrangement.
3 The device shall not leave a permanent impact			
R3.1 Adhesive Residue	*Visual Inspection* Adhesive Scale	The higher the adhesive scale test passed the more suitable the design.	**T3.1.1** The device shall not use permanent adhesives or leave residue after the removal of the device based on ASTM D3359 [3]. Adhesive scale residue shall be met at Permanent residue damages the wall socket and increases deployment/removal time in R2.3.
R3.2 Specialized Tool Use	*Visual Inspection*	The faster to remove the design the more suitable the design, this is linked to R2.3	**T3.2.1** The device shall be removable by hand without the need of any tools or any specialized tools. This allows for the deployment/removal time in R2.3 to be low and meets the needs of portability of the primary stakeholders too.
R3.3 Wall Socket Modifications	*Visual Inspection*	The less invasive the design the more suitable in the sense that it does latches onto less surface than other devices, etc.	**T3.3.1** The device shall not require any medication to existing wall sockets or electrical installation. This is due to the primary stakeholder need of being portable and usable on Campus as well as on Chestnut Residence [20].
R3.4 Material Hardness	Shore Hardness [Shore A]	There is a balance in the sense that softer materials are prone to warping whilst harder materials are prone to cracking due to their brittle nature [31]. A successful balance gives rise to a more suitable design.	**T3.4.1** The device shall have material that is in contact with the plug or wall socket and have a Shore Hardness of less than 70A to prevent scratching and wear on the wall socket and plug based on ISO 868 [13]. Primary Stakeholder analysis identified that Engineering Science students expected a potential solution to serve

		This means the shore hardness should be optimized to fulfil both R3.4 and R5.4. A suitable design balances both regimes.	them for at least 3 years and so softer materials are prone to breaking – there is indeed a balance that must be made.
R3.5 Insertion and Removal Cycles	*Visual Inspection* Contact Resistance [mΩ]	The longer the design lasts through the insertion and removal cycles the more suitable.	**T3.5.1** The device shall be able to last 8000 insertion and removal cycles without wear to the point that product becomes dangerous or unusable as identified in R1.2 and R1.1 respectively. Contact resistance can be measured at the end of the cycles.
4 The device shall not be an Electrical Safety Hazard			
R4.1 Short Circuit Prevention	Voltage Drop [V]	The lower the voltage drop the more suitable the design.	**T4.1.1** The device shall prevent contact between the live and neutral plug pins during insertion or removable to avoid short circuits as required by the Canadian safety code CSA C22.2 No. 42 [30], alongside general Canadian electrical safety code CSA C22.1 [26].
R4.2 Electrical Insulation Resistance	Insulation Resistance [MΩ]	The greater the insulation resistance the more suitable the design, however this must be balanced with R3.4 and R5.4, R2.1, and R2.2 to ensure that the device is not too heavy, bulky, hard material-wise, etc.	**T4.2.1** The device shall provide an electrical insulation such that the resistance between the plug pins (at their base) and all the contact surfaces the user would be able to reach is no less than 100 MΩ as required by Canadian electrical safety code CSA C22.1 [26]. Measure the insulation resistance between the base of the plug pins and all contact surfaces the user would be able to reach during *operation* using a megohmmeter. **T4.2.2** Measure the insulation resistance between the base of the plug pins and all contact surfaces the user would be able to reach during *insertion/removal* using a megohmmeter.
R4.3 Earthing and Ground	*Visual Inspection*	The less invasive a device (as balanced by R3.3) the more suitable the design.	**T4.3.1** The device shall not interfere with any ground systems of the plug, wall socket, or connected appliances as required by Canadian safety code CSA C22.2 No.0.4 [30], alongside general Canadian electrical safety code CSA

			C22.1 [26]. A visual inspection can be completed. If there is no visual interference (such as mechanisms or bodies interfering) then the test is passed. **T4.3.2** A live test can be completed under failure conditions in which the grounding system of an appliance is used without the device and then is completed with the device installed. If the grounding system is to work in both cases the test is passed.
R4.4 Dielectric Breakdown Protection	Current [A]	The lower the current flow the more suitable the design.	**T4.4.1** The device must be able to withstand a dielectric voltage of 240V between the plug pins and all contact surfaces the user would be able to reach such that no breakdown of the material occurs and current flows through the material.
5 The device shall not be an Other (Type of) Safety Hazard			
R5.1 Fire and Heat Resistance	Temperature [C]	The lower the temperature, the more suitable the design. Lower temperatures make the device more usable and safer.	**T5.1.1** All plugs and sockets must pass test 8.9.1 in the CSA C22.2 No. 42-10 [30], so the maximum temperature of the plug-socket system is 55 degrees Celsius. The device must not exceed 55 degrees Celsius over 4 hours of continuous use at the plug's maximum rated load.
R5.2 Sharp Edges	*Visual Inspection*	The less visible deformations on the test paper, the more suitable the design.	**T5.2.1** As informed by stakeholder analysis, the device will be deployed often sloppily in hectic environments (like the beginning or end of a lecture). It will also be carried in backpacks next to cables and notebooks. The device shall not be sharp enough to cut the user, cables or paper.
R5.3 Non-Toxic Materials	Inspection	The less materials containing toxic substances, the more suitable the design.	**T5.3.1** Must not use any materials that contain any toxic substances as outlined in the Canadian Environment Protection Act [15].
R5.4 Mechanical Strength	*Visual Inspection*	The less visually noticeable deformations and/or loosening of parts that could affect the functioning of the	**T5.5.1** Must pass the Mechanical Endurance test outlined in section 8.35.4 of the CSA C22.2 No. 42-10 [30].

		device, the more suitable the design.	
6 The device shall be generalized such that all North American plugs can fit			
R6.1 Minimum Receiving Size	Length [cm] Length [cm] Length [cm]	The larger the plug analogue handled the more suitable the design.	**T6.1.1** The device shall be able to handle effectively a plug that has the minimum dimensions of 10.0cm by 7.50cm by 6.00cm as given by Appendix C.
R6.2 Wall Socket Compatibility	*Visual Inspection*	The more surfaces that a given device can fit to the more suitable the design.	**T 6.2.1** The device shall be able to fit over all plugs that Engineering Science students use, this means that the device shall: one, be able to fit around table-edge-wall-sockets, two fit onto flat-wall-sockets, and three around low-profile-wall-sockets.

C1.0 Appendix C: Complete Testing Strategies

To ensure that a design can be tested against the above the following test methods and failure/success states have been developed.

Test Case Identifier	States		Method
	Success	**Failure**	
1 The device shall not cause the plug to slip			
T1.1.1	Engagement force greater than or equal to 13N Engagement force less than or equal to 67N	Engagement force less than 13N OR Engagement force greater than 67N	Gradually increase the pullout force applied on the plug, measure the max force until the plug slips out using a newton meter. Ensure that there is a range of plugs used as given in Appendix E.
T1.2.1	Contact Resistance less than 100 mΩ	Contact Resistance greater than 100 mΩ	Measure the contact resistance between the plug pins and the wall socket receptacles using a multimeter. A wall socket analogue can be used by using a metal strip the same width as the metal prongs and resistance measured between the two.
2 The device shall be portable			
T2.1.1	Mass less than or equal to 60g	Mass greater than 60g	Measure mass using an electronic Balance.
T2.2.1	Volume less than or equal to 150 cm^3	Volume greater than 150 cm^3	Measure the side lengths using a pair of calipers and then use the following equation to find the volume: $length \times width \times height$

			Ensure that lengths are in cm.
T2.3.1	Average Deployment and Removal time less than or equal to 5s	Average Deployment and Removal time greater than 5s	Time a range of Engineering Science Students' (or equivalent demographic) times to deploy and remove their plugs with and without the device. Take the average and compare the times using the following equation: $(time\ taken\ with\ device) - (time\ take$ $)$ Ensure that averages are taken for removal and deployment separately.
3 The device shall not leave a permanent impact			
T3.1.1	Visual Inspection of the paint strips shows that paint has not been stripped	Visual Inspection of the paint strips shows that paint has been stripped	Follow ASTM D3359 Adhesive Scale testing procedure [12] as outlined in the standard and in the following video [28].
T3.2.1	The only tools require are one's hands	Tools other than one's hands are involved	Visual Inspection shall be sufficient.
T3.3.1	The device does not modify and wall sockets	The device modifies wall sockets	Visual Inspection shall be sufficient.
T3.4.1	Shore hardness is less than or equal to 70A	Shore hardness is greater than 70A	Take the material datasheet of the constituent materials of the design and compare their Shore Hardness level to 70A.
T3.5.1	Contact Resistance less than 100 mΩ	Contact Resistance greater than 100 mΩ	Perform 8000 insertion/removal cycles and measure the contact resistance between the plug pins and the wall socket receptacles using a multimeter. Ensure that the wall socket receptacle pins are of the same material hardness than the plug pins to ensure that only the contact capability of the device is measured and not the wear of typical household plug-wall-socket usage.
4 The device shall not be an Electrical Safety Hazard			
T4.1.1	Voltage drop less than or equal to 3V	Voltage drop greater than 3V	The primary stakeholder analysis determined that a long-lasting solution is desired. Perform 10000 simulated insertion/removal tests where voltage is monitored to ensure that this is a voltage drop of no more than 3V voltage drop across the plug pings during these cycles. Applied voltage shall be tested at 120V as that is the voltage used in Canada [26].

T4.2.1	Insulation resistance greater than or equal to 100 MΩ	Insulation resistance less than 100 MΩ	Measure the insulation resistance between the base of the plug pins and all contact surfaces the user would be able to reach during *operation* using a megohmmeter.
T4.2.2	Insulation resistance greater than or equal to 100 MΩ	Insulation resistance less than 100 MΩ	Measure the insulation resistance between the base of the plug pins and all contact surfaces the user would be able to reach during *insertion/removal* using a megohmmeter.
T4.3.1	Visual inspection of the systems yields that there is no physical mechanism collision	Visual inspection of the systems yields that there is a physical mechanism collision	Visual Inspection shall be sufficient.
T4.3.2	Grounding or earthing system activates under activation condition of appliance	Grounding or earthing system fails to activate under activation condition of appliance	A live test can be completed under failure conditions in which the grounding system of an appliance is used without the device and then is completed with the device installed. If the grounding system is to work in both cases the test is passed. Ensure a range of appliances and devices are used (chargers, kettles, mini fridges) as identified by the primary stakeholder analysis.
T4.4.1	A current less than or equal to 0.0001A flows during the edge case test	A current greater than 0.0001A flows during the edge case test	Apply 240V dielectric voltage across the live (and neutral pin in a consecutive test) and a contact surface that a user would be able to touch. Measure current flow using a bench multimeter (a recommended instrument would be the HP Agilent 34401A, a similar bench multimeter is available at MyFab LFF), no greater than 0.0001A is to flow [26].
5 The device shall not be an Other (Type of) Safety Hazard			
T5.1.1	For the entirety of the test Temperature is less or equal to 55 degrees Celsius.	At some point during the test the temperature spikes above 55 degrees Celsius.	Deploy the device to secure a plug – socket connection. Apply the maximum rated load for the plug chosen for 4 hours. Repeat with at least 3 plugs of different dimensions (as shown in Appendix E).
T5.2.1	There are no major deformations to the paper from any of the edges of the device.	There are major deformations to the paper from at least one of the edges of the device.	On a test surface, a paper shall be placed. Each edge of the device shall be subjected to 30 N of vertical force and scraped along the paper. A major deformation is one that can be seen and felt. A minor deformation is a

			visibly noticeable deformation but smooth to the touch.
T5.3.1	Does not contain materials in the toxic materials list of the CEPA legislation	Contains materials in the toxic materials list of the CEPA legislation	Visual inspection of the materials used in the device.
T5.4.1	There are no visible deformations, and the tensile strength has not been affected	There are visible deformations or/and tensile strength has been affected	Follow the CSA C22.2 testing procedures for the Mechanical Endurance Test in section 8.9 [30] with one exclusion; the removals and insertions are to be done by hand instead of using a machine as the code suggests.
6 The device shall be generalized such that all North American plugs can fit			
T6.1.1	The device can handle plugs that are of size 10.0cm by 7.50cm by 6.00cm or less	The device cannot handle plugs that are of size 10.0cm by 7.50cm by 6.00cm or less	Measure max size of plug handled by plug using a ruler and compare to Appendix E.
T6.1.2	The device is able to fit flatly on a wall.	The device is not able to fit flatly on a wall.	Through visual inspection the design shall be able fit onto flat-wall-sockets. Additionally, it is recommended that it be able to fit around table-edge-wall-sockets, and around low-profile-wall-sockets. These can be tested at the locations outlined in appendix E.

D1.0 Appendix D: Plug Dimension Analysis

Plug Description	Image	Maximum Height	Maximum Width	Maximum Thickness	Source
Slim-Flat Type A		2 cm	3 cm	4 cm	[2]
Slim-Fast Type B		4 cm	3 cm	4 cm	[3]
Rounded		5 cm	5 cm	5 cm	[4]

Cubed		4 cm	4 cm	5 cm	[5]
Side-Facing Offset		7 cm	7 cm	5 cm	[6]
Large Universal Adapter		10 cm	7.5 cm	6 cm	[7]
Wall Attached Transformer		8 cm	7.5 cm	5 cm	[8]
Plug with built in Extension Cord		10 cm	7.5cm	6 cm	[9]
		10	7.5	6	
		Maximum Overall Height	Maximum Overall Width	Maximum Overall Length	

E1.0 Appendix E: Plug Fitting Data

Represented below is the data collected throughout spaces frequented by Engineering Science students and Chestnut Residence with a particular focus on spaces that Engineering Science Students use.

Socket Number	Location	Direction of Wall Socket	Fitting of Mid Type B Plug	Fitting of Heavy Type A Plug	Fitting of Light Type B Plug
1	Gerstein Library 1st Floor Main Hall	Upwards	Fits Well	Fits Well	Tight
2	Gerstein Library 1st Floor Main Hall	Upwards	Fits Well	Fits Well	Tight
3	Gerstein Library 1st Floor Main Hall	Upwards	Loose	Loose	Fits Well
4	Gerstein Library 1st Floor Main Hall	Upwards	Loose	Loose	Fits Well
5	Gerstein Library Reading Room	Upwards	Fits Well	Fits Well	Tight

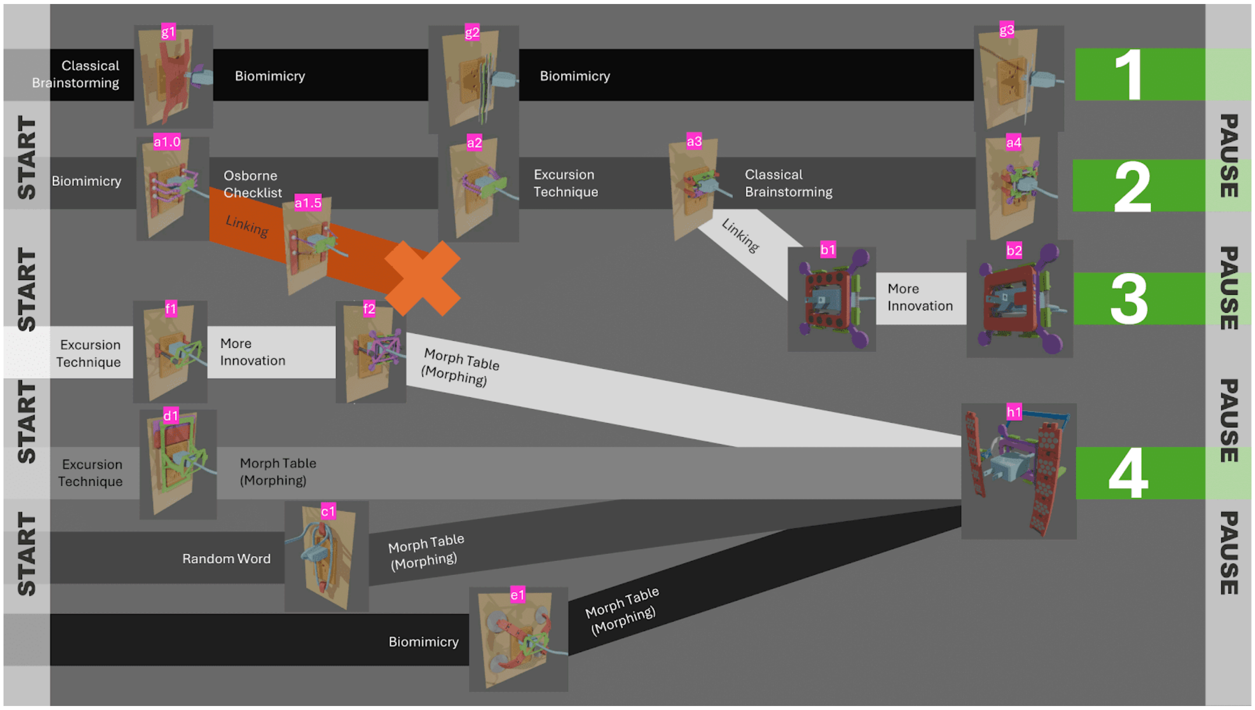
6	Gerstein Library Reading Room	Sideways	Fits Well	Fits Well	Tight
7	Gerstein Library Reading Room	Sideways	Fits Well	Loose	Fits Well
8	Gerstein Library Reading Room	Sideways	Fits Well	Loose	Fits Well
9	Gerstein Library 1st Floor Inner Library	Upwards	Fits Well	Fits Well	Fits Well
10	Gerstein Library 1st Floor Inner Library	Upwards	Fits Well	Loose	Fits Well
11	Gerstein Library 1st Floor Inner Library	Sideways	Fits Well	Fits Well	Tight
12	Gerstein Library 1st Floor Inner Library	Sideways	Loose	Loose	Loose
13	Gerstein Library 1st Floor Inner Library	Sideways	Loose	Loose	Loose
14	Gerstein Library 1st Floor Inner Library	Upwards	Fits Well	Loose	Fits Well
15	Gerstein Library 1st Floor Inner Library	Upwards	Loose	Loose	Loose
16	Gerstein Library Reading Room	Upwards	Fits Well	Fits Well	Fits Well
17	Gerstein Library Reading Room	Upwards	Fits Well	Loose	Fits Well
18	Gerstein Library Reading Room	Upwards	Fits Well	Fits Well	Fits Well
19	Gerstein Library Reading Room	Upwards	Fits Well	Fits Well	Fits Well
20	Gerstein Library 2nd Floor Inner Library	Upwards	Fits Well	Fits Well	Fits Well
21	Gerstein Library 2nd Floor Inner Library	Upwards	Fits Well	Loose	Fits Well
22	Gerstein Library 2nd Floor Inner Library	Upwards	Fits Well	Fits Well	Fits Well
23	Gerstein Library 2nd Floor Inner Library	Sideways	Fits Well	Loose	Fits Well
24	Gerstein Library Basement Floor	Sideways	Fits Well	Loose	Fits Well
25	Gerstein Library Basement Floor	Sideways	Loose	Loose	Loose
26	Gerstein Library Basement Floor	Sideways	Loose	Loose	Loose
27	Gerstein Library Basement Floor	Sideways	Tight	Tight	Tight
28	Gerstein Library Basement Floor	Sideways	Tight	Tight	Tight
29	Gerstein Library Basement Floor	Sideways	Tight	Tight	Fits Well
30	Gerstein Library Basement Floor	Sideways	Tight	Tight	Fits Well
31	Bahen Centre 1st Floor	Sideways	Fits Well	Loose	Fits Well
32	Bahen Centre 1st Floor	Sideways	Fits Well	Loose	Fits Well
33	Bahen Centre 1st Floor	Sideways	Fits Well	Loose	Fits Well
34	EngSci Common Room	Sideways	Tight	Tight	Loose
35	EngSci Common Room	Sideways	Tight	Tight	Loose
36	EngSci Common Room	Sideways	Fits Well	Fits Well	Fits Well
37	EngSci Common Room	Sideways	Fits Well	Fits Well	Fits Well
38	EngSci Common Room	Sideways	Fits Well	Loose	Fits Well
39	EngSci Common Room	Sideways	Fits Well	Fits Well	Fits Well
40	EngSci Common Room	Sideways	Fits Well	Loose	Fits Well
41	EngSci Common Room	Sideways	Fits Well	Fits Well	Fits Well
42	EngSci Common Room	Sideways	Fits Well	Loose	Fits Well

