Design of an Automated Wine Bottle Opener

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Abstract

This project focuses on designing and analyzing an automated wine bottle opener, accommodating various bottle sizes and shapes. The goal is to create a countertop device that is safe and user-friendly for both the abled and disabled. Utilizing a lever action mechanism, the opener removes the cork with downward force applied through a rack and pinion system. Once the lever is raised, friction between the cork and corkscrew prevents the corkscrew from rotating, allowing for easy cork removal. The device is stabilized onto surfaces with suction cups, ensuring stability during operation. Illustrating cultural traditions surrounding wine consumption, the design process prioritized accessibility for wine lovers. This project addresses the significance of accessible wine bottle opening solutions, closes a gap in the market for inclusive designs, outlines the methods used for design and analysis, presents results in terms of the chosen design's functionality and accessibility, and discusses implications for future development and user satisfaction.

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Section	Author(s)	Editor(s)
Abstract	Frank	Patrick, Cameron, Luke, ChatGPT
1. Introduction	Cameron	Frank, Chat GPT
2.1 Assistive Technology	Frank	Cameron, Chat GPT
2.2 Existing Wine Openers	Cameron, Luke	Frank
2.2.1 Advancements in Corkscrew History	Cameron	Frank, Luke
2.2.2 Current Automated Wine Bottle Openers	Frank, Cameron	Luke
2.3.1 Cork Properties	Patrick	Cameron, Chat GPT
2.3.2 Cork Production	Patrick	Cameron
2.3.3 Cork Alternatives	Patrick	Cameron, Chat GPT
2.3.4 Cork Contaminants	Patrick	Cameron
2.4.1 Properties of wine bott.	Patrick	Cameron
2.4.2 Comp. of wine bottle	Patrick	Cameron
2.5 Recycling and Reuse	Cameron	Patrick, Frank
3.1 Initial Client Statement	Patrick	Cameron, Frank, Luke, Chat GPT
3.2 Objectives and Constraints	Patrick	Cameron, Frank, Luke
3.3 Revised Client Statement	Frank	Cameron, Patrick, Luke
3.4 Project Approach	Luke	Frank
4.1 Design Requirements	Frank	Luke
4.2 Important Standards	Luke	Frank
4.3 Conceptual Designs	Luke	Frank
4.4 Alternative Designs	Frank, Luke	Patrick
4.5 Final Design and Model	Luke	Frank
5. Final Design Verification	Frank, Luke	Cameron
6. Final Design Validation	Frank, Luke	Cameron
7. Discussion	Cameron	Patrick, Chat GPT
8. Broader Impacts	Luke	Luke, Chat GPT
9. Conclusions and Recommendations	Cameron	Patrick

ChatGPT was used for wordsmithing and grammar purposes. All writing was the students' individual thinking and ideas.

Table of Contents

List of Figures

List of Tables

1. Introduction

Wine, an enduring cultural staple spanning centuries, has gained and reserved popularity throughout the years. Over time, advancements in wine production have paralleled innovations in bottle opening mechanisms. Handheld corkscrews and automated devices have proliferated, yet many require two-handed operation for either inserting or removing the cork.

In our modern, inclusive society, it is crucial to consider the diverse needs of individuals. For instance, an elderly person with arthritis may struggle to extract a cork, while a disabled veteran may find conventional corkscrews challenging to use.

The aim of this project was to develop a stationary, automated wine bottle opener accessible to all, ensuring safety and efficacy. Designed with inclusivity in mind, our solution integrates assistive technology, featuring a lever action rack and pinion system adaptable to individual needs.

After many potential designs were created and visualized on paper a final design was created using the Solidworks CAD software. There were many specific design choices made that keep in mind the inclusivity of all disabled people.

The following sections of the report contain an in depth literature review regarding the rising popularity of assistive technology, the background behind the culture of wine and the advancements in corkscrew technology, as well as the composition of wine bottles. Beyond that will be information on our project strategy and how the team made some of the important decisions. Finally the team will show the design process along with the design verification and validation.