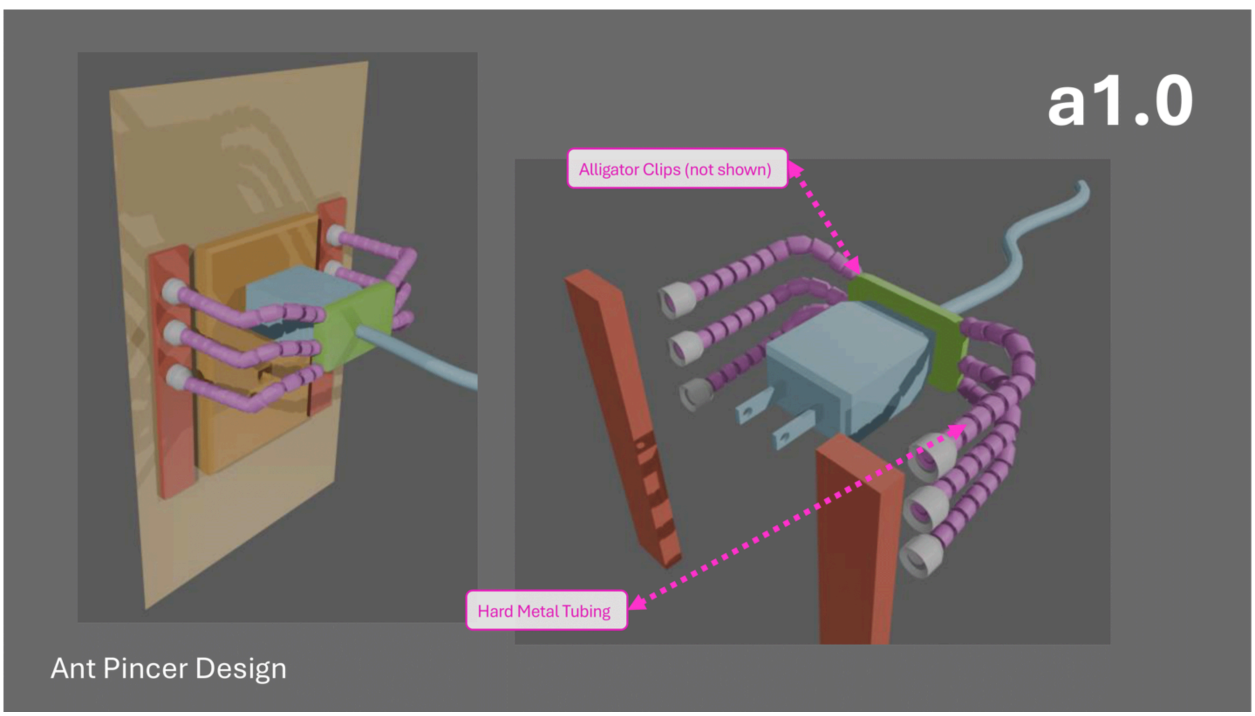
43	EngSci Common Room	Sideways	Fits Well	Fits Well	Fits Well
44	EngSci Common Room	Upwards	Fits Well	Fits Well	Fits Well
45	EngSci Common Room	Upwards	Fits Well	Loose	Fits Well
46	Bahen Centre 1st Floor	Upwards	Tight	Fits Well	Tight
47	Bahen Centre 1st Floor	Upwards	Tight	Fits Well	Tight
48	Bahen Centre 1st Floor	Upwards	Tight	Fits Well	Tight
49	Bahen Centre 1st Floor	Upwards	Loose	Loose	Loose
50	Bahen Centre 1st Floor	Upwards	Loose	Loose	Loose
51	Bahen Centre 1st Floor	Upwards	Fits Well	Fits Well	Fits Well
52	Bahen Centre 1st Floor	Upwards	Fits Well	Loose	Fits Well
53	Bahen Centre 2nd Floor	Upwards	Fits Well	Fits Well	Fits Well
54	Bahen Centre 2nd Floor	Sideways	Tight	Tight	Tight
55	Bahen Centre 2nd Floor	Sideways	Tight	Tight	Tight
56	Robarts Library 6th Floor	Sideways	Fits Well	Fits Well	Fits Well
57	Robarts Library 6th Floor	Upwards	Fits Well	Fits Well	Fits Well
58	Robarts Library 6th Floor	Sideways	Fits Well	Loose	Fits Well
59	Robarts Library 6th Floor	Upwards	Fits Well	Fits Well	Fits Well
60	Robarts Library 6th Floor	Sideways	Fits Well	Loose	Fits Well
61	Robarts Library 6th Floor	Upwards	Loose	Loose	Loose
62	Robarts Library 6th Floor	Upwards	Fits Well	Fits Well	Fits Well
63	Robarts Library 6th Floor	Upwards	Tight	Tight	Tight
64	Robarts Library 4th Floor	Sideways	Loose	Loose	Loose
65	Robarts Library 4th Floor	Sideways	Loose	Loose	Loose
66	Robarts Library 4th Floor	Sideways	Fits Well	Fits Well	Fits Well
67	Robarts Library 4th Floor	Sideways	Loose	Loose	Loose
68	Robarts Library 7th Floor	Sideways	Fits Well	Fits Well	Fits Well
69	Robarts Library 7th Floor	Sideways	Fits Well	Fits Well	Fits Well
70	Robarts Library 7th Floor	Sideways	Loose	Loose	Loose
71	Robarts Library 7th Floor	Sideways	Tight	Fits Well	Tight
72	18th Floor Chestnut Residence	Sideways	Loose	Loose	Fits Well
73	18th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
74	18th Floor Chestnut Residence	Sideways	Fits Well	Fits Well	Fits Well
75	18th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
76	18th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
77	18th Floor Chestnut Residence	Sideways	Loose	Loose	Fits Well
78	15th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
79	15th Floor Chestnut Residence	Sideways	Loose	Loose	Fits Well

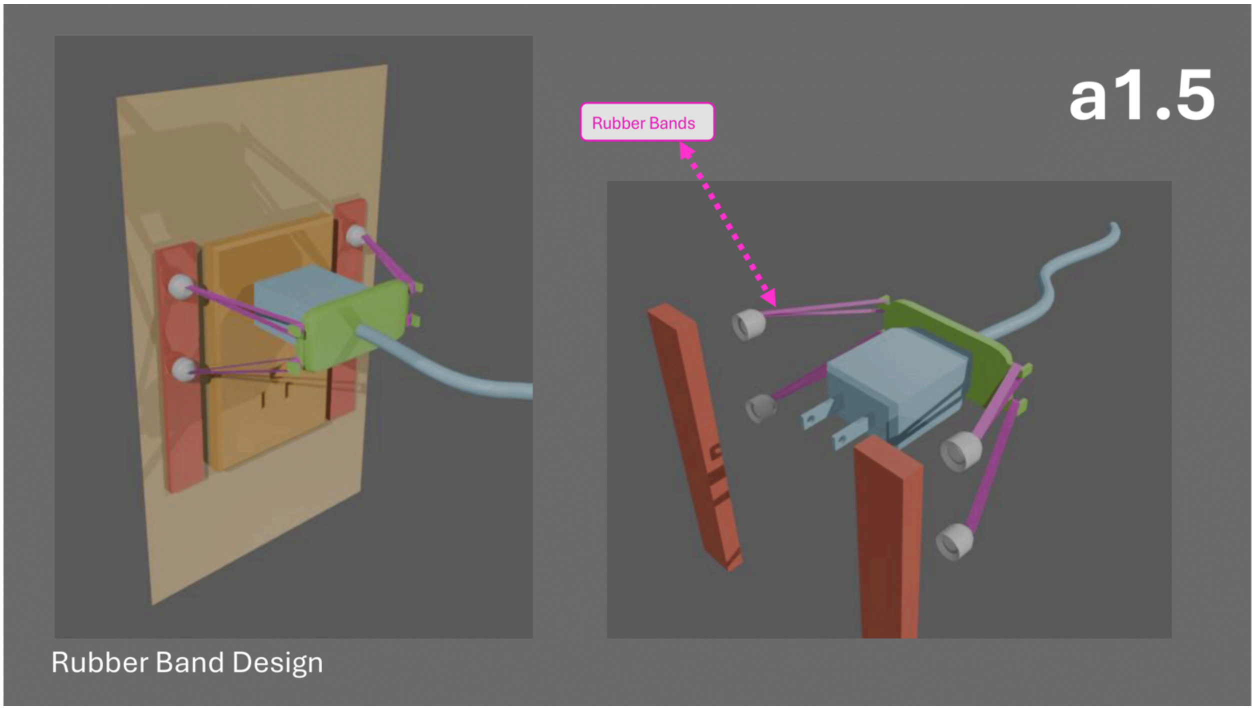
80	15th Floor Chestnut Residence	Sideways	Fits Well	Fits Well	Fits Well
81	15th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
82	15th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
83	28th Floor Chestnut Residence	Sideways	Loose	Loose	Fits Well
84	28th Floor Chestnut Residence	Sideways	Loose	Loose	Fits Well
85	28th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
86	28th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
87	28th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
88	28th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
89	27th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
90	27th Floor Chestnut Residence	Sideways	Loose	Loose	Fits Well
91	27th Floor Chestnut Residence	Sideways	Fits Well	Fits Well	Fits Well
92	27th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
93	MyHall 1st Floor	Sideways	Fits Well	Fits Well	Fits Well
94	MyHall 1st Floor	Sideways	Fits Well	Loose	Fits Well
95	MyHall 1st Floor	Sideways	Loose	Loose	Loose
96	MyHall 1st Floor	Sideways	Fits Well	Fits Well	Fits Well
97	MyHall 1st Floor	Sideways	Fits Well	Loose	Fits Well
98	MyHall 1st Floor	Sideways	Fits Well	Loose	Fits Well
99	MyHall 1st Floor	Downwards	Fits Well	Loose	Fits Well
100	MyHall 1st Floor	Downwards	Fits Well	Loose	Fits Well
101	MyHall 3rd Floor	Sideways	Fits Well	Fits Well	Tight
102	MyHall 3rd Floor	Sideways	Tight	Fits Well	Tight
103	MyHall 3rd Floor	Sideways	Tight	Tight	Tight
104	MyHall 3rd Floor	Sideways	Tight	Fits Well	Tight
105	MyHall 3rd Floor	Upwards	Tight	Tight	Tight
106	MyHall 3rd Floor	Upwards	Fits Well	Loose	Fits Well
107	MyHall 3rd Floor	Upwards	Fits Well	Fits Well	Fits Well
108	MyHall 3rd Floor	Upwards	Fits Well	Loose	Fits Well
109	MyHall 4th Floor	Sideways	Fits Well	Fits Well	Fits Well
110	MyHall 4th Floor	Sideways	Loose	Loose	Loose
111	MyHall 4th Floor	Sideways	Loose	Loose	Loose
112	102 McLennan Physical Laboratories	Upwards	Fits Well	Fits Well	Fits Well
113	102 McLennan Physical Laboratories	Upwards	Fits Well	Loose	Fits Well
114	102 McLennan Physical Laboratories	Upwards	Loose	Loose	Loose
115	102 McLennan Physical Laboratories	Downwards	Loose	Loose	Loose
116	102 McLennan Physical Laboratories	Downwards	Loose	Loose	Loose

117	102 McLennan Physical Laboratories	Downwards	Loose	Loose	Loose
118	126 McLennan Physical Laboratories	Upwards	Fits Well	Fits Well	Fits Well
119	126 McLennan Physical Laboratories	Upwards	Tight	Loose	Tight
120	126 McLennan Physical Laboratories	Downwards	Tight	Tight	Tight
121	126 McLennan Physical Laboratories	Sideways	Tight	Fits Well	Tight
122	126 McLennan Physical Laboratories	Sideways	Fits Well	Fits Well	Tight
123	126 McLennan Physical Laboratories	Upwards	Fits Well	Fits Well	Fits Well
124	126 McLennan Physical Laboratories	Upwards	Loose	Loose	Loose
		Loose:	40	67	32
		Fits Well:	63	44	67
		Tight:	20	12	23

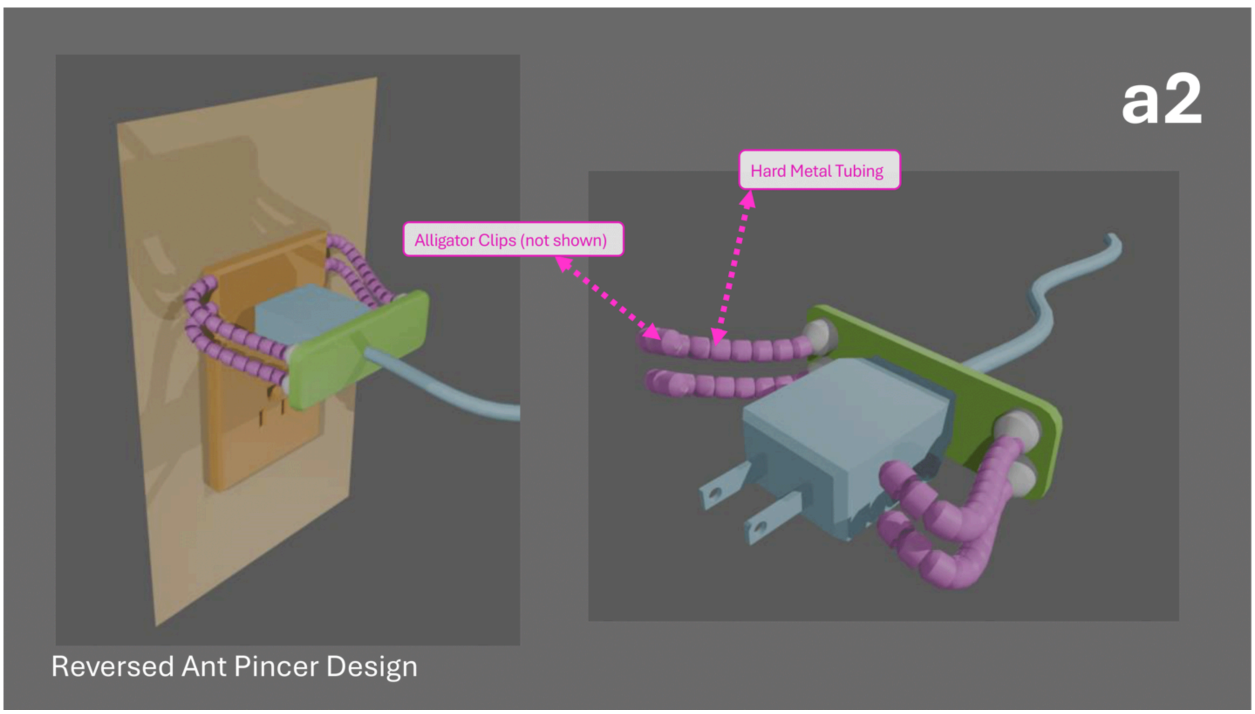
F1.0 Appendix F: Intermediary CAD Prototypes



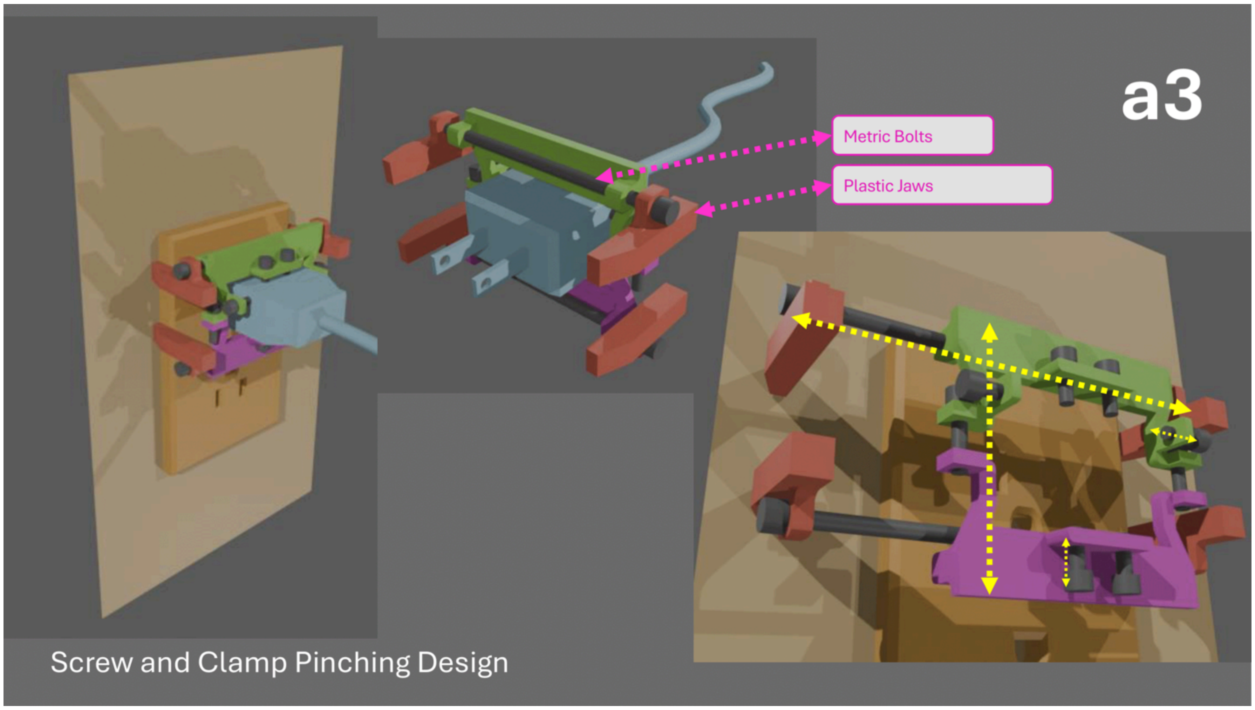


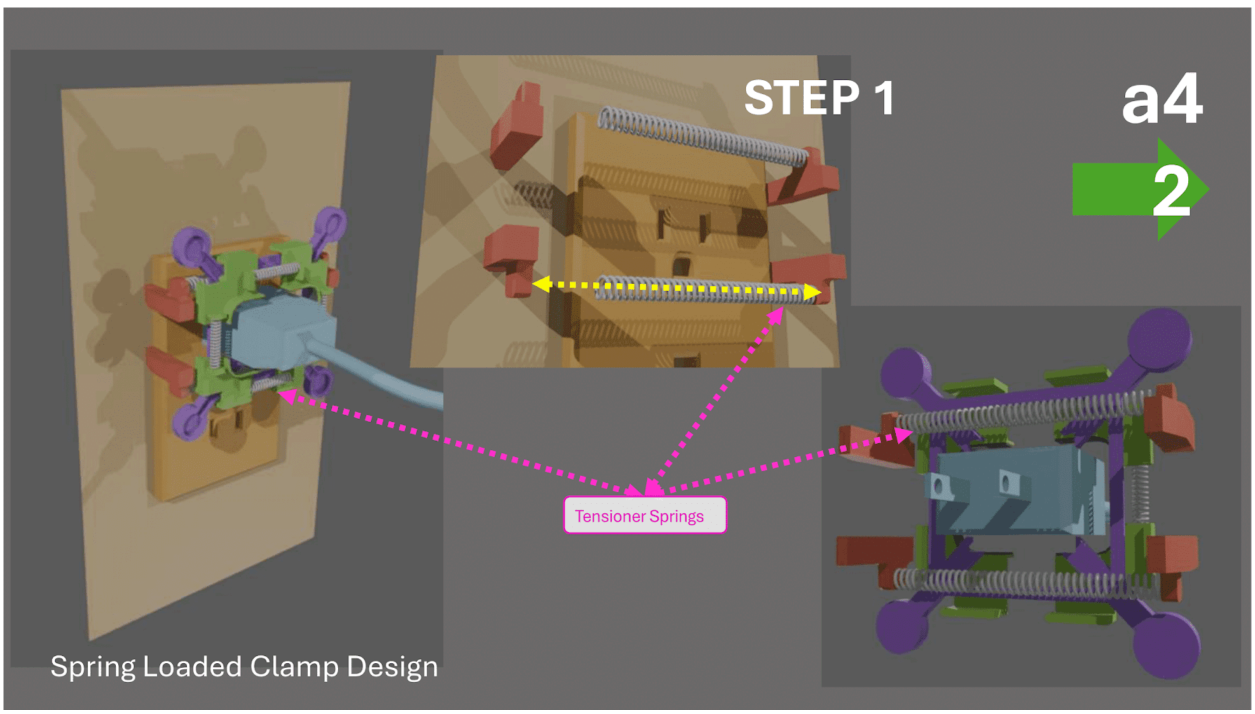


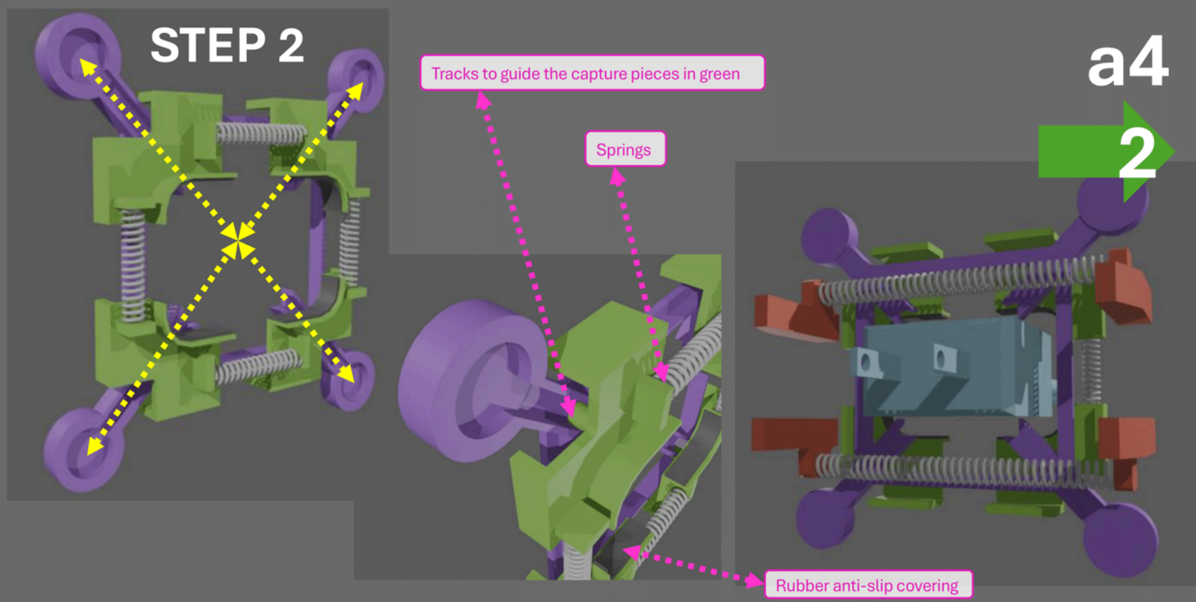
Rubber Band Design



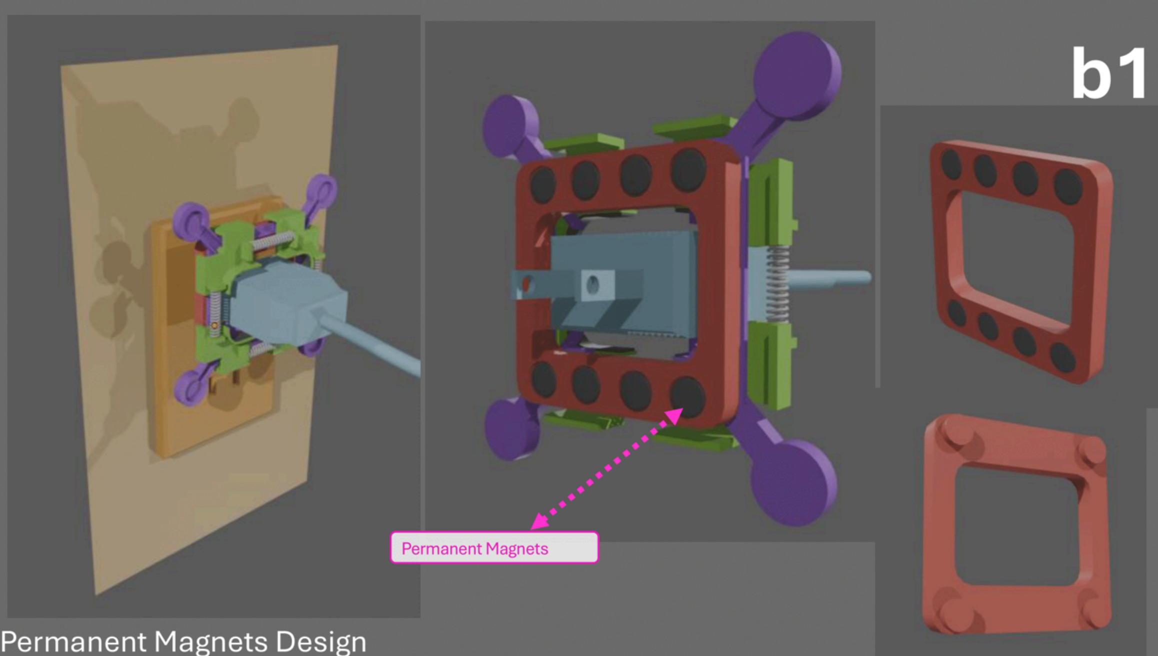
Reversed Ant Pincer Design


a3
Metric Bolts
Plastic Jaws
Screw and Clamp Pinching Design

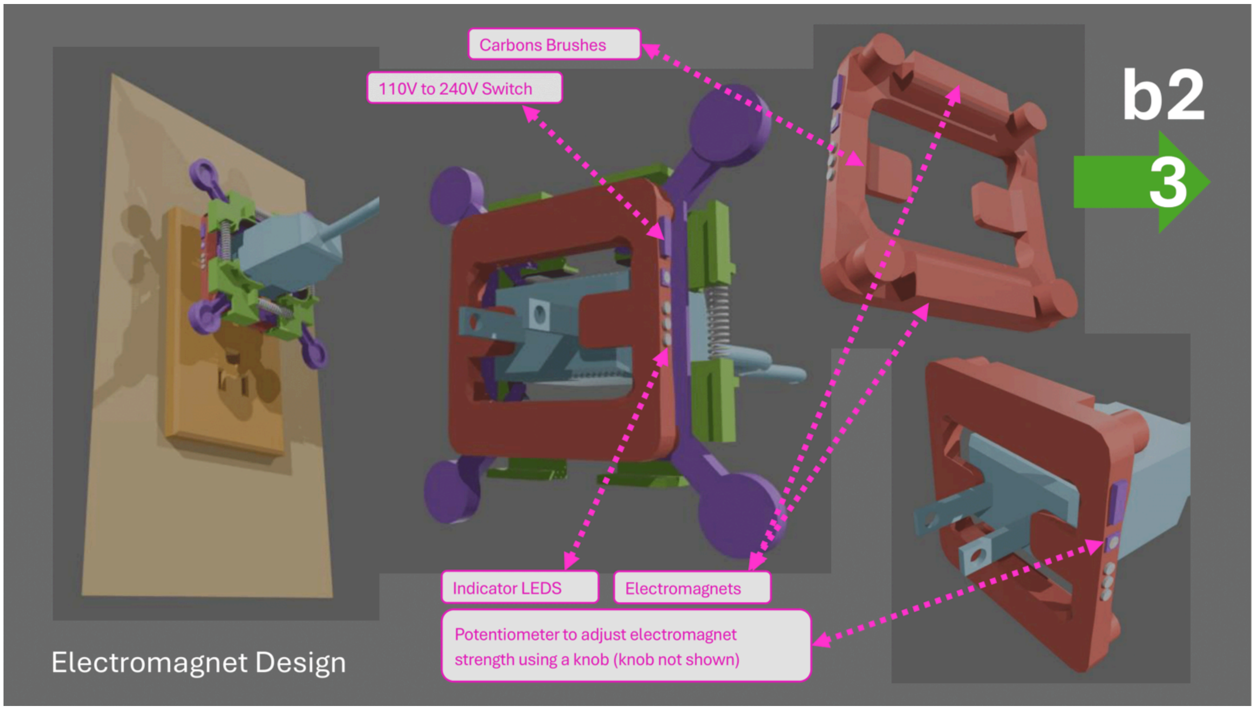

STEP 1
a4
2
Tensioner Springs
Spring Loaded Clamp Design

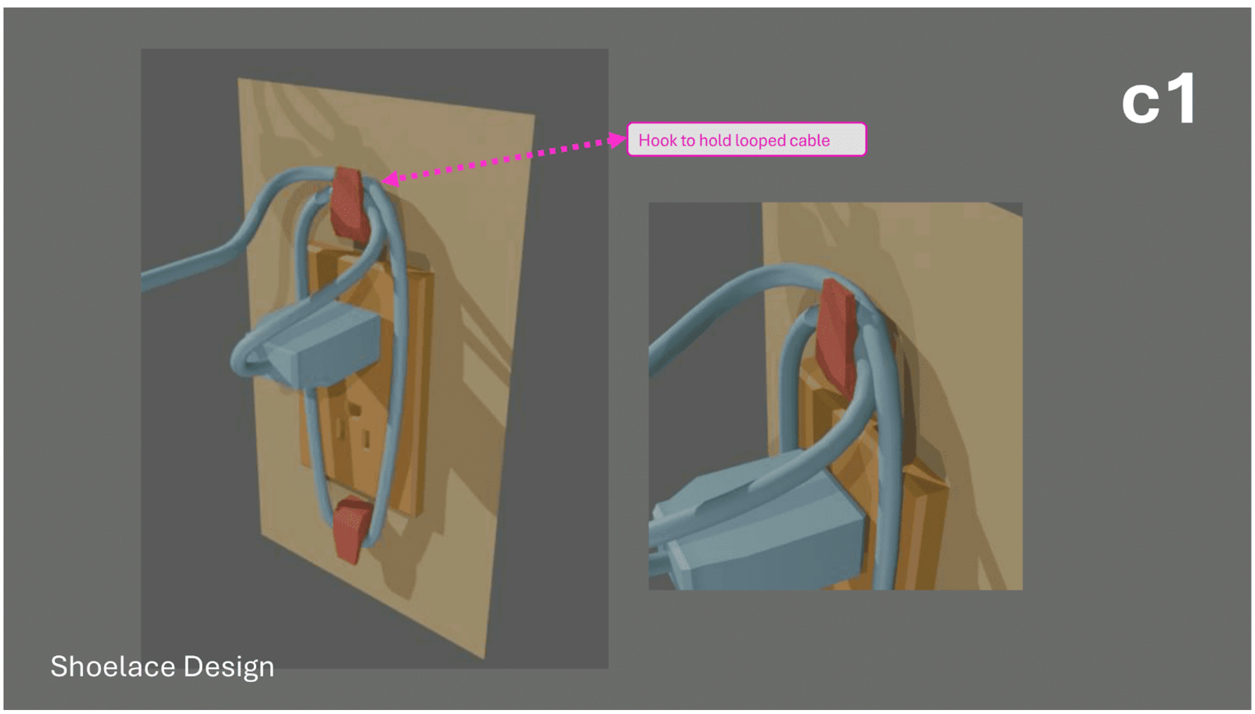


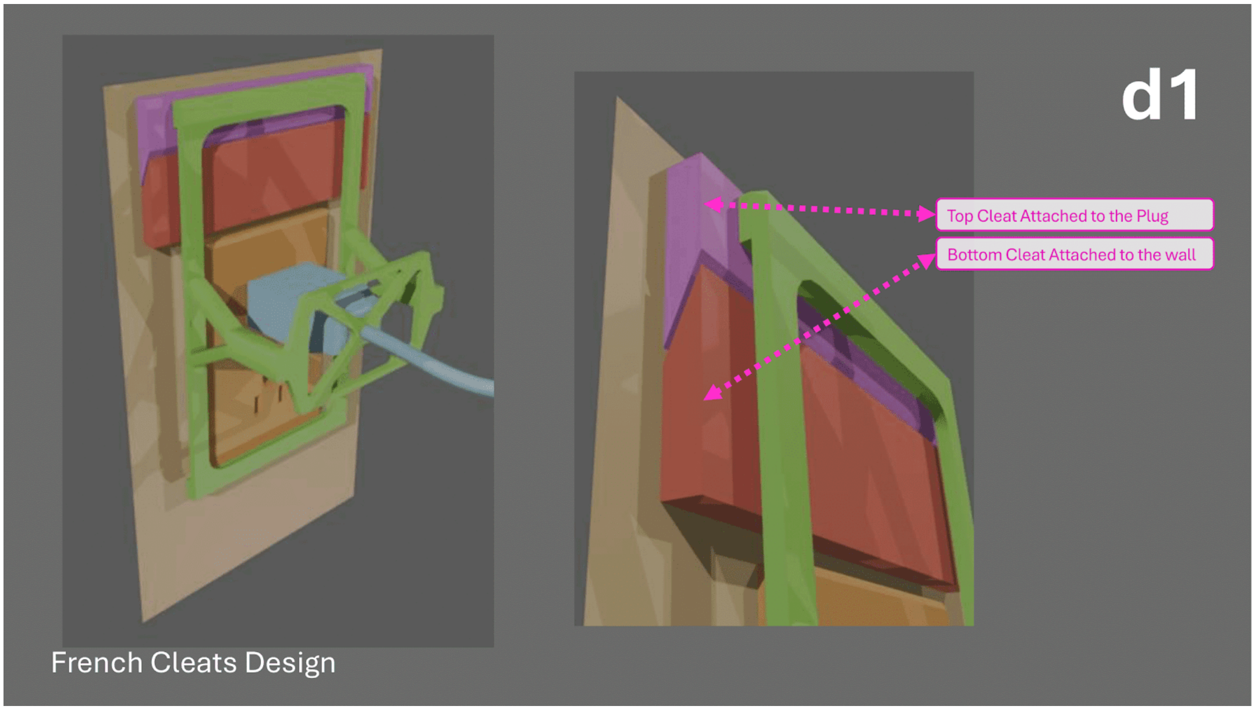
Spring Loaded Clamp Design Continued

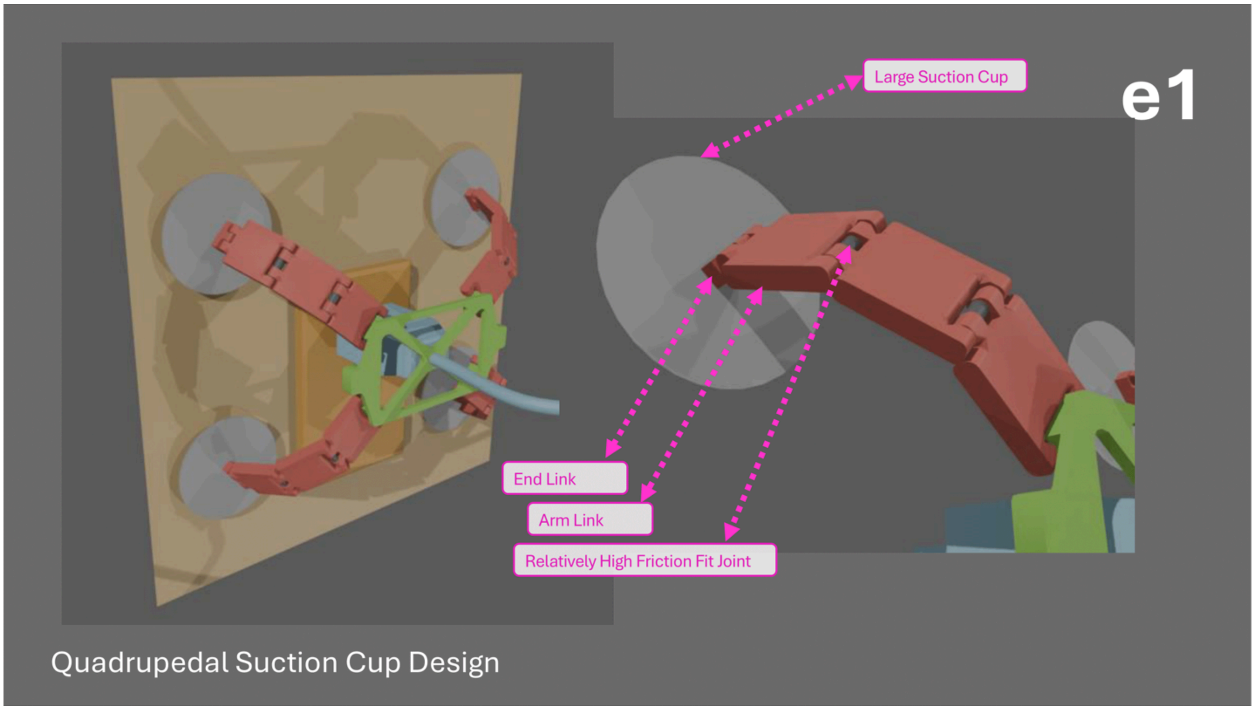


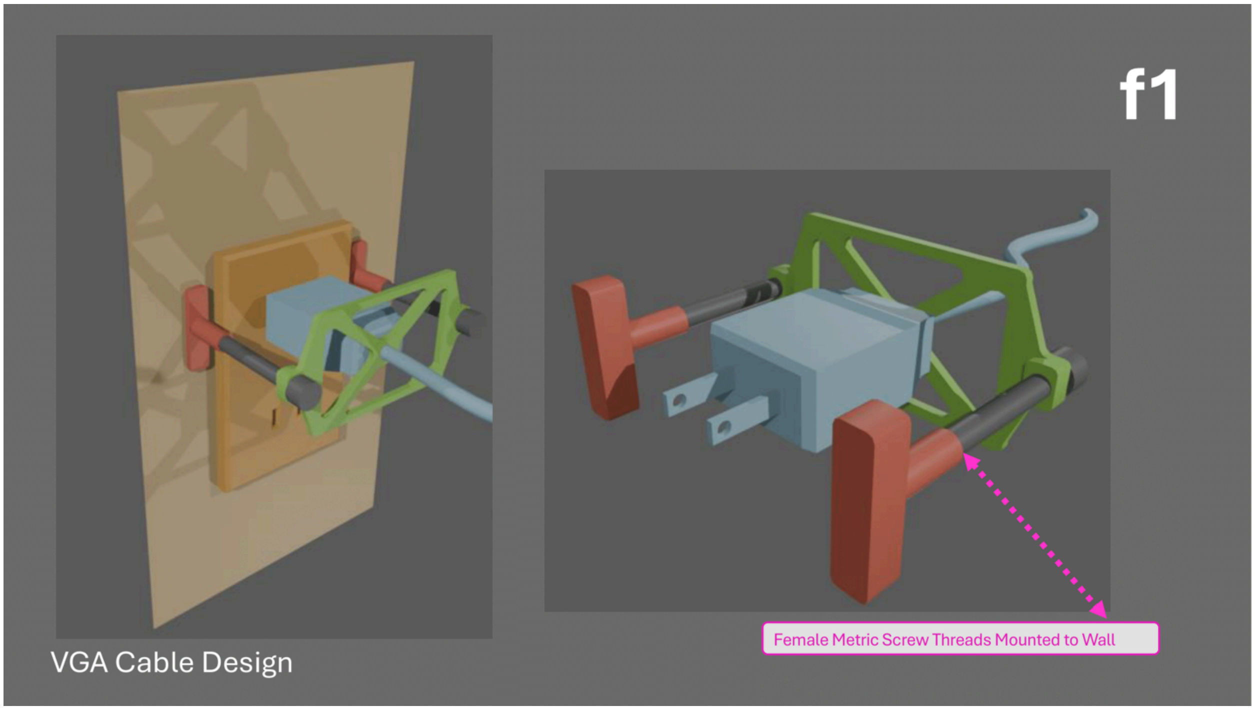
Permanent Magnets Design

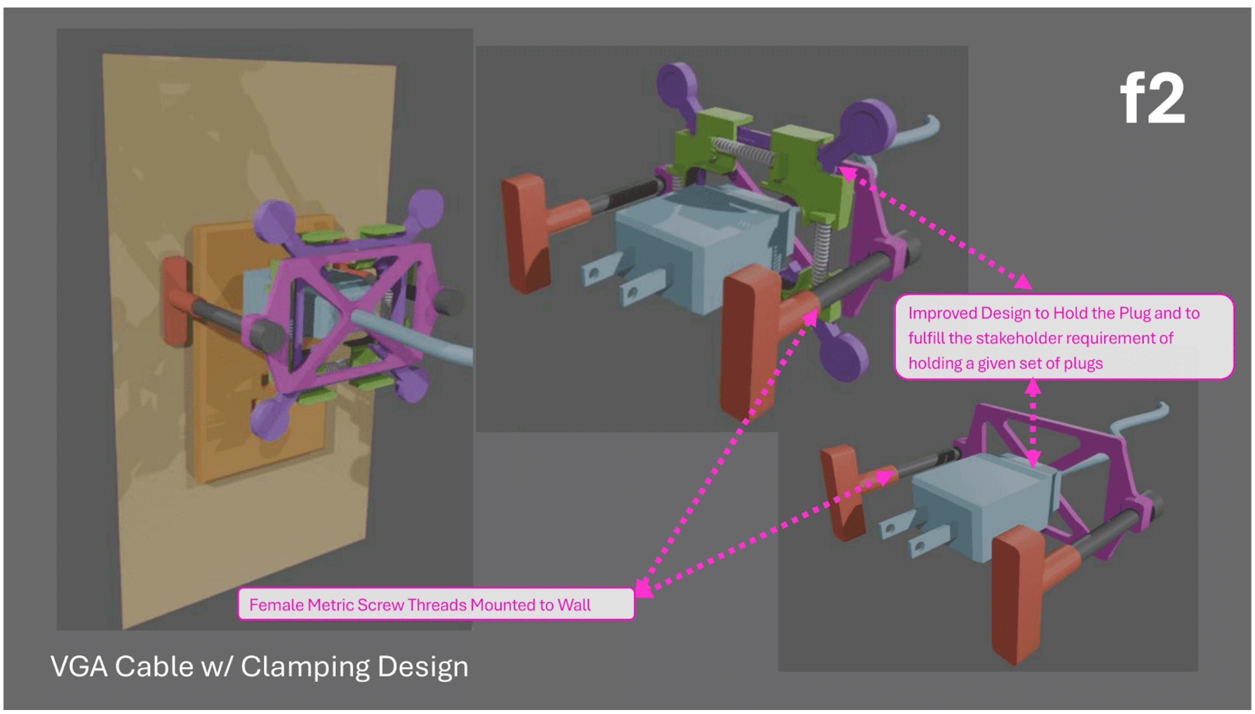

Carbons Brushes
110V to 240V Switch
b2
3
Indicator LEDS
Electromagnets
Potentiometer to adjust electromagnet strength using a knob (knob not shown)
Electromagnet Design

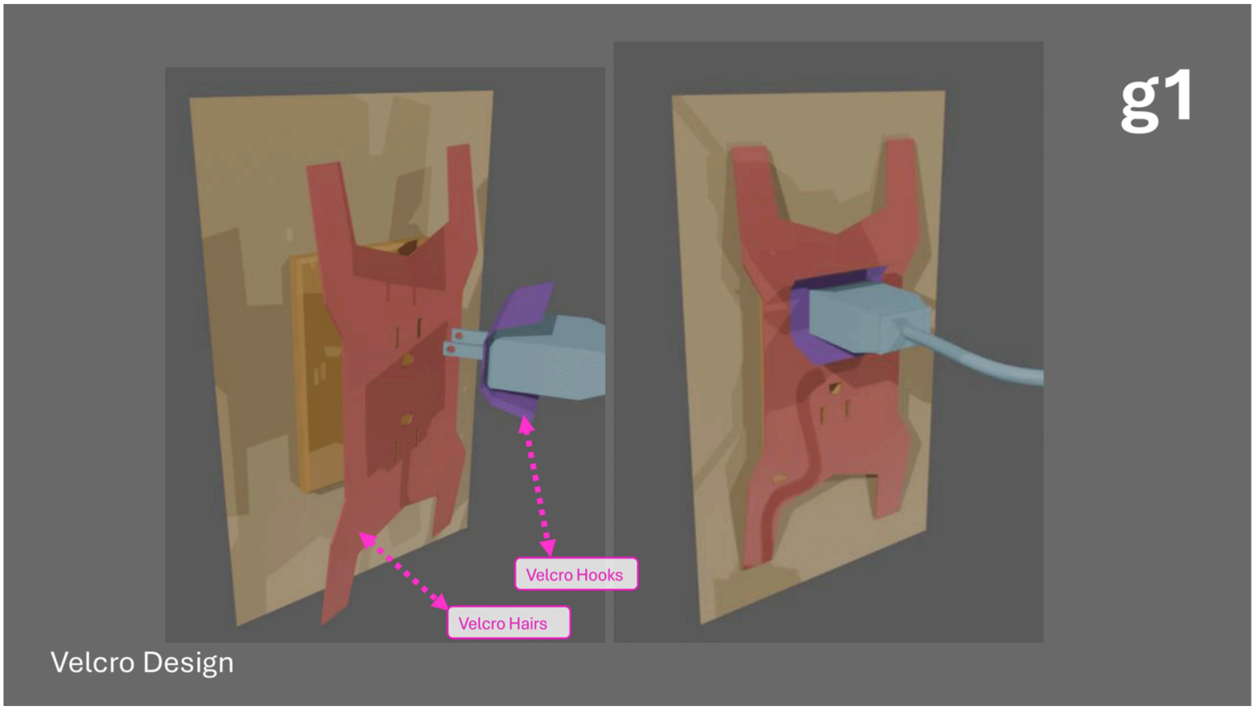

c1
Hook to hold looped cable
Shoelace Design

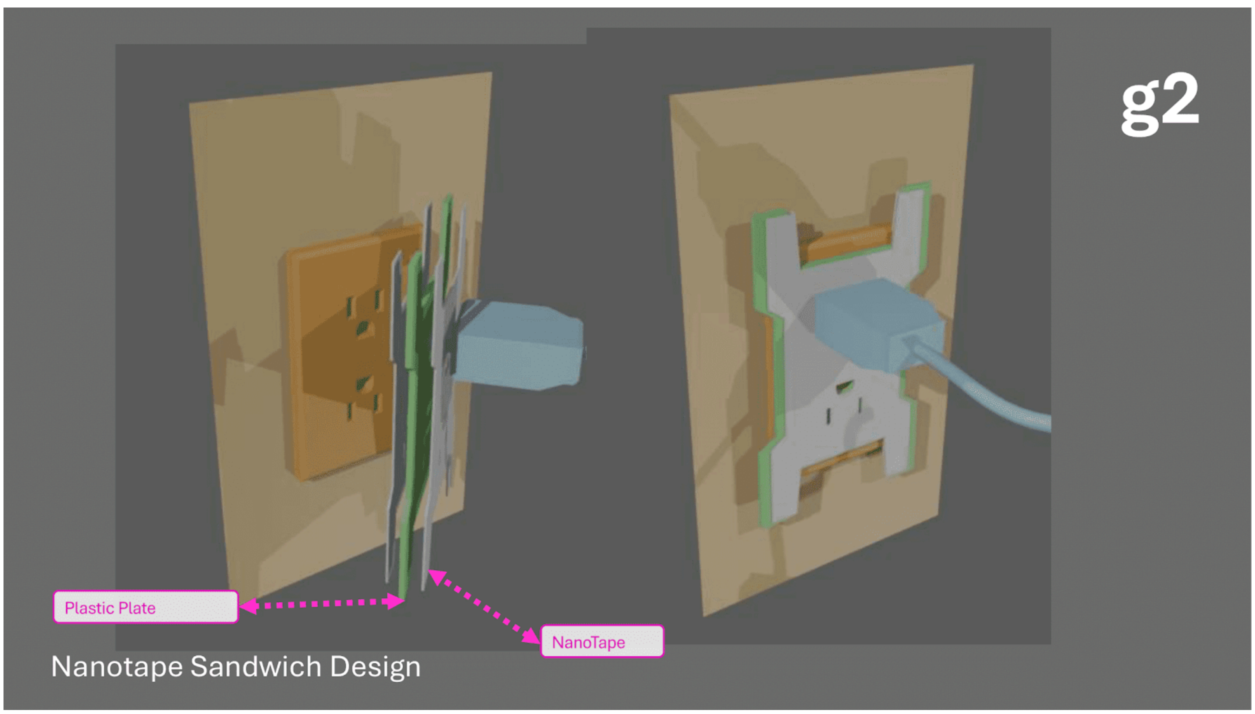

d1
Top Cleat Attached to the Plug
Bottom Cleat Attached to the wall
French Cleats Design

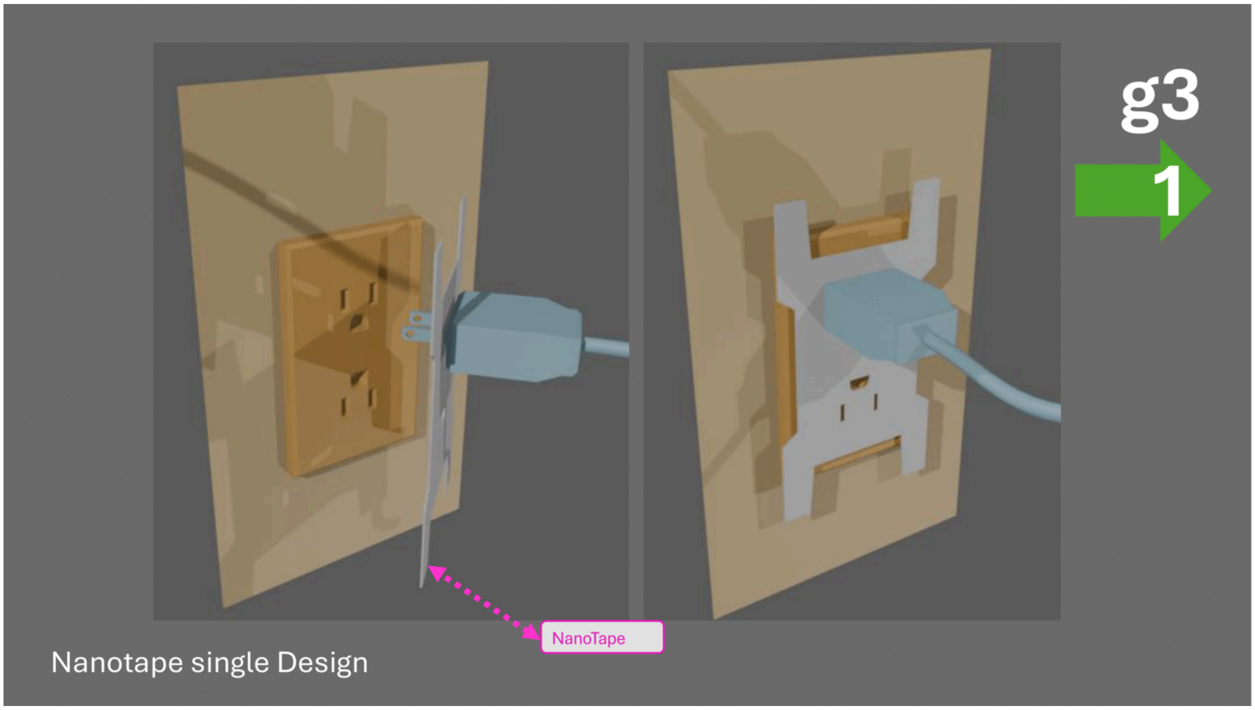

e1
Large Suction Cup
End Link
Arm Link
Relatively High Friction Fit Joint
Quadrupedal Suction Cup Design

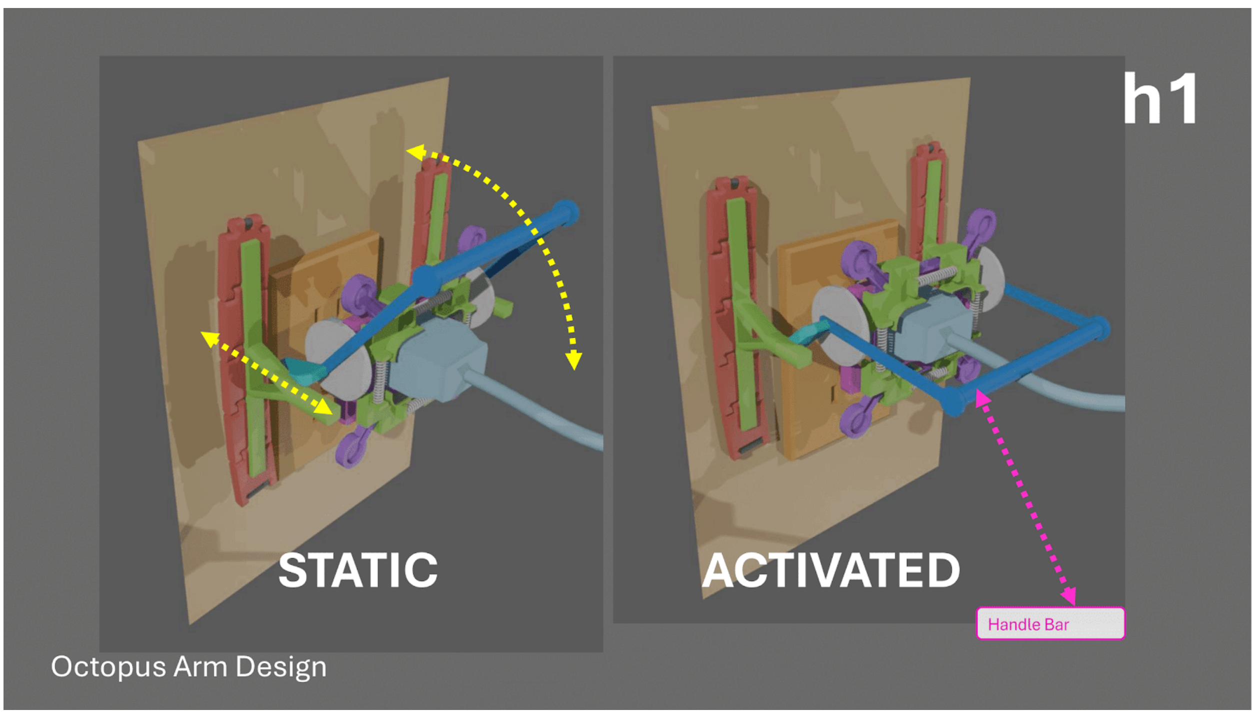

f1
Female Metric Screw Threads Mounted to Wall