2. Literature Review

Within the literature review, we dive into two interconnected ideals: both assistive technology as well as wine opening devices. To first explore these ideas is to define the words and importance of them. We then shed some light towards the history of assistive technology and the adaptations until modern day. We speak on the importance of their ability to enhance humans everyday lives especially those with disabilities. The second focal point being wine opening devices. Again we go back into the history of a corkscrew as well as a patent search. Also found is background on corks, including their properties, how they are produced, alternatives and potential contaminants. Later on wine bottle properties are discussed. Topics such as their composition and recycling process as well as potential reuse. Through this comprehensive review, we aim to offer a thorough understanding of these topics and their implications in various contexts.

2.1 Assistive Technology

In this section we look into the world of assistive technology, examining its definition, significance, and practical applications. We begin by clarifying the concept of assistive technology and its pivotal role in improving the quality of life for individuals with disabilities. Next, we explore historical and modern-day examples of assistive technologies, providing wisdom into assistive technology's evolution and the wide range of solutions they offer. Additionally, we explore the statistics regarding disabilities and the assistive technology equipment use in the United States, shedding light on the prevalence of various disabilities and the comparable assistive technologies applied to address them. Through this study, a deeper understanding of the life-changing impact of assistive technology on individuals' is achieved. [21]

2.1.1 What is Assistive Technology and its Importance

Assistive technology is any modified tool(s) and device that lets people with differences work around challenges. They make tasks and activities more accessible at school, work and home. Assistive technology is designed to help people with disabilities perform tasks that might otherwise be difficult or impossible for them. These technologies aim to enhance the quality of life, promote independence and facilitate inclusion for individuals with disabilities across various aspects of daily living, education, employment and social interaction. [21]

2.1.2 Examples of Assistive Technology Historically and Modern Day

The history of assistive technology is evidence of human ingenuity towards improving the lives of individuals with disabilities. While the concept of assisting individuals with disabilities dates back prior to any recorded history, the development of assistive technologies have significantly evolved over time [1]. The evolution of assistive technology showcases humanity's ongoing commitment to enhancing the quality of life for individuals with disabilities.

Ancient civilizations, such as the Egyptians, Greeks and Romans, developed introductory assistive devices to aid people with disabilities. For example, evidence of prosthetic limbs made from wood and metal date back to ancient Egypt [2]. These early examples laid the foundation for the advancements seen in modern assistive technology, highlighting the goal to overcome physical limitations and allowing individuals to lead more independent lives.

During the Middle Ages and Renaissance period, craftsmen created various assistive devices, including early forms of prosthetic limbs, crutches and eyeglasses. It is believed that eyeglasses were invented in Italy between 1268 and 1289. These innovations were often handcrafted and tailored to individual needs [3]. The Renaissance saw a resurgence of interest in science and innovation, leading to further developments in assistive technology. Innovations during this period paved the way for the more sophisticated and specialized devices we have today, marking a significant step forward in improving the quality of life for individuals with disabilities.

While both chairs and wheels have been around for thousands of years, the Ancient Greeks and the Chinese were the first to combine the two. Ancient Greeks were famous for their chariots, and records show that they used wheeled beds to transport people unable to walk. In

China, wheelchairs have been used since around 525 AD, with the earliest known record being found in an inscription on a stone slate in China[3]. In 1665 the first self-propelled wheelchair was invented by Stephan Farffler, a 22 year old German paraplegic watchmaker [4]. These early inventions laid the foundation for the modern wheelchair, which has undergone significant advancements in design and functionality over the centuries. Today, wheelchairs are essential mobility aids for millions of people worldwide, providing independence and accessibility in everyday life.

The 19th century experienced significant advancements in assistive technology catapulted by the Industrial Revolution. Innovations such as the Braille system revolutionized access to written communication for those with visual impairments. Similarly, developments in orthopedics led to more sophisticated prosthetic limbs and other orthotic devices [2]. These advancements marked a turning point in the accessibility and quality of life for individuals with disabilities. Today, assistive technologies continue to evolve rapidly, driven by advancements in science, engineering and digital technology, with a focus on improving accessibility and inclusivity for people of all abilities.