VGA Cable Design

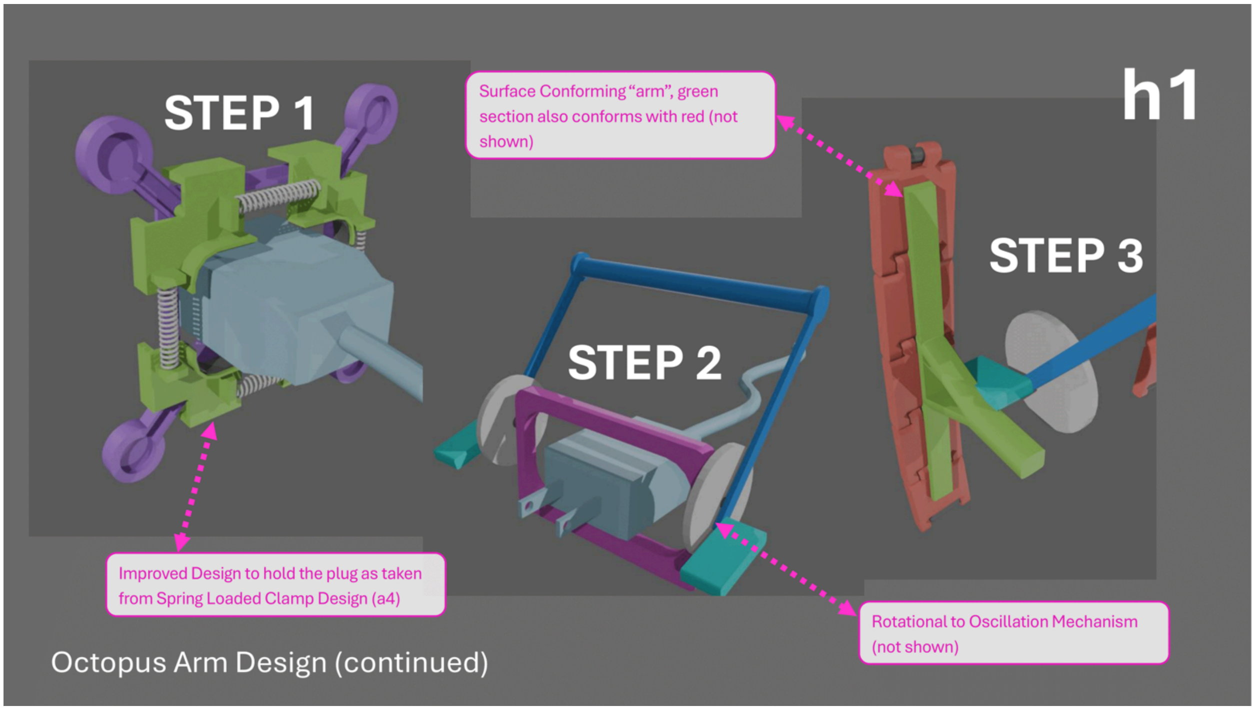

f2
Improved Design to Hold the Plug and to fulfill the stakeholder requirement of holding a given set of plugs
Female Metric Screw Threads Mounted to Wall
VGA Cable w/ Clamping Design

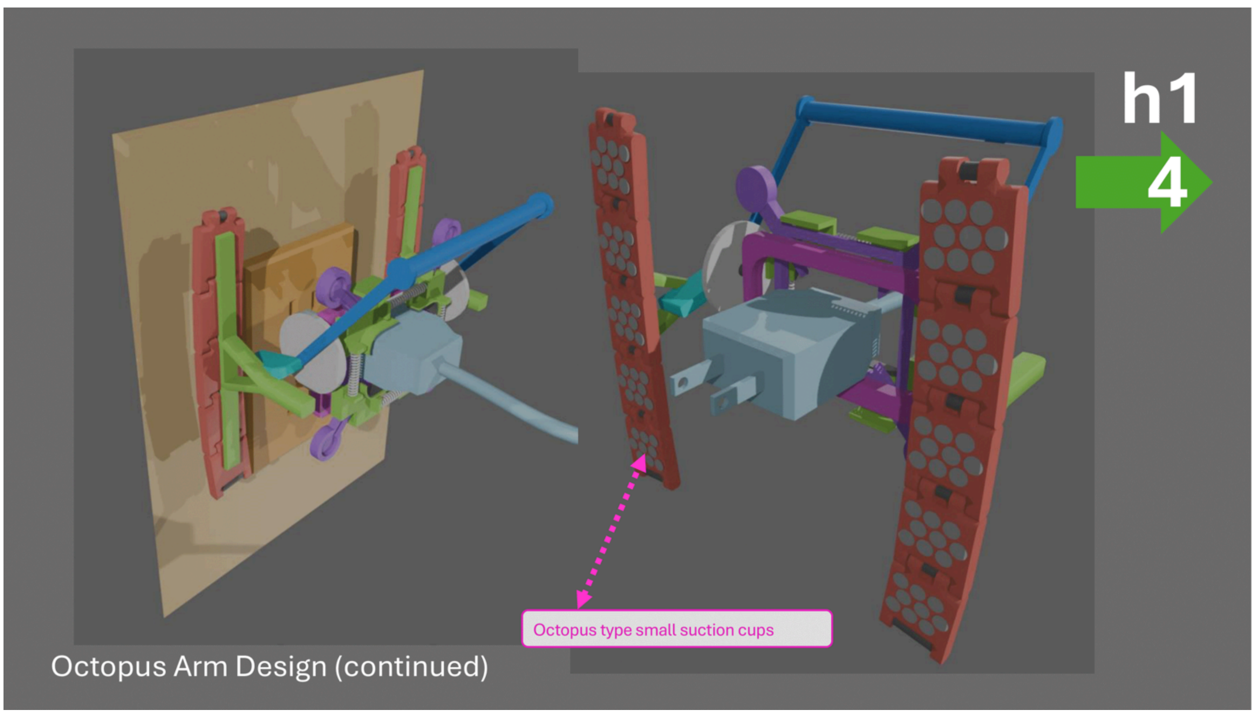

g1
Velcro Hooks
Velcro Hairs
Velcro Design


g2
Plastic Plate
NanoTape
Nanotape Sandwich Design


g3
1
NanoTape
Nanotape single Design


h1
STATIC
ACTIVATED
Handle Bar
Octopus Arm Design


STEP 1
Surface Conforming "arm", green section also conforms with red (not shown)
h1
STEP 3
STEP 2
Improved Design to hold the plug as taken from Spring Loaded Clamp Design (a4)
Rotational to Oscillation Mechanism (not shown)
Octopus Arm Design (continued)


h1
4
Octopus type small suction cups
Octopus Arm Design (continued)

G1.0 Appendix F: Designs Diverging

G1.1 Nanotape (Biomimicry)

Biomimicry – geckos stick to surfaces by using electrical (Van Der Waal) forces between dipoles in molecules to stick to surfaces. They do it by having microscopic hairs (also known as a lamellar structure). We can create a similar kind of surface manually, as is done in the case of nano tape. A modified version of it could be used to secure the connection between a loose plug and socket pairing.

Big Question: How is the material able to withstand high currents and temperatures when sparking occurs or the material comes into contact with the wall socket prongs?

G1.2 Electromagnetic Mechanism (Classical Brainstorming)

Inspired by the use of electromagnets in MagSafe by Apple, a plug – wall socket mechanism that adapts the technology to create a connection force.

Flowing current from the wall socket to the plug generates a magnetic field in the surrounding region. These magnetic fields interact with the magnetic field from permanent magnets on the plug creating a magnetic connection force between plug and wall socket.

Big Question: How do different devices draw different currents over time and affect the strength of the connection of the plug to wall socket? -> show transformer and solenoid design

G1.3 Spring Clamping (Classical Brainstorming)

Using a clamping mechanism in four directions (similar phone stands in cars) with springs that auto lock in and a button that disengages, it allows a non-permanent solution to securely fasten the plug to the wall socket.

Big Question: How durable is this mechanism if tossed around in a backpack or dropped by clumsy EngSci students?

G1.4 Octopi Suction cups with Tentacles (Morphing)

Orange boxes show chosen elements.

Function	Quadrupedal Suction	Shoelace	VGA Screw Mechanism	Velcro

Wall Attachment Mechanism	Suction cups	Rope	Screwed in	Sticking via Velcro
Plug Securing Mechanism	Solid surface behind the plug	The cord itself	Spring cage	Sticking via Velcro
Surface Conformity	Pressed manually	Rotated manually with mechanical advantage	Screwed in	Bends to conform around surfaces
Moderation of the Force of Attachment	Manual/pushing it harder	Mechanical advantage through a pulley system/manual	Screws/manual	Manual/pushing it harder

G1.5 Quadrupedal Suction cups (Biomimicry)

Looking at things in the nature that attach well to surfaces, octopus tentacles have suction cups that easily attach and detach from surfaces, using a similar technique, the plug has four suction cups which attach to the wall surrounding the wall socket which can easily be fastened and removed.

G1.6 Velcro Strap (Classical Brainstorming)

Thinking of cases where two things are attached together such as shoe straps, the same attachment mechanism is adopted as it is fast, secure and easy to use. The plug has a Velcro strap on the face and the whole wall socket has a Velcro layer on it that is double sided taped to the surface. To attach and detach is simply pushing and pulling.

G1.7 Ants Pincers (Biomimicry)

Small Ants are able to hold and carry leaves that are a multitude larger size than them. The hooking mechanism is strong and effective. A similar mechanism is used by having arms come off the wall and hook onto plugs to secure them.

G1.8 Reverse Ants Pincers (Osborn Checklist - Clipping)

Put to other use	Having arms on the plug allows it to be attached to anything – not just the socket.

Adapt	By inspecting insect pincers, adapt arms to have a flexible hinge mechanism.
Modify	Make the ends of the arms flat to get more friction when securing to a socket
Magnify	Increase the contact area.
Minify	Reduce the number of joints to make the design simpler since the arms no longer wrap around the plug.
Substitute	Change the material of the tips to silicone for a better grip and to stay below the shore hardness required.
Rearrange	Rearrange the arms towards the top and bottom of the plug so that they can hold it more securely as to maximize the grip.
Reverse	Grip from below and above instead of from the sides.
Combine	Add small suction cups potentially to the tips.

G1.9 Screw Clamping Mechanism (Excursion Technique)

During an imaginary excursion to a forest, two fallen trees were observed forming two crossing logs of wood lying across a river stream, and a monkey whose leg was trapped in between the two logs. The same clamping method is used to hold the plug into a wall socket. Two long screws that go above and below the plug and lock onto the sides of the wall sockets through mechanical advantage.

G1.10 Shoelace (Random Input)

Shoelaces are like wires which can coil and have mechanical strength enough to resist the weight of the plug. The wire from the plug can coil around two clips at the side of the wall socket.

G1.11 VGA Screw Mechanism (More Innovation)

Similar to the VGA Cable Connection, two screws come from the ends of the plug and screw into two holes at the side of the wall socket.

G1.12 French Cleats (Excursions)

At a museum entrance, there is a French cleat mechanism to hang jackets on the wall, the simplicity and strength of the arrangement inspired the design team to apply French cleats to wall plugs.

H1.0 Appendix H: Requirements Matching

The following outlines requirements that may perhaps not be met by the above given designs which has therefore informed the analysis on defining the critical metrics of the primary and secondary stakeholder.

Nanotape	Electrical Continuity R1.2 Adhesive Residue R3.1 Insertion and Removal Cycles R3.5 Short Circuit Prevention R4.1 Electrical Insulation Resistance R4.2 Earthing and Ground R4.3 Dialectic Breakdown Protection? R4.4 Heat and Fire resistance R5.1
Magnetic Mechanism	Engagement Force R1.1
Octopi Suction	Maximum Volume Limit R2.2 Deployment Time R2.3 Insertion and Removal Cycles R3.5
Quadrupedal Suction	Maximum Volume Limit R2.2 Deployment Time R2.3 Insertion and Removal Cycles R3.5
Spring Clamping	Maximum Mass Limit R2.1 Maximum Volume Limit R2.2 Deployment Time R2.3 Insertion and Removal Cycles R3.5
Screw Clamping	Maximum Mass Limit R2.1 Maximum Volume Limit R2.2 Deployment Time R2.3

	Insertion and Removal Cycles R3.5
Reverse Ant Pincers	Maximum Volume Limit R2.2 Deployment Time R2.3 Wall Socket Modifications R3.3 Insertion and Removal Cycles R3.5
Ant Pincers	Maximum Volume Limit R2.2 Deployment Time R2.3 Wall Socket Modifications R3.3 Insertion and Removal Cycles R3.5
Velcro	Electrical Continuity R1.2 Adhesive Residue R3.1 Wall Socket Modifications R3.3 Short Circuit Prevention R4.1 Electrical Insulation Resistance R4.2 Earthing and Ground R4.3 Dielectric Breakdown Protection? R4.4 Heat and Fire resistance R5.1
French Cleats	Wall Socket Modifications R3.3
Shoelace	Wall Socket Modifications R3.3
VGA Screw Mechanism	Deployment Time R2.3 Wall Socket Modifications R3.3

I1.0 Appendix I: Design Brief

See next page.

Plug Retention Device for Loose Plugs in Spaces Used by Engineering Science Students

Word Count: 5112

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Introduction

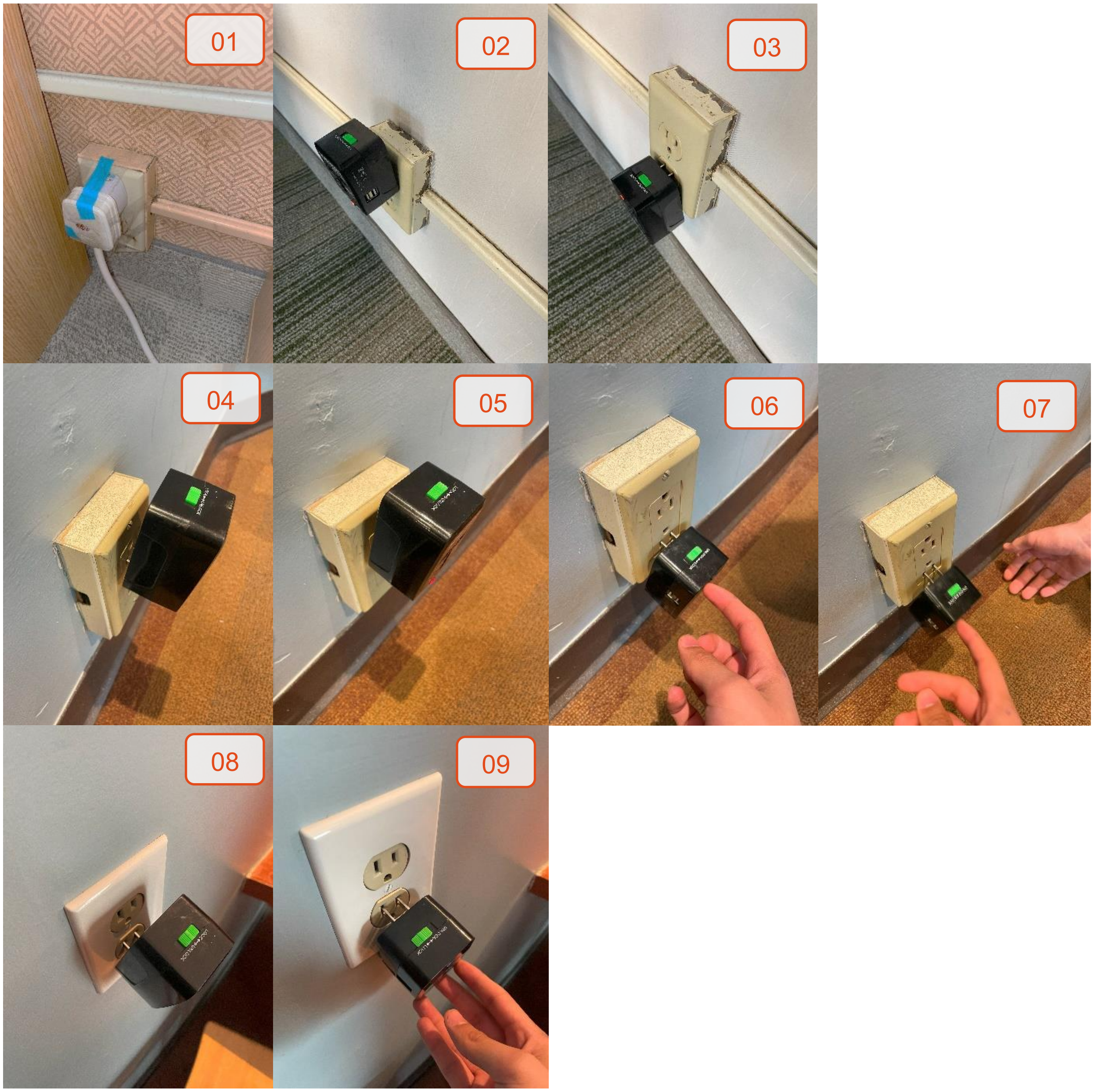


Figure 1: 01 shows what an Engineering Science Student at Chestnut Residence has undertaken to temporarily fix the problem. 02 and 03 show the Heavy Type A Plug (see figure 3) loose on Chestnut Floor 28. 04, 05, 06, 07 show the same plug on Chestnut Floor 27 (Commons), the plug on the upwards orientation was loose but still held its own weight, in the downwards orientation in 07 the plug was loose enough to fall out on its own. 08 and 09 show a loose wall socket in Chestnut Floor 28 Study Rooms.

At the spaces used by Engineering Science students and in residence, North American power sockets are prone to wear and tear, making plugs easily tilt and slip out. This disturbs students' learning experience by interrupting the charging and power flow to their devices. Moreover, loose plugs expose live metal pins which pose a safety hazard during use, increasing the risk of electric shock or sparking which leads to fires. This design brief sets a framework and provides information for an engineering team to tackle this Splartz by detailing the needs of all stakeholders, analysing reference designs, and laying out the requirements and evaluation criteria for a potential solution.

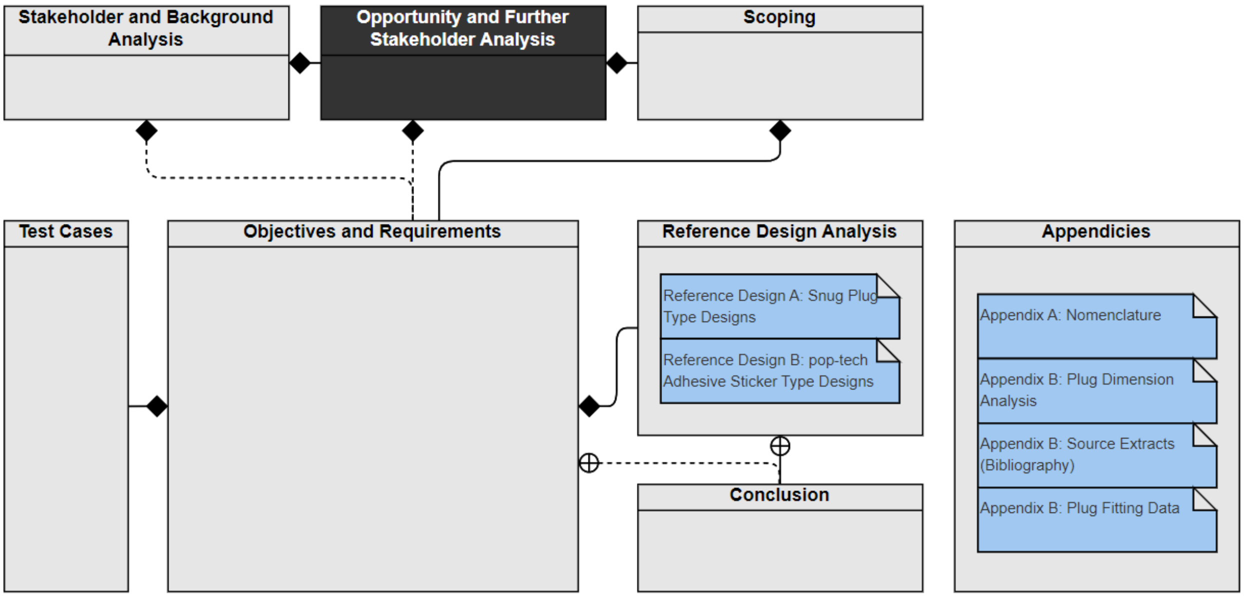


Figure 2: A high-level overview of this design brief and how each component links together to form a final opportunity and what sorts of requirements must be met for a successful design to be made.

Figure 2 gives the layout of this design brief and gives the framework of how such information shall be delivered to the engineering team to tackle this Splartz.

Stakeholders and Background

The primary stakeholders are first year Engineering Science students, and by extension, the design team. Out of the 124 wall sockets tested on campus with 3 different plugs (see Appendix D), the plug most prone to tilting and slipping is Heavy Type A Plug with a loose connection in 54% of wall sockets.

Figure 3: 01 and 02 are the Heavy Type A Plug ; 03 and 04 are the Mid Type B Plug ; 05 and 06 are the Light Type B Plug. Refer to Appendix D for data surrounding their fitting.

In general, the data collected from the campus showed most older buildings such as McLennan Physical Laboratories had many loose fittings while several sockets in newer buildings such as MyHall faced the same issue, irrespective of socket orientation (refer to Appendix D). Therefore, it was concluded that a solution needs to be portable, apply to all standardized North American sockets, work for all plug types so that students can use one device on sockets across campus.

The design team's core values reflect sustainability, design for non-obsolescence, equal learning opportunities, low-friction solutions and safety. This guided the requirements and objectives in making the product a long-lasting, effective, and safe device.

By approaching and interviewing 22 Engineering Science students on in the Engineering Science Common Room and in Chestnut residence, 18 reported facing issues with loose connections once a week while 9 students claimed experiencing this issue daily, and of them, 15 mentioned that they would be interested in a solution.

When asked what would matter to them in a hypothetical solution, the top 3 responses were a secure connection or similar (14/22), fast deployment or similar (12/22), and non-damaging over a long cycle of constant use or similar (10/22). When presented with a tennis ball, 16/22 students said they would only consider a solution with a smaller volume (150 cm^3) [14] and lighter mass (59.4 g) [14] than the tennis ball presented. It must be noted that the data is limited due to a small sample size, however this can still be considered a viable path of design to pursue as this is indeed a Splartz that affects the Engineering Science community.

The secondary stakeholders, the University of Toronto maintenance staff, mandate this solution not to be damaging to campus infrastructure and residence as given by the Chestnut Housing Occupancy Agreement section 5.0 [20]. Lastly, there are government-mandated codes concerning sockets, plugs and other electrical products such as the CSA C22.1 [26] code and CEPA legislation [15] that a potential solution would have to adhere to.

Opportunity and Further Stakeholder Analysis

From secondary data collected on campus and the questionnaire above, primary stakeholders desire a secure, portable, temporary, non-damaging, and simple-to-use solution. Secondary stakeholders require the solution to be non-damaging to the sockets. The team's values encourage a sustainable, non-obsolescent, low-friction and safe solution. Together this introduces an opportunity to provide Engineering Science students with a *secure, portable, low-friction, non-damaging, universal, and safe* way to charge devices no matter where they are or how loose the wall socket or the plug is. The goal of the solution is to let students' study and participate in learning activities without interruption no matter what device they employ or location on campus.

Scoping

The device shall address Engineering Science students and spaces where they would charge and power their devices, in residence and on campus in places such as libraries, hallways, and classrooms. The device shall accommodate most common plug types, dimensions, and weight and North American wall sockets that are oriented upwards, sideways and downwards. The device is used temporarily such that it does not impact others who may use the wall socket in the future.

Objectives and Requirements

Bring all the above design team values, primary stakeholder values, secondary stakeholder needs, opportunity statement, and goals we can obtain the following high-level objectives which can go onto inform the further refined objectives. We can fit these refined objectives back into our goals and use that to constrain the design space to inform the design process.