The 20th century saw rapid advancements and widespread adoption of technologies such as hearing aids and mobility aids like wheelchairs and crutches. World War II, in particular, heavily sped up the development of prosthetics and mobility devices to assist injured soldiers returning from war. Electronic devices such as speech generating devices and text to speech software emerged later in the 20th century, helping improve the communication abilities for those with speech or language impairments.

In the late 20th century into the 21st century the arrival of computers and digital technology revolutionized assistive technology. Screen readers, screen magnification software and alternative input devices warranted individuals with visual, motor and cognitive disabilities to access digital information. In the 21st century, assistive technology continues to advance rapidly, driven by innovations in areas like robotics, artificial intelligence, wearable technology and smart devices [2]. These devices allow and offer new possibilities for enhancing accessibility and independence for individuals with disabilities across various domains of life from education to employment opportunities.

Throughout history, the development of assistive technology has been intertwined with societal attitudes towards disability. As technology continues to evolve, the future of assistive technology holds promise for further breaking down barriers and creating opportunities for people of all abilities to live fulfilling lives.

2.1.3 Disabilities and the Assistive Technology Used in the United States Statistics

Disabilities affect a significant portion of the population in the United States, impacting individuals of all ages, race and socioeconomic backgrounds. According to data from the U.S. Census Bureau, approximately 61 million adults in the United States live with a disability, around 26% of the entire population [5]. This includes individuals with physical, sensory, cognitive and mental health impairments. Disabilities vary in nature and severity. The most common types of disabilities include mobility impairments, such as difficulty walking or climbing stairs, sensory impairments, including vision and hearing loss, cognitive disabilities such as developmental or intellectual disabilities, and mental health conditions, such as depression, anxiety and post-traumatic stress disorder. Disabilities affect individuals throughout their life. While children may experience developmental disabilities or chronic health conditions impacting their development and functioning. Elderly people may face age-related disabilities, such as mobility limitations, cognitive decline and sensory impairments. There is also an impact on daily life as well with disabilities. Including education, employment, healthcare access, transportation and social participation. Individuals with disabilities can encounter many barriers to accessing services, accommodations, and opportunities to access full inclusion and participation in society. There are federal laws that have been put in place such as the Americans with Disabilities Act and the Rehabilitation Act of 1973 that prohibit discrimination against individuals with disabilities and mandates equal access to employment, public services, transportation and accommodations. These laws have helped advance disability rights and promote accessibility and inclusion in various settings. The Centers for Disease Control and Prevention (CDC) presents data from the National Health Interview Survey (NHIS) regarding the usage of anatomical devices, mobility devices and vision devices broken down by age demographic[5]. These statistics were compiled and can be found in the following tables found below.

Anatomical devices, also known as orthotic devices, are medical devices designed to support, protect or improve the function of various body parts. Typically these devices are prescribed by healthcare professionals, such as orthopedic specialists, physical therapists or prosthetists, to address a wide range of musculoskeletal or anatomical issues. Below is a table regarding common types of anatomical devices and the statistical breakdown of the American population that requires them for daily life, broken down by age demographic.

[5,Table 1.] Assistive Technology use by age of person and anatomical device. (Numbers are in thousands) **Numbers do not add to these totals because categories are not mutually exclusive; a person could be counted more than once for any device

Anatomical Device	All Ages	44 Years and younger	45-64 years	65 years and older
Any Anatomical Device**	4565	2491	1325	748
Back Brace	1688	795	614	279
Neck Brace	168	76	78	13
Hand Brace	332	171	119	42
Arm Brace	320	209	86	25
Leg Brace	596	266	138	192
Foot Brace	282	191	59	31
Knee Brace	989	694	199	96
Other Brace	399	239	104	56
Any Artificial Limb	199	69	59	70
Artificial Leg or Foot	173	58	50	65
Artificial Arm or Hand	21	9	6	6

As seen above in Table 1, a comprehensive breakdown of ten different anatomical devices, along with the quantity of each device being utilized across different age groups in the United States. Overall, approximately 4,565,000 anatomical devices are in use nationwide, with the largest portion being utilized by individuals aged 44 and younger. As the age demographic increases, there is a gradual decline in anatomical device usage, as depicted in the table. Among the various devices, those designed to address back issues and lower limbs are the most prevalent. Notably, back, leg and knee braces make up the majority of braces in use, while artificial legs and feet are the most commonly utilized artificial limbs.

Mobility devices are essential tools for enhancing independence and improving the quality of life for individuals with disabilities. Specifically designed to address mobility impairments, these devices enable users to navigate their surroundings with greater freedom and engage in a wide range of activities. From wheelchairs to walkers, each mobility device is carefully designed to meet the unique needs of its user, providing essential support, stability and freedom of movement. Below is a statistical breakdown of common types of mobility devices and the age demographics of individuals who utilize them.

[5,Table 2.] Assistive Technology use by age of person and mobility device. (Numbers are in thousands) **Numbers do not add to these totals because categories are not mutually exclusive; a person could be counted more than once for any device

Mobility Device	All Ages	44 Years and younger	45-64 years	65 years and older
Any Mobility Device**	7394	1151	1699	4544
Crutch	575	227	188	160
Cane	4762	434	1116	3212
Walker	1799	109	295	1395
Medical Shoes	677	248	226	203
Wheelchair	1564	335	365	863
Scooter	140	12	53	75

Above in Table 2 is a detailed breakdown of the usage of six prevalent mobility devices across different age demographics. With approximately 7,394,000 mobility devices in use throughout the United States, that majority of users are aged 65 years or older, amounting to 61.5% of the total population utilizing such aids. Among the most commonly used mobility devices, canes emerge as the top choice, with around 64% of the population relying on them for assistance. Walkers follow closely behind, serving 24% of users, while wheelchairs accommodate around 21% of patients. Notably, there is an observable correlation between age and the adoption of mobility aids, with older individuals comprising a larger proportion of users. Specifically, those aged 65 years and older represent the predominant user demographic, while individuals aged 44 years and younger constitute the minority of users.

Visual devices for disabilities encompass a diverse array of tools and technologies tailored to enhance the accessibility and independence for individuals with visual impairments or blindness. These innovative devices serve to mitigate the challenges posed by vision loss by offering alternative methods for accessing information, navigating surroundings and participating in everyday tasks. Below is a statistical breakdown of various common types of visual aids, along with the demographic distribution of their users.

[5,Table 3]. Assistive Technology use by age of person and vision device. (Numbers are in thousands) **Numbers do not add to these totals because categories are not mutually exclusive; a person could be counted more than once for any device

Vision Devices	All Ages	44 years and younger	45-64 years	65 years and older
Any Device**	527	123	135	268
Telescopic Lenses	158	40	49	70
Braille	59	28	23	8
Readers	68	15	14	39
White Cane	130	35	48	47
Computer Equipment	34	19	8	7
Other Vision Technology	277	51	76	151

Highlighted here are seven prevalent types of visual aids, spanning from white canes to telescopic lenses and braille (Found above in Table 3). Approximately 527,000 Americans benefit from these aids. Among them, white cans are one of the most widely used, accounting for approximately 130,000 users, closely followed by telescopic lenses with around 158,000 users. Interestingly, there is a distinguishable correlation between age and the utilization of certain vision devices. While aids like white canes and braille exhibit consistent usage across age groups, the adoption of telescopic lenses and other advanced vision technologies tends to increase with age.

Our device of creating an automated wine opener is deeply rooted in considerations for individuals with disabilities, acknowledging the significant impact disabilities have on the population. With approximately 61 million adults in the United States living with disabilities, encompassing various physical, sensory, cognitive and mental health impairments, our aim is to develop a solution that promotes accessibility and inclusivity for all users. Understanding the diverse needs of individuals with disabilities throughout their lives, our design process takes into account the challenges they face in daily activities such as opening wine bottles. We have carefully examined data from sources such as the Centers for Disease Control and Prevention (CDC), which provides valuable insights into the usage of assistive devices across different age demographics. For instance, in our consideration of anatomical devices, we have analyzed statistics indicating the prevalence of various braces and artificial limbs among different age groups, ensuring our device accommodates the needs of users with mobility impairments. Similarly, in our exploration of mobility devices, we have taken note of the distribution of devices such as canes, walkers and wheelchairs among different age demographics, informing our design choices to cater to the majority of users. Additionally, in our examination of vision devices, we have observed trends in the usage of aids like white canes and telescopic lenses, guiding us in incorporating features such as textured grips and bases to assist visually impaired users in positioning the wine bottle and operating the device with ease. By integrating these considerations into our design, we aim to create an automated wine opener that not only meets the needs of individuals with disabilities but also enhances and promotes their independence in everyday tasks. [21]