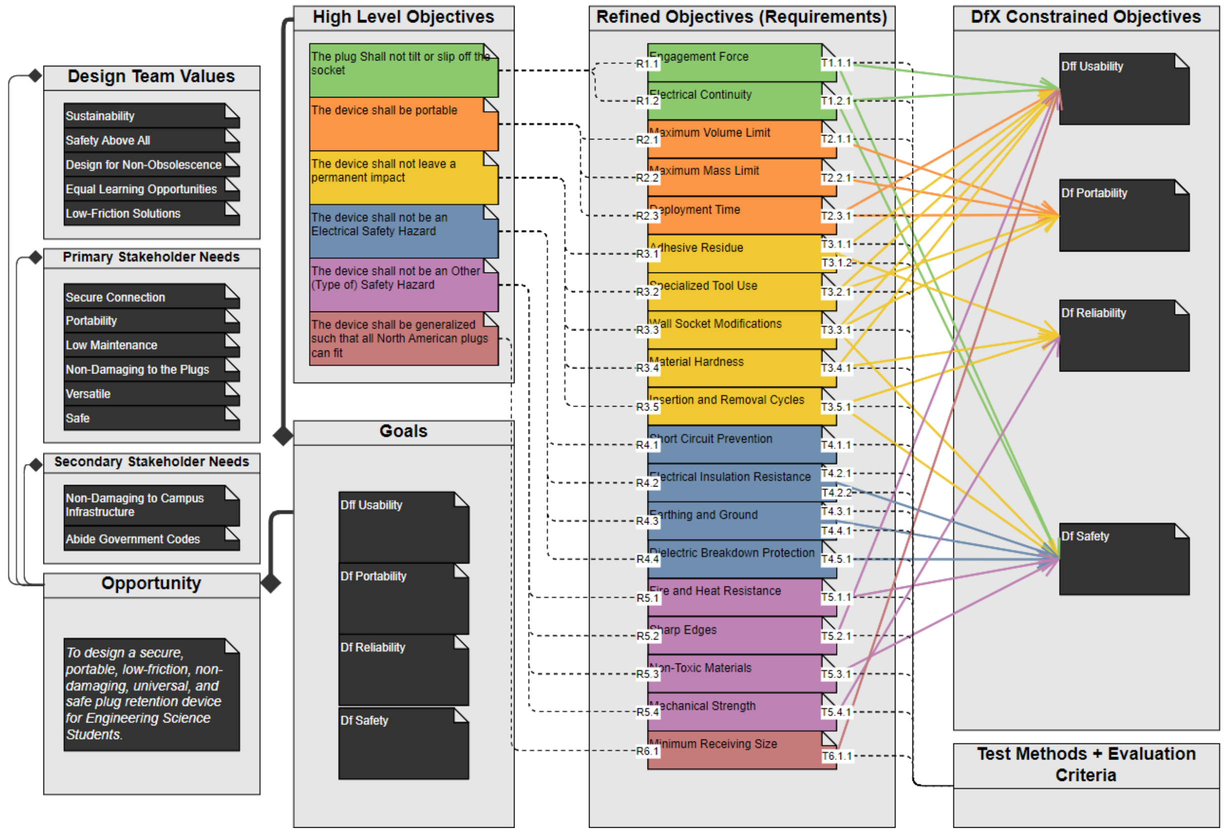


Figure 4: A high-level overview of the objectives and requirements for a successful design. The stakeholder needs and design team values create an overall opportunity from which a set of goals are formed, these form high level objectives which can be further refined into objectives to create various evaluation criteria, metrics, and requirements.

Given the needs of the stakeholders (both primary and secondary) we can split the needs into the following four goals, from here we can split up our high-level objectives and refined objectives into each of these four goals. The refined objectives can link to multiple areas and so the above diagram has been adopted to help inform you on what scope and design space the design is expected to solve.

Goal 1, Design for Usability

1. The device shall not tilt or slip off the socket

Engineering Science students need to power and charge their devices without interruptions. When the plug slips repetitively due to worn out sockets, it requires manual realignment to resume charging, distracting the students from their work. Moreover, the exposed live wires may lead to sparks and electric shocks that harm students. Both concerns are concerns that have been raised by the primary stakeholders, where having a secure connection it being safe was their main concern. Moreover, our design team values align with a design that ensures that everyone has equal opportunity to learn and having a slipping plug distracts one from being productive.

3. The device shall not leave a permanent impact
Stakeholder analysis showed that for most Engineering Science students who do experience this Splartz, experience it with multiple different sockets. In simple words, a bad plug is often the common denominator, and a permanent solution would not be applicable. Moreover, a permanent solution cannot be applied inside the classroom by individuals as it damages university property.

6. The device shall be generalized such that most North American plugs can fit
On the basis of the research completed in Appendix B, we can determine that there is max size in the possible plug types that are used by Engineering Science Students at large. If the size that has been informed through our primary sources cannot be effectively accommodated, we do not meet the stakeholder requirements.

Goal 2, Design for Portability

2. The device shall be portable
Stakeholder analysis indicated that Engineering Science students face this issue in and outside of the classroom. The portability of the device allows students to use one device on multiple worn out wall sockets at home, and on campus.

Goal 3, Design for Reliability

This design space does not have a high-level objective as many refined objectives can link to it.

Goal 4, Design for Safety

4. The device shall not be an Electrical Safety Hazard
The device must meet CSA C22.1 [26] and certain parts (as given below) of CSA C22.2 [30] to be able to be sold as an electrical product in Canada [27] (and by extension in the World). If these codes are not met the product cannot be sold.

The device should not be an electrical safety hazard as electrical shocks have a mortality rate between 3 to 15% [1], if multiple shocks are to happen over the lifetime of the use of the device, it would be almost fatal. The first shock would be off-putting and would result in multiple product callbacks, not to mention government intervention.

5. The device shall not be an Other (Type of) Safety Hazard
Safety has been determined to be a major need for primary stakeholders and secondary stakeholders. Others on campus and in Chestnut residence who may not themselves have this issue would prefer for there not to be a safety hazard. Additionally, across Canada and, most importantly in Ontario, the CEC enforces the CSA C22.1 [26]. For the product to be legally sold in Canada it must adhere to the code.

Refined Objective	Criteria		Requirement
	Metric	Evaluation	
1 The device shall not cause the plug to slip			
R1.1 Engagement Force	Force [N] Force [N]	The engagement force shall be balanced in the middle of the range, the	**T1.1.1** The device shall provide the plug an engagement force with the wall

	Force [N]	more suitable the balance the more suitable the design. Engagement force can change based on the tightness of the plug and so an engagement force that meets R1.1 for all use cases is best, refer to Appendix D for data on tight, well fitting, and loose use cases.	socket such that it is not too low to lead to slipping, and not too high to make it difficult to detach the plug. An engagement force of 13 N shall be provided to ensure secure plug retention based on UL 498 [10]. A maximum engagement force can be at 67N to ensure that the plug can be removed easily based on UL 498 [10].
R1.2 Electrical Continuity	Contact Resistance [mΩ]	The lower the contact the resistance the more suitable the design as resistive heating is reduced thereby reducing the risk of fire.	**T1.2.1** The device shall not affect the electrical continuity between the plug and the socket by maintaining a contact resistance below 10 mΩ between the wall socket and the plug pins based on IEC 60512-2-1 [11] which indicated a low electrical continuity and general market values for North American Plugs.
2 The device shall be portable			
R2.1 Maximum Mass Limit	Mass [g]	The lower the weight the more suitable the design as the user would be more inclined to use it as it would not weigh them down, it would appeal to the convenient need.	**T2.1.1** The device shall weigh no more than 60g to allow for the device to carry easily as suggested by primary stakeholder needs through questioning Engineering Science Students.
R2.2 Maximum Volume Limit	Volume [cm^3]	The smaller the volume the more suitable the design as the user would be more inclined to use it if it was not bulky, it would appeal to the convenient need.	**T2.2.1** The device shall not have a volume larger than 150 cm^3.
R2.3 Deployment Time	Deployment Time [s]	The shorter the time the more suitable the design as the user would be more inclined to use it if it did not take time to setup, it would appeal to the convenient need.	**T2.3.1** The device shall take no longer than 5s increase in deployment compared to using a typical plug-wall socket arrangement. It shall also add no more than 5s in removal time compared to a typical plug-wall-socket arrangement.
3 The device shall not leave a permanent impact			
R3.1 Adhesive Residue	*Visual Inspection*	The higher the adhesive scale test passed the more suitable the design.	**T3.1.1** The device shall not use permanent adhesives or leave

	Adhesive Scale		residue after the removal of the device based on ASTM D3359 [3]. Adhesive scale residue shall be met at Permanent residue damages the wall socket and increases deployment/removal time in R2.3.
R3.2 Specialized Tool Use	*Visual Inspection*	The faster to remove the design the more suitable the design, this is linked to R2.3	**T3.2.1** The device shall be removable by hand without the need of any tools or any specialized tools. This allows for the deployment/removal time in R2.3 to be low and meets the needs of portability of the primary stakeholders too.
R3.3 Wall Socket Modifications	*Visual Inspection*	The less invasive the design the more suitable in the sense that it does latches onto less surface than other devices, etc.	**T3.3.1** The device shall not require any medication to existing wall sockets or electrical installation. This is due to the primary stakeholder need of being portable and usable on Campus as well as on Chestnut Residence [20].
R3.4 Material Hardness	Shore Hardness [Shore A]	There is a balance in the sense that softer materials are prone to warping whilst harder materials are prone to cracking due to their brittle nature [31]. A successful balance gives rise to a more suitable design. This means the shore hardness should be optimized to fulfil both R3.4 and R5.4. A suitable design balance both regimes.	**T3.4.1** The device shall have material that is contact with the plug or wall socket have a Shore Hardnes of less than 70A to prevent scratching and wear on the wall socket and plug based on ISO 868 [13]. Primary Stakeholder analysis identified that Engineering Science students expected a potential solution to serve them for at least 3 years and so softer materials are prone to breaking – there is indeed a balance that must be made.
R3.5 Insertion and Removal Cycles	*Visual Inspection* Contact Resistance [mΩ]	The longer the design lasts through the insertion and removal cycles the more suitable.	**T3.5.1** The device shall be able to last 8000 insertion and removal cycles without wear to the point that product becomes dangerous or unusable as identified in R1.2 and R1.1 respectively. Contact resistance can be measured at the end of the cycles.
4 The device shall not be an Electrical Safety Hazard			

R4.1 Short Circuit Prevention	Voltage Drop [V]	The lower the voltage drop the more suitable the design.	**T4.1.1** The device shall prevent contact between the live and neutral plug pins during insertion or removable to avoid short circuits as required by the Canadian safety code CSA C22.2 No. 42 [30], alongside general Canadian electrical safety code CSA C22.1 [26].
R4.2 Electrical Insulation Resistance	Insulation Resistance [MΩ]	The greater the insulation resistance the more suitable design, however this must be balanced with R3.4 and R5.4, R2.1, and R2.2 to ensure that the device is not too heavy, bulky, hard in material-wise, etc.	**T4.2.1** The device shall provide an electrical insulation such that the resistance between the plug pins (at their base) and all the contact surfaces the user would be able to reach is no less than 100 MΩ as required by Canadian electrical safety code CSA C22.1 [26]. Measure the insulation resistance between the base of the plug pins and all contact surfaces the user would be able to reach during *operation* using a megohmmeter. **T4.2.2** Measure the insulation resistance between the base of the plug pins and all contact surfaces the user would be able to reach during *insertion/removal* using a megohmmeter.
R4.3 Earthing and Ground	*Visual Inspection*	The less invasive a device (as balanced by R3.3) the more suitable the design.	**T4.3.1** The device shall not interfere with any ground systems of the plug, wall socket, or connected appliances as required by Canadian safety code CSA C22.2 No.0.4 [30], alongside general Canadian electrical safety code CSA C22.1 [26]. A visual inspection can be completed. If there is no visual interference (such as mechanisms or bodies interfering) then the test is passed. **T4.3.2** A live test can be completed under failure conditions in which the grounding system of an appliance is used without the device and then is completed with the device

			installed. If the grounding system is to work in both cases the test is passed.
R4.4 Dielectric Breakdown Protection	Current [A]	The lower the current flow the more suitable the design.	**T4.4.1** The device must be able to withstand a dielectric voltage of 240V between the plug pins and all contact surfaces the user would be able to reach such that no breakdown of the material occurs and current flows through the material.
5 The device shall not be an Other (Type of) Safety Hazard			
R5.1 Fire and Heat Resistance	Temperature [C]	The lower the temperature, the more suitable the design. Lower temperatures make the device more usable and safer.	**T5.1.1** As all plugs and sockets must pass test 8.9.1 in the CSA C22.2 No. 42-10 [30], so the maximum temperature of the plug-socket system is 55 degrees Celsius. The device must not exceed 55 degrees Celsius over 4 hours of continuous use at the plugs maximum rated load.
R5.2 Sharp Edges	*Visual Inspection*	The less visible deformations on the test paper, the more suitable the design.	**T5.2.1** As informed by stakeholder analysis, the device will be deployed often sloppily in hectic environments (like the beginning or end of a lecture). It will also be carried in backpacks next to cables and notebooks. The device shall not be sharp enough to cut the user, cables or paper.
R5.3 Non-Toxic Materials	Inspection	The less materials containing toxic substances, the more suitable the design.	**T5.3.1** Must not use any materials that contain any toxic substances as outlined in the Canadian Environment Protection Act [15].
R5.4 Mechanical Strength	*Visual Inspection*	The less visually noticeable deformations and/or loosening of parts that could affect the functioning of the device, the more suitable the design.	**T5.5.1** Must pass the Mechanical Endurance test outlined in section 8.35.4 of the CSA C22.2 No. 42-10 [30].
6 The device shall be generalized such that all North American plugs can fit			
R6.1 Minimum Receiving Size	Length [cm] Length [cm]	The larger the plug analogue handled the more suitable the design.	**T6.1.1** The device shall be able to handle effectively a plug that has the minimum dimensions of 10.0cm by

	Length [cm]		7.50cm by 6.00cm as given by Appendix B.
R6.2 Wall Socket Compatibility	*Visual Inspection*	The more surfaces that a given device is able to fit to the more suitable the design.	**T 6.2.1** The device shall be able to fit over all plugs that Engineering Science students use, this means that the device shall: one, be able to fit around table-edge-wall-sockets, two fit onto flat-wall-sockets, and three around low-profile-wall-sockets.

To ensure that a design can be tested against the above the following test methods and failure/success states have been developed.

Test Case Identifier	States		Method
	Success	**Failure**	
1 The device shall not cause the plug to slip			
T1.1.1	Engagement force greater than or equal to 13N Engagement force less than or equal to 67N	Engagement force less than 13N OR Engagement force greater than 67N	Gradually increase the pullout force applied on the plug, measure the max force until the plug slips out using a newton meter. Ensure that there is a range of plugs used as given in Appendix D.
T1.2.1	Contact Resistance less than 100 mΩ	Contact Resistance greater than 100 mΩ	Measure the contact resistance between the plug pins and the wall socket receptacles using a multimeter. A wall socket analogue can be used by using a metal strip the same width as the metal prongs and resistance measured between the two.
2 The device shall be portable			
T2.1.1	Mass less than or equal to 60g	Mass greater than 60g	Measure mass using an electronic Balance.
T2.2.1	Volume less than or equal to 150 cm^3	Volume greater than 150 cm^3	Measure the side lengths using a pair of calipers and then use the following equation to find the volume: $length \times width \times height$ Ensure that lengths are in cm.
T2.3.1	Average Deployment and Removal time less than or equal to 5s	Average Deployment and Removal time greater than 5s	Time a range of Engineering Science Students' (or equivalent demographic) times to deploy and remove their plugs with and without the device. Take the average and compare the times using the following equation:

			$(time\ taken\ with\ device) -$ $(time\ taken\ without\ device)$ Ensure that averages are taken for removal and deployment separately.
3 The device shall not leave a permanent impact			
T3.1.1	Visual Inspection of the paint strips shows that paint has not been stripped	Visual Inspection of the paint strips shows that paint has been stripped	Follow ASTM D3359 Adhesive Scale testing procedure [12] as outlined in the standard and in the following video [28].
T3.2.1	The only tools require are one's hands	Tools other than one's hands are involved	Visual Inspection shall be sufficient.
T3.3.1	The device does not modify and wall sockets	The device modifies wall sockets	Visual Inspection shall be sufficient.
T3.4.1	Shore hardness is less than or equal to 70A	Shore hardness is greater than 70A	Take the material datasheet of the constituent materials of the design and compare their Shore Hardness level to 70A.
T3.5.1	Contact Resistance less than 100 mΩ	Contact Resistance greater than 100 mΩ	Perform 8000 insertion/removal cycles and measure the contact resistance between the plug pins and the wall socket receptacles using a multimeter. Ensure that the wall socket receptacle pins are of the same material hardness than the plug pins to ensure that only the contact capability of the device is measured and not the wear of typical household plug-wall-socket usage.
4 The device shall not be an Electrical Safety Hazard			
T4.1.1	Voltage drop less than or equal to 3V	Voltage drop greater than 3V	The primary stakeholder analysis determined that a long-lasting solution is desired. Perform 10000 simulated insertion/removal tests where voltage is monitored to ensure that this is a voltage drop of no more than 3V voltage drop across the plug pings during these cycles. Applied voltage shall be tested at 120V as that is the voltage used in Canada [26].

T4.2.1	Insulation resistance greater than or equal to 100 MΩ	Insulation resistance less than 100 MΩ	Measure the insulation resistance between the base of the plug pins and all contact surfaces the user would be able to reach during *operation* using a megohmmeter.
T4.2.2	Insulation resistance greater than or equal to 100 MΩ	Insulation resistance less than 100 MΩ	Measure the insulation resistance between the base of the plug pins and all contact surfaces the user would be able to reach during *insertion/removal* using a megohmmeter.
T4.3.1	Visual inspection of the systems yields that there is no physical mechanism collision	Visual inspection of the systems yields that there is a physical mechanism collision	Visual Inspection shall be sufficient.
T4.3.2	Grounding or earthing system activates under activation condition of appliance	Grounding or earthing system fails to activate under activation condition of appliance	A live test can be completed under failure conditions in which the grounding system of an appliance is used without the device and then is completed with the device installed. If the grounding system is to work in both cases the test is passed. Ensure a range of appliances and devices are used (chargers, kettles, mini fridges) as identified by the primary stakeholder analysis.
T4.4.1	A current less than or equal to 0.0001A flows during the edge case test	A current greater than 0.0001A flows during the edge case test	Apply 240V dielectric voltage across the live (and neutral pin in a consecutive test) and a contact surface that a user would be able to touch. Measure current flow using a bench multimeter (a recommended instrument would be the HP Agilent 34401A, a similar bench multimeter is available at MyFab LFF), no greater than 0.0001A is to flow [26].
5 The device shall not be an Other (Type of) Safety Hazard			
T5.1.1	For the entirety of the test Temperature is less or equal to 55 degrees Celsius.	At some point during the test the temperature spikes above 55 degrees Celsius.	Deploy the device to secure a plug – socket connection. Apply the maximum rated load for the plug chosen for 4 hours. Repeat with at least 3 plugs of different dimensions (as shown in Appendix D).
T5.2.1	There are no major deformations to the paper from	There are major deformations to the paper from at least one of the	On a test surface, a paper shall be placed. Each edge of the device shall be subjected to 30 N of vertical force and scraped along the paper.

	any of the edges of the device.	edges of the device.	A major deformation is one that can be seen and felt. A minor deformation is a visibly noticeable deformation but smooth to the touch.
T5.3.1	Does not contain materials in the toxic materials list of the CEPA legislation	Contains materials in the toxic materials list of the CEPA legislation	Visual inspection of the materials used in the device.
T5.4.1	There are no visible deformations, and the tensile strength has not been affected	There are visible deformations or/and tensile strength has been affected	Follow the CSA C22.2 testing procedures for the Mechanical Endurance Test in section 8.9 [30] with one exclusion; the removals and insertions are to be done by hand instead of using a machine as the code suggests.
6 The device shall be generalized such that all North American plugs can fit			
T6.1.1	The device can handle plugs that are of size 10.0cm by 7.50cm by 6.00cm or less	The device cannot handle plugs that are of size 10.0cm by 7.50cm by 6.00cm or less	Measure max size of plug handled by plug using a ruler and compare to Appendix D.
T6.1.2	The device is able to fit flatly on a wall.	The device is not able to fit flatly on a wall.	Through visual inspection the design shall be able fit onto flat-wall-sockets. Additionally, it is recommended that it be able to fit around table-edge-wall-sockets, and around low-profile-wall-sockets. These can be tested at the locations outlined in appendix D.