2.2 Existing Wine Opening Devices

There are many different types of wine opener. The best one for you depends on your budget, how often you open bottles of wine, and your physical limitations. For casual wine drinkers on a low budget, a waiter's corkscrew, a simple and affordable two-pronged design, might be just the best option. However, they require some finesse and upper body strength to use and can be tough to use on fragile corks. Winged corkscrews address this challenge by incorporating a lever mechanism for additional leverage at an accessible price point, but they still struggle with very old or crumbly corks and can stress the bottle over time. If you want an easier solution and don't mind spending a bit more, lever corkscrews are a great option. They're almost effortless to use, often come with a foil cutter, and can pull out most cork types. However, they tend to be bulkier and pricier than the other openers on the market, and some may not handle very dry or weak corks. Electric wine openers are the best out there in convenience, perfect for people with hand limitations or those who simply don't want to put in any effort. They're the fastest and easiest way to open a bottle, but they also come with the largest price tag and require an electrical outlet or batteries. Improper use can even damage the cork. Finally, pneumatic wine openers, which use air pressure to extract the cork, offer another easy and quick option that's gentle on the cork. The downside is the cost, they can be expensive and require refills of compressed air cartridges, which adds to the operating expense. All of these require one hand on the corkscrew and one hand on the bottle. [21]

2.2.1 Advancements in Corkscrew History

Wine packaging has evolved significantly over time, much like the evolution of wine itself. Initially, wine was not commonly corked or bottled in glass. It wasn't until the late 1700s and early 1800s that glass containers gained popularity for storing wine.

In 1795, in England, Reverend Samuel Henshall introduced the first patented corkscrew [6]. His design featured a metal helix attached to a perpendicular metal handle (United States patent found in Appendix A.1). The corkscrew operates by twisting it downward into the cork. With one hand on the handle and the other on the bottle, a firm upward motion easily removes the cork. However, this method typically requires the use of both hands. There is also a potential to break the neck of the bottle as there is nothing supporting it. Henshalls design was so effective that it did last hundreds of years and is still very commonly used today with slight variation.

It wasn't until 1882, nearly a century later, that a German inventor Carl F.A. Wienke introduced his patented design known as the 'Waiter's Friend' [7]. This design closely resembled Henshall's, featuring a metal helix and handle. However, the notable improvement was the helix folding into the handle, making it more convenient and safer for travel and storage (United States patent found in Appendix A.2). Like Henshall's design, it still required the use of both hands to remove the cork. As soon as this corkscrew began to rise in popularity many other people got their hands on making new designs.

Just six years later, in England, in 1888, another innovative patent emerged: the A1 Heeley Double Lever, named after its creator H.S. Heeley. This device featured a double-lever rack and pinion system, earning it the nickname "the wing" due to its two arm-like levers on each side. A similar patent reached the United States much later, in 1930, patented by Italian designer Dominick Rosati [8]. Both designs operate similarly, with the corkscrew screwing into the cork while gears cause the levers to rise on each side (United States patent found in Appendix A.3). With one hand on each lever and a firm downward motion, the cork is effortlessly removed, albeit still requiring the use of two hands.

Advancements in technology and materials gave oil and aerospace engineer Herbet Allen the skills to create a new innovation on the corkscrew. His creation, the 'Screwpull', incorporated polycarbonate plastic and advanced metals [7]. The Screwpull featured a plastic screw on the top with a slim mouth designed to fit around the neck of the bottle. Operating the device was simple: turning the plastic screw pulled the cork into the sheath surrounding the neck (United States patent found in Appendix A.4). Notably, this design required only one hand to twist and remove the cork, eliminating the need for a firm upward or downward motion as seen in prior corkscrews.

Herbert Allen refined his designs for the corkscrew, securing an additional patent. This updated design included a handle and lever, enabling a series of simple down-up-down movements to insert the corkscrew into the cork, extract it, and release the cork from the device's end [7]. (United States patent found in Appendix A.5) This streamlined operation necessitated only a single-handed up-down pumping motion to remove the cork.

This design, crafted nearly two decades ago, remains highly functional and optimal to this day. Its modern adaptations, particularly the 'Rabbit' device developed by a small team in Seattle, have gained immense popularity in the United States. (United States Patent found in Appendix A.6) This simple to use lever device removes a cork effortlessly whilst only requiring one hand to operate. [21]

2.2.2 Current Automated Wine Bottle Openers

As mechanical engineering progressed, traditional corkscrews adapted alongside the emergence of automated devices, thus giving rise to automated corkscrews. These devices offer users the convenience of opening wine bottles with the push of a button or through simple, user-friendly operations, greatly increasing accessibility and ease of use. Automated wine openers represent a modern innovation in the field of wine accessories, offering convenience and ease of use for wine enthusiasts and consumers. These devices are designed to automate the process of removing the cork from a wine bottle, eliminating the need for manual corkscrews and reducing the risk of cork breakage or wine spillage.

Automated wine openers have become increasingly accessible to people due to their growing popularity and advancements in technology. These devices are now widely available for purchase both online and in retail stores, catering to a wide range of budgets and preferences. Many online retailers offer a diverse selection of automated wine openers, allowing consumers to compare features, prices and customer reviews before making a purchase. Additionally, retail stores that specialize in kitchen appliances, such as home goods, or wine accessories often keep automated wine openers in stock. Providing shoppers the ability to see and test the products in person before buying. Overall increasing the accessibility of wine openers, allowing wine enthusiasts to enjoy the convenience and efficiency of these modern devices.

Automated wine openers are prized for their ease of use, offering a convenient and efficient way to uncork wine bottles with minimal effort. These devices typically feature user-friendly design and intuitive operation. Making them accessible to wine enthusiasts of all experience levels. With the push of a button or the activation of a simple mechanism, automated wine openers effortlessly remove corks from bottles, eliminating the need for manual twisting or pulling. Many models are well-designed to fit comfortably in the hand, providing a comfortable grip and reducing strain during operation. Additionally, automated wine openers come with foil cutters and charging stations, further enhancing their ease of use and versatility. Overall, the intuitive design and convenient functionality of automated wine openers make them a popular choice for those seeking a hassle-free way to enjoy their favorite wines.

Automated wine openers vary in cost depending on factors such as brand, features and quality. Entry level models are typically relatively affordable, while high-end options with more advanced features come with a higher price tag. In terms of cleaning, many automated wine openers can vary in difficulty depending on the make and model. Some automated wine openers feature removable parts that can make cleaning straightforward, however most automated wine openers have more complex designs that make cleaning more challenging. For example, devices with built in foil cutters or other integrated features may require more detailed cleaning to ensure all components are thoroughly sanitized. Additionally, models with non-removable parts may require special cleaning tools or techniques to reach all areas effectively. [21]

Chinese inventor Xiaoxian Song patented an invention titled “Wine bottle opener with screw mechanism for cork extraction” that is universally used by all companies. His design is handheld, utilizing a base, an elongated support structure and a motorized opener mounted on the support structure [8]. (United States Patent Found in Appendix A.7.) The base supports the wine bottle, while a locking mechanism prevents the bottle from rotating during the cork extraction.

The motorized opener includes a screw mechanism and a cap gripper designed to engage and remove the cork from the bottle.