Reference Design Analysis

Reference Design A: Snug Plug Type Designs

Figure 5: Above is the snug plug branded plastic insert that can be placed into the wall socket thereby effectively reducing the size of the opening and increasing the friction of the pins in the wall socket [16].

Figure 6: Above is a generic version of the plastic insert that can be placed into a wall socket thereby effectively reducing the size of the opening and increasing the friction of the pins in the wall socket [18].

This design involves the insertion of a plastic sleeve that increases the resistance between the plug pins and the wall socket receptacles.

Based on our design requirements and therefore by extension the needs of our stakeholders we can assert that this design does not meet their needs as the following requirements are not met:

1.1 This design does not meet this requirement as given by product review [21, X], the design is sometimes too tight and sometimes too loose, in this way the engagement force is too high or sometimes too low.

1.2 This design does not meet this requirement as given by product review [22], this is because sometimes plugs have pins that are short and therefore do not reach the attachment contacts inside the wall socket. This results in a high contact resistance that can lead to fires through resistive heating.

2.3 This design does not meet this requirement is not met as even if the deployment time was under 5 seconds the removal time is greater than 5 seconds as sometimes the plug is difficult to see [23] and when dropped might be difficult to find, and requires a sort of lever force to wrench out of the wall socket (perhaps using a fingernail or the like) which increases removal time beyond 5 seconds.

This design does not meet the below requirements as the seller page or box does not mention it meeting CSA C21.1 [26] meaning it cannot be sold legally in Canada [27]. Therefore, by extension it cannot meet the following codes CSA C22.2 No. 42, ULC-S80, and CSA C22.2 No.0.4. Thus, by extension it cannot meet the following design requirements:

4.1 Short Circuit Prevention

4.2 Electrical Insulation Resistance

4.3 Earthing Interference

4.4 Dielectric Breakdown Protection

5.2 This design does not meet this requirement as inspection of the design shows that the ends of the prongs (the deepest part in the wall socket) have sharp ends that most likely have ejector pin marks which add to the sharpness of the ends.

Reference Design B: pop-tech Adhesive Sticker Type Designs

Figure 7: Given above is the pop-tech adhesive “anti-tilt” stickers [19].

Figure 8: Given above is another generic adhesive “anti-tilt” sticker [20].

Another design target to improve the tilt-slip problem of plugs is the pop-tech adhesive sticker, this product works by permanently attaching charging bricks and the link to wall sockets such that they do not move. This design does not meet the design above design requirements for the following reasons:

1.1 This design does not meet this requirement as the force required to remove the device is far greater than the 67N value as a 3M VHD Super Gel is used and it has bonding strength of minimum 178.2N (as given by taking the Peel Strength Multiplied by the longest length of the tape, thus it is 54 multiplied by 3.3cm (as measured at Chestnut Residence)) [29].

2.3 This design does not meet this requirement as the deployment time involves the use of a temporary tape fixture [19] that gives enough time for the bonding of the plug to the wall socket. Moreover, since it is permanent, it has a long removal time because of using large forces to remove and clean-up is required to remove the adhesive residue.

3.1 This design uses permanent adhesives and leaves residue after removal as given in the product demonstration [19].

Conclusion

The design brief introduces the Splartz of plugs tilting and slipping on worn out wall sockets as a common problem faced by Engineering Science students. It begins by highlighting the relatability of this problem by many students through primary data collection. Then, by examining the stakeholders' needs and aligning them with team values, it details an opportunity to address this problem. Through specific requirements and evaluation criteria, and with references to secondary research (specifically, standards and codes), a clear guideline is developed for the engineering team to design an effective solution to address this issue. The design brief emphasizes the importance of a safe, effective, and reliable solution. Overall, this brief establishes a framework for a design team to begin the brainstorming and development of a device to make all wall sockets on campus and in residence effectively and safely be used by Engineering Science students.

Appendix A: Nomenclature

Wall Socket / Socket

This is defined as a receptacle for plugs that are situated usually in walls, tables, etc. The wall socket contains receptacle female metal contacts that the male contacts of the plug can contact to allow current to flow.

Plugs

This is the cable connector that is attached to the end of an appliance or charger cable that is inserted into a wall socket. The plugs contain male pins that contact the metal female counterpart in the wall socket.

Appendix B: Plug Dimension Analysis

Plug Description	Image	Maximum Height	Maximum Width	Maximum Thickness	Source
Slim-Flat Type A		2 cm	3 cm	4 cm	[2]
Slim-Fast Type B		4 cm	3 cm	4 cm	[3]
Rounded		5 cm	5 cm	5 cm	[4]

Cubed		4 cm	4 cm	5 cm	[5]
Side-Facing Offset		7 cm	7 cm	5 cm	[6]
Large Universal Adapter		10 cm	7.5 cm	6 cm	[7]
Wall Attached Transformer		8 cm	7.5 cm	5 cm	[8]
Plug with built in Extension Cord		10 cm	7.5cm	6 cm	[9]
		10	7.5	6	
		Maximum Overall Height	Maximum Overall Width	Maximum Overall Length	

Appendix C: Source Extracts (Bibliography)

Add all the remaining sources, fix up the figure numbers, fix up the source numbers

[01] "Evaluation of Tp-e / QTc ratio in determining the risk of arrhythmia in Electrics Shocks." Research Gate. Accessed: Oct. 11, 2024. [Online]. Available: SHORTENED URL

[02] "Printer Power Cord for HP Officejet Pro 4500 6600 4650 4630 5255 6962 8600 8710 7740/Envy 5055 5530/Deskjet 2652 3755/Photosmart 7520 6520/All-in-One/Canon Pixma 2 Prong Replacement Cable(6Ft) : Amazon.ca: Electronics." Amazon.ca. Accessed: Oct. 11, 2024. [Online]. Available: SHORTEND URL

[03] “Cablelera North American Power Cord Extension, NEMA 5-15P to C19, 8', 14 AWG, 15A, 125V (ZWACPFAC-08) : Amazon.ca: Electronics.” Amazon.ca. Accessed: Oct. 11, 2024. [Online]. Available: SHORTENED URL

[04] “UNIVERSAL MULTI-OUTLET AMERICAN, CANADA 15 AMPERE-125 VOLT PLUG ADAPTER, TYPE B, 2 POLE-3 WIRE GROUNDING (2P+E). IVORY.” International Configurations, Inc. - CORDSETS, CORD SET, DETACHABLE CORDSETS, IEC60320, IEC320, IEC60309, IEC309, PLUGS, OUTLETS, SOCKETS, PLUG ADAPTERS, RECEPTACLES, OUTLET STRIPS, POWER STRIPS - International Configurations, Inc. Accessed: Oct. 11, 2024. [Online]. Available: https://internationalconfig.com/icc6.asp?item=30250-NS

[05] “Genuine Apple 5W USB Power Adapter Charger Wall Plug Cube for iPhone.” Ebay. Accessed: Oct. 11, 2024. [Online]. Available: https://www.ebay.ca/itm/195428617212

[06] “Multi Plug Outlet Extender, TESSAN Mini Wall Plug Expander with 3 Electrical Outlet, 3 USB Outlet Plug, Cube Multiple Plug Outlet Splitter for Travel, Home, Office, Cruise Ship, Dorm Room Essentials.” Amazon. Accessed: Oct. 11, 2024. [Online]. Available: SHORTENED URL

[07] “Universal Travel Adapter, All in One Plug Adapter with USB C, Worldwide Power Adapter USB Type C Port, International Wall Charger Foldable Plug Converter Outlet for Europe EU UK AUS (Type G/C/I/A).” Amazon.com. Accessed: Oct. 11, 2024. [Online]. Available: SHORTENED URL

[08] “12V LED Strip Power Supply, 2A 24W Power Adapter, 12V Power Supply for LED Strip Lights Security Camera DVD Player, AC 100-240V to DC 12V Transformer, US Plug (2 Pack) : Amazon.ca: Tools & Home Improvement.” Amazon.ca. Accessed: Oct. 11, 2024. [Online]. Available: SHORTENED URL

[09] “Amazon.com: Unidapt Multi Plug Outlet Extender, 3 Outlet Wall Adapt er, Multiple Outlet Splitter, Grounded Wall Tap Power Plug Expander for Cruise Ship Home Office Dorm Essentials, 2-Pack : Tools & Home Improvement.” Amazon.com. Accessed: Oct. 11, 2024. [Online]. Available: SHORTENED URL

[10] “UL 498, Standard for Safety for Attachment Plugs and Receptacles.” 114 Retention of Plugs Test Pg. 117, 15th Ed, Underwriters Laboratories, Northbrook, IL, USA, 2020. Accessed: Oct. 13, 2024. [Online]. Available: SHORTENED URL

114 Retention of Plugs Test

114.1 The contacts of the receptacles illustrated in Figures C1.1, C1.5, C1.6, C1.9, and C1.10 shall be capable of holding an attachment plug so that a force of 3 – 15 lbf (13 – 67 N) is required to withdraw the plug when tested as described in this Section.

Exception: A receptacle that has provision for locking the plug in place after the blades have been inserted in the female contacts need not be subjected to this test.

114.2 Each device is to be subjected to ten conditioning cycles of insertion and withdrawal of a standard solid-blade attachment plug of a type with which the device is intended for use and that has American National Standard detent holes in rigidly mounted blades, following which the plug is to be fully reinserted into the device. A pull of 3 lbf (13 N) in a direction perpendicular to the plane of the face of the receptacle and tending to withdraw the plug from the device is then to be applied to the plug for 1 minute. The results are unacceptable if there is any displacement of the plug.

114.3 The receptacle is then to be subjected to the regular overload and temperature tests, following which the entire procedure described above is to be repeated. In the repeated test, the results are unacceptable if the plug is displaced by the 3 lbf (13 N) pull, but it is required that the cap be withdrawn when the pull is increased to 15 lbf (67 N). If the device is intended to accommodate either a 2- or 3-wire plug, the entire procedure described above is to be performed with a 2-wire plug, after which a 3-wire plug inserted into the device is required to be withdrawn by a 15 lbf (67 N) pull.

[11] "IEC 60512-2-1:2002. Connectors for electronic equipment." Tests and measurements - Part 2-1: Electrical continuity and contact resistance tests - Test 2a: Contact resistance - Millivolt level method, 5 Requirements, Pg 7 International Electrotechnical Commission, 2002. Accessed: Oct. 13, 2024. [Online]. Available: SHORTENED URL

5 Requirements

The value of the contact resistance shall not exceed, for any measurement, the value specified in the detail specification.

The contact resistance measurement with d.c. shall be the average of the two readings obtained with forward and reverse current.

Use of the following equation will ensure that the calculated resistance is always correct:

$$R = \frac{|V_{mf} - V_{mr}|}{|I_f| + |I_r|}$$

NOTE In the equation, the sign of the voltage measurements must be included.

where

R is the resistance;

V_{mf} is the measured forward voltage;

V_{mr} is the measured reverse voltage;

I_f is the forward current;

I_r is the reverse current.

NOTE Any deviation from the standard test procedure should be clearly indicated in the test report.

[12] "ASTM D3359-20. Standard Test Methods for Measuring Adhesion by Tape Test." ASTM International, 2020. Section 4 Test Methods, Page 2. Accessed: Oct. 13, 2024. [Online]. Available: https://cdn.standards.iteh.ai/samples/112953/22ddb3d5fb0948ed9acd68d9f2dded63/ASTM-D3359-22.pdf

4. Summary of Test Methods

4.1 *Test Method A*—An X-cut is made through the film to the substrate, pressure-sensitive tape is applied over the cut and then removed, and adhesion is assessed qualitatively on a 0 to 5 scale.

[13] "ISO 868:2003. Plastics and ebonite - Determination of indentation hardness by means of a durometer (Shore hardness)." International Organization for Standardization, 2003. Accessed: Oct. 13, 2024. [Online]. Available: https://cdn.standards.iteh.ai/samples/34804/a84cf1ebb91149e39513cc01c9e01050/ISO-868-2003.pdf

8 Procedure

8.1 Place the test specimen on a hard, horizontal, plane surface. Hold the durometer in a vertical position with the point of the indenter (4.2) at least 9 mm from any edge of the test specimen. Apply the presser foot (4.1) to the test specimen as rapidly as possible, without shock, keeping the foot parallel to the surface of the test specimen. Apply just sufficient pressure to obtain firm contact between presser foot and test specimen.

NOTE Better reproducibility may be obtained by using either a durometer stand or a weight centred on the axis of the indenter, or both, to apply the presser foot to the test specimen. Recommended masses are 1 kg for the type A durometer and 5 kg for the type D durometer.

Read the scale of the indicating device (4.3) after 15 s ± 1s. If an instantaneous reading is specified, read the scale within 1 s after the presser foot is in firm contact with the test specimen, unless the durometer has a maximum indicator, in which case the maximum reading shall be taken.

[14] "A GUIDE TO PRODUCTS & TEST METHODS." CLASSIFIED SURFACES & RECOGNISED COURTS. Accessed: Oct. 13, 2024. [Online]. Available: https://www.itftennis.com/media/4420/2023-technical-booklet.pdf

Test balls

A high-specification ball is required for court testing to reduce the effect of ball properties on the measurement of surface characteristics (see Table 1).

Type of ball	Pressurised
Mass	57.6 ± 0.3 g
Diameter	6.60 ± 0.05 cm (2.598 ± 0.020 inches)
Forward deformation	0.64 ± 0.04 cm (0.252 ± 0.016 inches)
Return deformation	0.94 ± 0.14 cm (0.370 ± 0.055 inches)
Rebound	141 ± 1 cm (55.5 ± 0.4 inches)
Woven cloth	55 ± 5% wool, 45 ± 5% nylon

Table 1. Ball specification for surface testing.

[15] "Toxic substances list - Canada.ca." Canada.ca. Accessed: Oct. 13, 2024. [Online]. Available: https://www.canada.ca/en/environment-climate-change/services/CEenvironmental-protection-act-registry/substances-list/toxic.html

Toxic substances list: schedule 1

Updated Schedule 1 as of May 12, 2021

1. Chlorobiphenyls that have the molecular formula $C_{12}H_{(10-n)}Cl_n$ in which "n" is greater than 2
2. Dodecachloropentacyclo [$5.3.0.0^{2,6}.0^{3,9}.0^{4,8}$] decane (Mirex)
3. Polybrominated biphenyls that have the molecular formula $C_{12}H_{(10-n)}Br_n$ in which "n" is greater than 2
4. Chlorofluorocarbon: totally halogenated chlorofluorocarbons that have the molecular formula $C_nCl_xF_{(2n+2-x)}$
5. Polychlorinated terphenyls that have a molecular formula $C_{18}H_{(14-n)}Cl_n$ in which "n" is greater than 2
6. Asbestos
7. Lead
8. Mercury and its compounds
9. Vinyl chloride
10. Bromochlorodifluoromethane that has the molecular formula CF_2BrCl
11. Bromotrifluoromethane that has the molecular formula CF_3Br
12. Dibromotetrafluoroethane that has the molecular formula $C_2F_4Br_2$
13. Fuel containing toxic substances that are dangerous goods within the meaning of section 2 of the Transportation of Dangerous Goods Act, 1992 and that
    (a) are neither normal components of the fuel nor additives designed to improve the characteristics or the performance of the fuel or
    (b) are normal components of the fuel or additives designed to improve the characteristics or performance of the fuels, but are present in quantities or concentrations greater than those generally accepted by industry standards
14. Dibenzo-para-dioxin that has the molecular formula of $C_{12}H_8O_2$
15. Dibenzofuran that has the molecular formula $C_{12}H_8O$
16. Polychlorinated dibenzo-para-dioxins that have the molecular formula $C_{12}H_{(8-n)}O_2Cl_n$ in which "n" is greater than 2
17. Polychlorinated dibenzofurans that have the molecular formula $C_{12}H_{(8-n)}OCl_n$ in which "n" is greater than 2
18. Tetrachloromethane (carbon tetrachloride) CCl_4
19. 1,1,1-trichloroethane (methyl chloroform) CCl_3-CH_3
20. Bromofluorocarbons other than those set out in items 10 to 12
21. Hydrobromofluorocarbons that have the molecular formula $C_nH_xF_yBr_{(2n+2-x-y)}$ in which $0<n\leq3$
22. Methyl bromide
23. Bis(chloromethyl) ether that has the molecular formula $C_2H_4Cl_2O$
24. Chloromethyl methyl ether that has the molecular formula C_2H_5ClO

List has been truncated as it is 200 items long, see above link for the full list.

[16] "Amazon.ca." Amazon.ca: Low Prices – Fast Shipping – Millions of Items. Accessed: Oct. 13, 2024. [Online]. Available: https://www.amazon.ca/Snug-Plug-Loose-Outlet-Clear/dp/B082889X7C/ref=cm_cr_arp_d_product_top?ie=UTF8&th=1

[17] "volport Loose Outlet Plug Fix, 6Pcs Adhesive Snug Insert for Falling Out Wall Electrical Socket, Power Outlet Tightener Compatible with Charger/ Hair Dryer/ Hand Blender/ Extender/ Adapter/ Timer." Amazon.ca. Accessed: Oct. 13, 2024. [Online]. Available: SHORTENED URL

[18] "10 Loose Outlet Fix Snug Plug, Keeps Loose Sockets Tight Against Power Plugs Socket, Extender Prevents Loose Socket Issues, Easily Fix Loose Outlets, Loose Socket Plugs for Outlets" Amazon.ca. Accessed: Oct. 13, 2024. [Online]. Available: SHORTENED URL

[19] "pop-tech Adhesive Stickers for Loose Outlet Plug: 12 Pcs Double Sided Tape Fix Wall Plugs Socket - 3M Sticky for Outlet Wall Mount Holder WiFi Extender Electrical Multi Outlets Power Adapter." Amazon.ca. Accessed: Oct. 13, 2024. [Online]. Available: SHORTENED

[20] Home - Chestnut Residence at University of Toronto. Accessed: Oct. 13, 2024. [Online]. Available: https://chestnut.utoronto.ca/wp-content/uploads/2024-25-Occupancy-Agreement.pdf

UNIVERSITY OF TORONTO | **Chestnut Residence** Spaces & Experiences

Meal Plan fees are available on the Food Services website - [Meal Plans - Food Services at University of Toronto (utoronto.ca)]

FACILITIES

5.0 Responsibility for Resident's Room

The Resident agrees to pay for all missing items, damages, or cleaning caused to the premises by the Resident or guest(s) during the term of this Agreement. The Resident agrees to not make any alterations, additions, or change in any way to the premises.

5.1 Responsibility for Shared Unit Facilities

All residents occupying a room or unit are jointly and severally responsible for items missing from, cleaning to, or damages caused to, the Shared Unit Facilities within the room or unit, which include, but are not necessarily limited to, the bathroom and living space.

5.2 Responsibility for Common Areas

All residents are jointly and severally responsible for items missing from, cleaning to, or damages caused to, the areas accessible by all residents, which include, but are not necessarily limited to lounges, stairwells, kitchenettes, laundry rooms, and hallways (hereinafter called the "Common Areas"). The Residence Life Office may, in its sole and absolute discretion, assign liability for missing items, cleaning, or damages caused to the Common Areas to residents occupying specific rooms, floors, or buildings.

5.3 Access & Entry

The Resident must produce their room key card for inspection by Security upon entering Chestnut Residence.

[21] "Amazon.ca." Amazon.ca. Accessed: Oct. 13, 2024. [Online]. Available: https://www.amazon.ca/gp/customer-reviews/R1DLM4U3S0DSAV/ref=cm_cr_arp_d_rvw_ttl?ie=UTF8&ASIN=B082889X7C

Mosaic

★☆☆☆☆ **Didn't work for me**

Reviewed in Canada on January 15, 2024

Item Parcel Quantity: 25 | Colour Name: Clear | Verified Purchase

Didn't work for me. Couldn't push the plug flush into outlet with this thing inserted into it.