2.3 History and Background of Corks

To create an automated wine opener that meets accessibility, convenience, maintenance, and cost-effectiveness criteria while also ensuring the preservation of wine integrity and taste, it's crucial to explore both the production process of cork and its alternatives, along with understanding the properties of wine bottles. Understanding the nuances of cork and bottle production provides valuable insights into its properties and characteristics, which are crucial for engineering an efficient wine-opening mechanism. [21]

2.3.1 Properties of Natural Cork

Cork is available in various sizes, primarily distinguished by length, including options such as 1.5 inches (35 mm), 1.75 inches (44 mm), and 2 inches (49 mm) [9]. Longer corks are often preferred for higher-quality wines with longer shelf lives, as they provide a tighter seal, while shorter corks may suffice for less expensive wines intended for shorter storage periods. Generally, cork has a standard diameter of 24 mm (size 9), although variations are found with diameters of 21 mm (size 7) or 22 mm (size 8) [10].

Understanding the friction properties of cork plays a significant role in comprehending its behavior as a wine stopper. It requires a force ranging from 300 to 400 Newtons to extract the cork from a bottle. Typically, there's a radial stress of about 0.3 Megapascals (MPa) exerted on the bore of the bottle during this process. The area of contact between the bottle and the cork is approximately 20 square centimeters, resulting in a friction coefficient (μ) of 0.5 [11]. It's important to note that this friction factor varies depending on the radial stress applied, indicating the dynamic nature of cork's interaction with the bottle neck during removal. Understanding these friction properties aids in optimizing cork design and bottle sealing mechanisms to ensure efficient and effective usage [21].

2.3.2 Production Process of Natural Cork

Initially, a cork tree is debarked within 15-30 years of its life or when it reaches a diameter of about 70 cm [9]. The cork obtained during this first stripping is typically not of high enough quality to be used as wine stoppers and is instead utilized for other cork materials. Subsequent bark removal occurs approximately nine years later, with the cork from this layer also deemed unsuitable for stoppers. It's only around the third stripping, another nine years after the first, that the cork harvested is considered high-quality for wine stoppers [9].

After harvesting, cork is typically stored outdoors to undergo a curing process. Following curing, the cork undergoes boiling to disinfect and soften it, enhancing its workability. Once softened, the cork is cut into strips or boards and punched into shape. Approximately 30% of the cork board is punched into stoppers. This process ensures that cork achieves the desired properties and shapes required for wine stoppers.

After the punching process, corks undergo several important treatments to ensure their cleanliness and sterility. Initially, they are polished and rinsed to remove any residual debris. Following this, sterilization is conducted, which involves rinsing the corks in a solution typically composed of sodium hypochlorite and oxalic acid, although this method is acknowledged to have limitations. Subsequently, the corks are rinsed again, this time with a peracetic acid solution, which provides enhanced sterilization. Finally, to further guarantee sterility, the corks are irradiated using cobalt-60. These steps are essential to ensure that the corks meet the required standards for hygiene and safety in their application as wine stoppers.

After processing and sterilization, cork is carefully dried to achieve a moisture content ranging from 6% to 8%, a crucial step to ensure its stability and durability. Following drying, cork may be coated with protective substances, commonly silicon or paraffin, which serve to enhance its resilience and sealing properties. The cork is then stored in a controlled environment, typically an atmosphere containing sulfur dioxide (SO_2), maintained at a temperature of 20°C and humidity levels between 50% and 70% [9]. This meticulous storage method further safeguards the cork from microbes that can produce wine contaminants as well as the wine from oxidation, thus preserving its quality and suitability for use as wine stoppers.

Cork grading is essential in determining its quality and longevity, with Grade A cork boasting the highest standards. Lasting between 5 to 20 years, Grade A cork exhibits minimal flaws, with pores less than 2mm, body cracks under 18%, and end cracks less than 11%. Grade B cork, with a lifespan of 5 to 15 years, features no major flaws, though pores may measure up to 5mm and cracks are limited to 25% for body cracks and 18% for end cracks. In contrast, Grade C cork, lasting 5 to 10 years, presents significant flaws, including cracks or channels exceeding 55%, making it less suitable for long-term use [10]. These grading criteria help ensure that cork meets the desired standards for durability and performance in various applications, particularly as wine stoppers. [21]