One person found this helpful

Helpful | Report

[22] "Amazon.ca." Amazon.ca. Accessed: Oct. 13, 2024. [Online]. Available: https://www.amazon.ca/gp/customer-reviews/R33WDQX4889FFV/ref=cm_cr_arp_d_rvw_ttl?ie=UTF8&ASIN=B082889X7C

AG Pizzle

★★☆☆☆ **Disappointed**

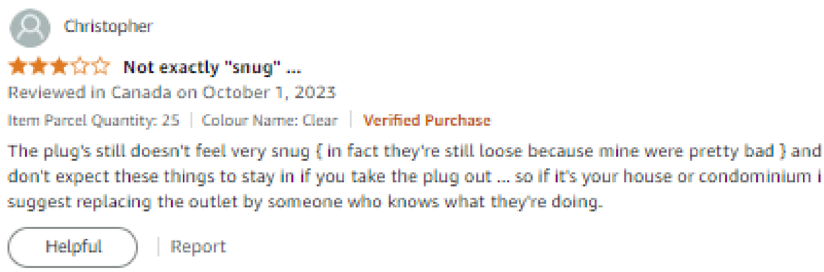
Reviewed in Canada on October 9, 2024

Item Parcel Quantity: 25 | Colour Name: Glow in the Dark | Verified Purchase

First of all for a tiny little piece of plastic they're hella expensive. And be careful of your plug… If the prongs aren't long enough, this prevents your electronic device from actually being useful.

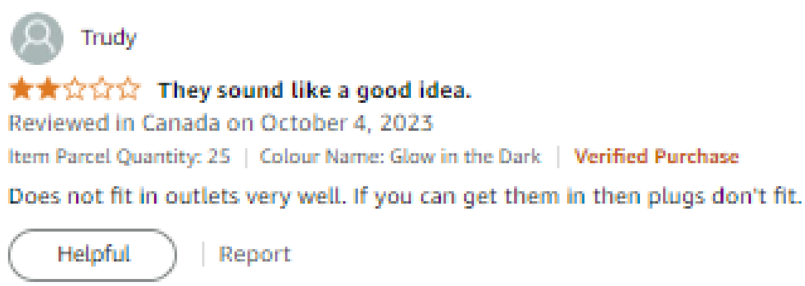
Helpful | Report

[23] “Amazon.ca.” Amazon.ca. Accessed: Oct. 13, 2024. [Online]. Available: https://www.amazon.ca/gp/customer-reviews/R3LMXP75Y9IIQK/ref=cm_cr_arp_d_rvw_ttl?ie=UTF8&ASIN=B082889X7C



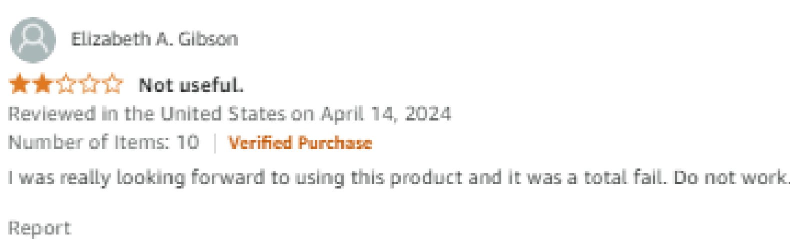
Christopher
Not exactly "snug" ...
Reviewed in Canada on October 1, 2023
Item Parcel Quantity: 25 | Colour Name: Clear | Verified Purchase
The plug's still doesn't feel very snug { in fact they're still loose because mine were pretty bad } and don't expect these things to stay in if you take the plug out ... so if it's your house or condominium i suggest replacing the outlet by someone who knows what they're doing.
Helpful | Report

[24] “Amazon.ca.” Amazon.ca. Accessed: Oct. 13, 2024. [Online]. Available: https://www.amazon.ca/gp/customer-reviews/R2CSV6PIEQ1JDP/ref=cm_cr_getr_d_rvw_ttl?ie=UTF8&ASIN=B082889X7C



Trudy
They sound like a good idea.
Reviewed in Canada on October 4, 2023
Item Parcel Quantity: 25 | Colour Name: Glow in the Dark | Verified Purchase
Does not fit in outlets very well. If you can get them in then plugs don't fit.
Helpful | Report

[25] “Amazon.ca.” Amazon.ca. Accessed: Oct. 13, 2024. [Online]. Available: https://www.amazon.ca/Sockets-Against-Extender-Prevents-Outlets/product-reviews/B0CWTWRGB3/ref=cm_cr_dp_d_show_all_btm?ie=UTF8&reviewerType=all_reviews#:~:text=Elizabeth%20A.%20Gibson,Report



Elizabeth A. Gibson
Not useful.
Reviewed in the United States on April 14, 2024
Number of Items: 10 | Verified Purchase
I was really looking forward to using this product and it was a total fail. Do not work.
Report

[26] “University of Toronto Libraries” University of Toronto Libraries. Accessed: Oct. 13, 2024. [Online]. Available: https://subscriptions-techstreet-com.myaccess.library.utoronto.ca/products/1004558

There is no screenshot available as this code must be followed in its entirety as it is the Canadian Electrical Standard.

[27] "Standards and Regulations | ECE Engineering Services." Home | ECE Engineering Services. Accessed: Oct. 13, 2024. [Online]. Available: SHORTENED URL

Standards and Regulations

As an engineer, anything that is made and placed on the market is subject to a set of rules and standards. By law, all electrical equipment in Canada must meet CSA Electrical Standards. These rules are closely followed by UBC as we are a public Canadian institution and all our equipment must be CSA certified. Below are links to where to find the information regarding CSA approval.

[28] Spektrochem Paint Technical Center. *Tape Adhesion ASTM D3359 [Paint Testing]*. (Sep. 17, 2020). Accessed: Oct. 13, 2024. [Online Video]. Available: https://www.youtube.com/watch?v=zTdJzbVQfDQ

[29] "3M™ VHB™ High-Strength Bonding Tapes." Accessed: Oct. 13, 2024. [Online]. Available: https://multimedia.3m.com/mws/media/1235572O/uv-primer-technical-data-sheet-canada-english-pdf.pdf

Product number	4905	4910	4915	5925	5952	5962	LSE-060WF	LSE-110WF	LSE-160WF	GPH-060GF	GPH-110GF	GPH-160GF	4936
Total thickness [mm]	0.5	1.0	1.5	0.6	1.1	1.6	0.6	1.1	1.6	0.6	1.1	1.6	0.6
Adhesive type	Acrylic	Acrylic	Acrylic	Acrylic	Acrylic	Acrylic	Mod. Acrylic	Mod. Acrylic	Mod. Acrylic	Acrylic	Acrylic	Acrylic	Acrylic
Colour	Clear	Clear	Clear	Black	Black	Black	White	White	White	Grey	Grey	Grey	Grey
Foam density [kg/m³]	960	960	960	590	590	590	715	715	715	710	710	710	720
Peel strength [Newton/cm] ASTM D-3330	21	26	26	30	39	39	30	44	54	25	37	34	30
Tensile strength (T-block) [kPa] ASTM D-897	690	690	690	620	620	620	566	479	450	636	681	729	620
Dynamic overlap shear [kPa] ASTM D-1002	480	480	480	620	550	550	814	592	538	848	738	581	550

[30] "University of Toronto Libraries" University of Toronto Libraries. Accessed: Oct. 13, 2024. [Online]. Mechanical Endurance Test – 8.9 Pages 70-71 Available: https://subscriptions-techstreet-com.myaccess.library.utoronto.ca/products/585478

8.35.4 Mechanical endurance test

8.35.4.1

At the completion of this test, there shall not be any chipping, breaking, or loosening of parts that could adversely affect the functioning of the device as determined in Clause 8.35.4.2. The tamper-resistance mechanism shall be capable of performing its intended function.

8.35.4.2

Upon completion of this test, each device shall be

a) capable of completely mating with the intended attachment plugs (both grounding and nongrounding types, rated 15 and 20 A, where applicable);
b) subjected to a repeated probe test in accordance with Clause 8.35.2; and
c) subjected to the dielectric-voltage withstand test in accordance with Clause 8.35.5.

8.35.4.3

Six devices that were previously subjected to the probe test described in Clause 8.35.2 shall be used. One outlet face of each device shall be tested by inserting and withdrawing 5000 times an attachment plug having rigidly secured solid brass blades. When an equipment-grounding connection is provided in the device being tested, a grounding-type attachment plug shall be used. For duplex receptacles, three devices shall be tested using one outlet and three using the other outlet.

8.35.4.4

The test shall be conducted by machine. The machine shall withdraw and insert an unrestricted attachment plug with an average velocity of 760 mm/s ± 75 mm/s in each direction during a 64 mm

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stroke measured from the full insertion position. The velocity shall be determined without the outlet device installed on the machine to remove restrictions on the plug motion.

8.35.4.5

Blades, contacts, or tamper-resistance mechanisms shall not be adjusted, lubricated, or otherwise conditioned before or during the test. The attachment plug used for this test may be changed after each 1000 cycles.

[31] W. D. Callister, *Materials Science and Engineering: An Introduction*. Wiley, 2013.

8.4 BRITTLE FRACTURE

Brittle fracture takes place without any appreciable deformation and by rapid crack propagation. The direction of crack motion is very nearly perpendicular to the direction of the applied tensile stress and yields a relatively flat fracture surface, as indicated in Figure 8.1*c*.

Appendix D: Plug Fitting Data

Represented below is the data collected throughout spaces frequented by Engineering Science students and Chestnut Residence with a particular focus on spaces that Engineering Science Students use.

Socket Number	Location	Direction of Wall Socket	Fitting of Mid Type B Plug	Fitting of Heavy Type A Plug	Fitting of Light Type B Plug
1	Gerstein Library 1st Floor Main Hall	Upwards	Fits Well	Fits Well	Tight
2	Gerstein Library 1st Floor Main Hall	Upwards	Fits Well	Fits Well	Tight
3	Gerstein Library 1st Floor Main Hall	Upwards	Loose	Loose	Fits Well
4	Gerstein Library 1st Floor Main Hall	Upwards	Loose	Loose	Fits Well
5	Gerstein Library Reading Room	Upwards	Fits Well	Fits Well	Tight
6	Gerstein Library Reading Room	Sideways	Fits Well	Fits Well	Tight
7	Gerstein Library Reading Room	Sideways	Fits Well	Loose	Fits Well
8	Gerstein Library Reading Room	Sideways	Fits Well	Loose	Fits Well
9	Gerstein Library 1st Floor Inner Library	Upwards	Fits Well	Fits Well	Fits Well
10	Gerstein Library 1st Floor Inner Library	Upwards	Fits Well	Loose	Fits Well
11	Gerstein Library 1st Floor Inner Library	Sideways	Fits Well	Fits Well	Tight
12	Gerstein Library 1st Floor Inner Library	Sideways	Loose	Loose	Loose
13	Gerstein Library 1st Floor Inner Library	Sideways	Loose	Loose	Loose
14	Gerstein Library 1st Floor Inner Library	Upwards	Fits Well	Loose	Fits Well
15	Gerstein Library 1st Floor Inner Library	Upwards	Loose	Loose	Loose
16	Gerstein Library Reading Room	Upwards	Fits Well	Fits Well	Fits Well
17	Gerstein Library Reading Room	Upwards	Fits Well	Loose	Fits Well
18	Gerstein Library Reading Room	Upwards	Fits Well	Fits Well	Fits Well
19	Gerstein Library Reading Room	Upwards	Fits Well	Fits Well	Fits Well
20	Gerstein Library 2nd Floor Inner Library	Upwards	Fits Well	Fits Well	Fits Well
21	Gerstein Library 2nd Floor Inner Library	Upwards	Fits Well	Loose	Fits Well
22	Gerstein Library 2nd Floor Inner Library	Upwards	Fits Well	Fits Well	Fits Well
23	Gerstein Library 2nd Floor Inner Library	Sideways	Fits Well	Loose	Fits Well
24	Gerstein Library Basement Floor	Sideways	Fits Well	Loose	Fits Well

25	Gerstein Library Basement Floor	Sideways	Loose	Loose	Loose
26	Gerstein Library Basement Floor	Sideways	Loose	Loose	Loose
27	Gerstein Library Basement Floor	Sideways	Tight	Tight	Tight
28	Gerstein Library Basement Floor	Sideways	Tight	Tight	Tight
29	Gerstein Library Basement Floor	Sideways	Tight	Tight	Fits Well
30	Gerstein Library Basement Floor	Sideways	Tight	Tight	Fits Well
31	Bahen Centre 1st Floor	Sideways	Fits Well	Loose	Fits Well
32	Bahen Centre 1st Floor	Sideways	Fits Well	Loose	Fits Well
33	Bahen Centre 1st Floor	Sideways	Fits Well	Loose	Fits Well
34	EngSci Common Room	Sideways	Tight	Tight	Tight
35	EngSci Common Room	Sideways	Tight	Tight	Tight
36	EngSci Common Room	Sideways	Fits Well	Fits Well	Fits Well
37	EngSci Common Room	Sideways	Fits Well	Fits Well	Fits Well
38	EngSci Common Room	Sideways	Fits Well	Loose	Fits Well
39	EngSci Common Room	Sideways	Fits Well	Fits Well	Fits Well
40	EngSci Common Room	Sideways	Fits Well	Loose	Fits Well
41	EngSci Common Room	Sideways	Fits Well	Fits Well	Fits Well
42	EngSci Common Room	Sideways	Fits Well	Loose	Fits Well
43	EngSci Common Room	Sideways	Fits Well	Fits Well	Fits Well
44	EngSci Common Room	Upwards	Fits Well	Fits Well	Fits Well
45	EngSci Common Room	Upwards	Fits Well	Loose	Fits Well
46	Bahen Centre 1st Floor	Upwards	Tight	Fits Well	Tight
47	Bahen Centre 1st Floor	Upwards	Tight	Fits Well	Tight
48	Bahen Centre 1st Floor	Upwards	Tight	Fits Well	Tight
49	Bahen Centre 1st Floor	Upwards	Loose	Loose	Loose
50	Bahen Centre 1st Floor	Upwards	Loose	Loose	Loose

51	Bahen Centre 1st Floor	Upwards	Fits Well	Fits Well	Fits Well
52	Bahen Centre 1st Floor	Upwards	Fits Well	Loose	Fits Well
53	Bahen Centre 2nd Floor	Upwards	Fits Well	Fits Well	Fits Well
54	Bahen Centre 2nd Floor	Sideways	Tight	Tight	Tight
55	Bahen Centre 2nd Floor	Sideways	Tight	Tight	Tight
56	Robarts Library 6th Floor	Sideways	Fits Well	Fits Well	Fits Well
57	Robarts Library 6th Floor	Upwards	Fits Well	Fits Well	Fits Well
58	Robarts Library 6th Floor	Sideways	Fits Well	Loose	Fits Well
59	Robarts Library 6th Floor	Upwards	Fits Well	Fits Well	Fits Well
60	Robarts Library 6th Floor	Sideways	Fits Well	Loose	Fits Well
61	Robarts Library 6th Floor	Upwards	Loose	Loose	Loose
62	Robarts Library 6th Floor	Upwards	Fits Well	Fits Well	Fits Well
63	Robarts Library 6th Floor	Upwards	Tight	Tight	Tight
64	Robarts Library 4th Floor	Sideways	Loose	Loose	Loose
65	Robarts Library 4th Floor	Sideways	Loose	Loose	Loose
66	Robarts Library 4th Floor	Sideways	Fits Well	Fits Well	Fits Well
67	Robarts Library 4th Floor	Sideways	Loose	Loose	Loose
68	Robarts Library 7th Floor	Sideways	Fits Well	Fits Well	Fits Well
69	Robarts Library 7th Floor	Sideways	Fits Well	Fits Well	Fits Well
70	Robarts Library 7th Floor	Sideways	Loose	Loose	Loose
71	Robarts Library 7th Floor	Sideways	Tight	Fits Well	Tight
72	18th Floor Chestnut Residence	Sideways	Loose	Loose	Fits Well
73	18th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
74	18th Floor Chestnut Residence	Sideways	Fits Well	Fits Well	Fits Well
75	18th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
76	18th Floor Chestnut Residence	Sideways	Loose	Loose	Loose

77	18th Floor Chestnut Residence	Sideways	Loose	Loose	Fits Well
78	15th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
79	15th Floor Chestnut Residence	Sideways	Loose	Loose	Fits Well
80	15th Floor Chestnut Residence	Sideways	Fits Well	Fits Well	Fits Well
81	15th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
82	15th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
83	28th Floor Chestnut Residence	Sideways	Loose	Loose	Fits Well
84	28th Floor Chestnut Residence	Sideways	Loose	Loose	Fits Well
85	28th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
86	28th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
87	28th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
88	28th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
89	27th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
90	27th Floor Chestnut Residence	Sideways	Loose	Loose	Fits Well
91	27th Floor Chestnut Residence	Sideways	Fits Well	Fits Well	Fits Well
92	27th Floor Chestnut Residence	Sideways	Loose	Loose	Loose
93	MyHall 1st Floor	Sideways	Fits Well	Fits Well	Fits Well
94	MyHall 1st Floor	Sideways	Fits Well	Loose	Fits Well
95	MyHall 1st Floor	Sideways	Loose	Loose	Loose
96	MyHall 1st Floor	Sideways	Fits Well	Fits Well	Fits Well
97	MyHall 1st Floor	Sideways	Fits Well	Loose	Fits Well
98	MyHall 1st Floor	Sideways	Fits Well	Loose	Fits Well
99	MyHall 1st Floor	Downwards	Fits Well	Loose	Fits Well
100	MyHall 1st Floor	Downwards	Fits Well	Loose	Fits Well
101	MyHall 3rd Floor	Sideways	Fits Well	Fits Well	Tight
102	MyHall 3rd Floor	Sideways	Tight	Fits Well	Tight

103	MyHall 3rd Floor	Sideways	Tight	Tight	Tight
104	MyHall 3rd Floor	Sideways	Tight	Fits Well	Tight
105	MyHall 3rd Floor	Upwards	Tight	Tight	Tight
106	MyHall 3rd Floor	Upwards	Fits Well	Loose	Fits Well
107	MyHall 3rd Floor	Upwards	Fits Well	Fits Well	Fits Well
108	MyHall 3rd Floor	Upwards	Fits Well	Loose	Fits Well
109	MyHall 4th Floor	Sideways	Fits Well	Fits Well	Fits Well
110	MyHall 4th Floor	Sideways	Loose	Loose	Loose
111	MyHall 4th Floor	Sideways	Loose	Loose	Loose
112	102 McLennan Physical Laboratories	Upwards	Fits Well	Fits Well	Fits Well
113	102 McLennan Physical Laboratories	Upwards	Fits Well	Loose	Fits Well
114	102 McLennan Physical Laboratories	Upwards	Loose	Loose	Loose
115	102 McLennan Physical Laboratories	Downwards	Loose	Loose	Loose
116	102 McLennan Physical Laboratories	Downwards	Loose	Loose	Loose
117	102 McLennan Physical Laboratories	Downwards	Loose	Loose	Loose
118	126 McLennan Physical Laboratories	Upwards	Fits Well	Fits Well	Fits Well
119	126 McLennan Physical Laboratories	Upwards	Tight	Loose	Tight
120	126 McLennan Physical Laboratories	Downwards	Tight	Tight	Tight
121	126 McLennan Physical Laboratories	Sideways	Tight	Fits Well	Tight
122	126 McLennan Physical Laboratories	Sideways	Fits Well	Fits Well	Tight
123	126 McLennan Physical Laboratories	Upwards	Fits Well	Fits Well	Fits Well
124	126 McLennan Physical Laboratories	Upwards	Loose	Loose	Loose
		Loose:	40	67	32
		Fits Well:	63	44	67
		Tight:	20	12	23