2.3.3 Alternatives to Natural Cork

Alternative corks have emerged as innovative solutions to traditional natural cork for sealing wine bottles. These alternatives offer various benefits such as cost-effectiveness, consistency, and reduced environmental impact. Agglomerated cork, for instance, is made from natural cork granules bonded with synthetic glue, providing a reliable sealing option at a lower cost compared to pure cork [9]. Technical cork takes this a step further by combining agglomerated cork with natural cork disks, offering a hybrid solution that maintains some of the traditional cork characteristics while improving consistency [10]. Colmated cork addresses quality issues in natural cork by filling imperfections with cork powder and resin, ensuring a more reliable seal [10]. Synthetic cork, made from materials like low-density polyethylene or plant-based plastics, provides a completely different approach, offering consistent performance and reduced risk of cork taint [10]. These alternative corks cater to diverse needs in the wine industry, offering options that balance performance, cost, and sustainability.

2.3.4 Contamination of Wine

TCA, or 2,4,6-trichloroanisole, is a compound that can develop in wine bottles due to contact with chlorine and certain microorganisms present within the cork. When TCA forms, it can impart a tainted and muddled taste to the wine, affecting its overall quality and enjoyment. This occurrence is estimated to affect approximately 3-5% of wine bottles [12], highlighting the significance of this issue within the wine industry. Additionally, this taste can appear with a TCA concentration of only 3-10 ng/L [13]. However, by ensuring proper storage conditions and utilizing cleaning products free from chlorine, the risk of TCA formation can be minimized, resulting in the preservation of the wine's optimal taste profile.

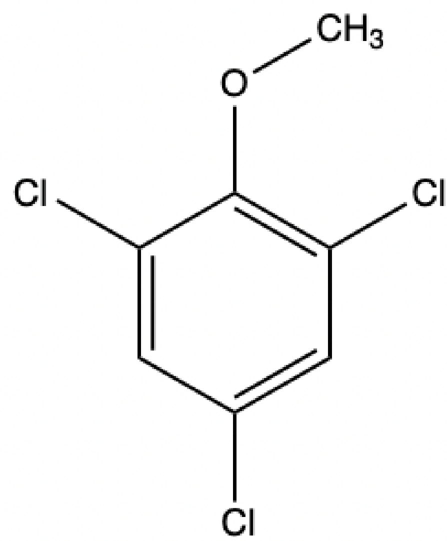

Figure 1: Chemical Structure of TCA

Additionally, other contaminants and chlorinations of TCA can contaminate the wine from the cork. These other contaminants, PCA and TeCA, are typically found in lower quantities than TCA and will have less of an affect on the taste of the wine, however should be noted as significant possible sources of contamination in wine.

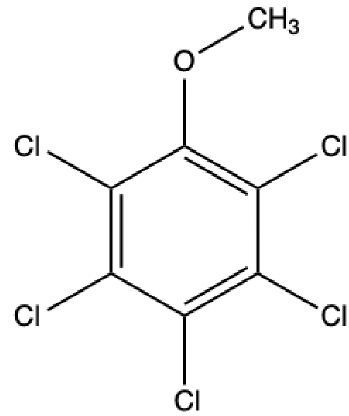

Figure 2: Chemical Structure of PCA

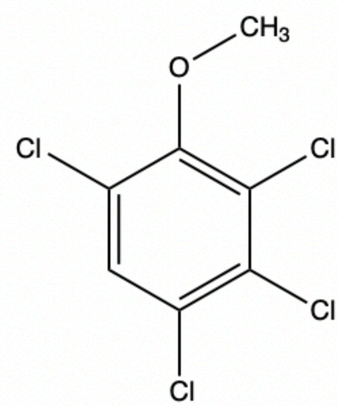

Figure 3: Chemical Structure of TeCA

Compounds in the cork along with microorganisms, filamentous fungi [13], that can grow on the cork can react to form TCA and the other contaminants found in wine. Glucose in the cork can react to form shikimic acid which can decompose into phenol. Phenol in the cork can then be chlorinated to TCP or undergo an o-methylation reaction catalyzed by the filamentous fungi to form anisole. The TCP or anisole will then undergo an o-methylation or chlorination respectively to form TCA. [21]

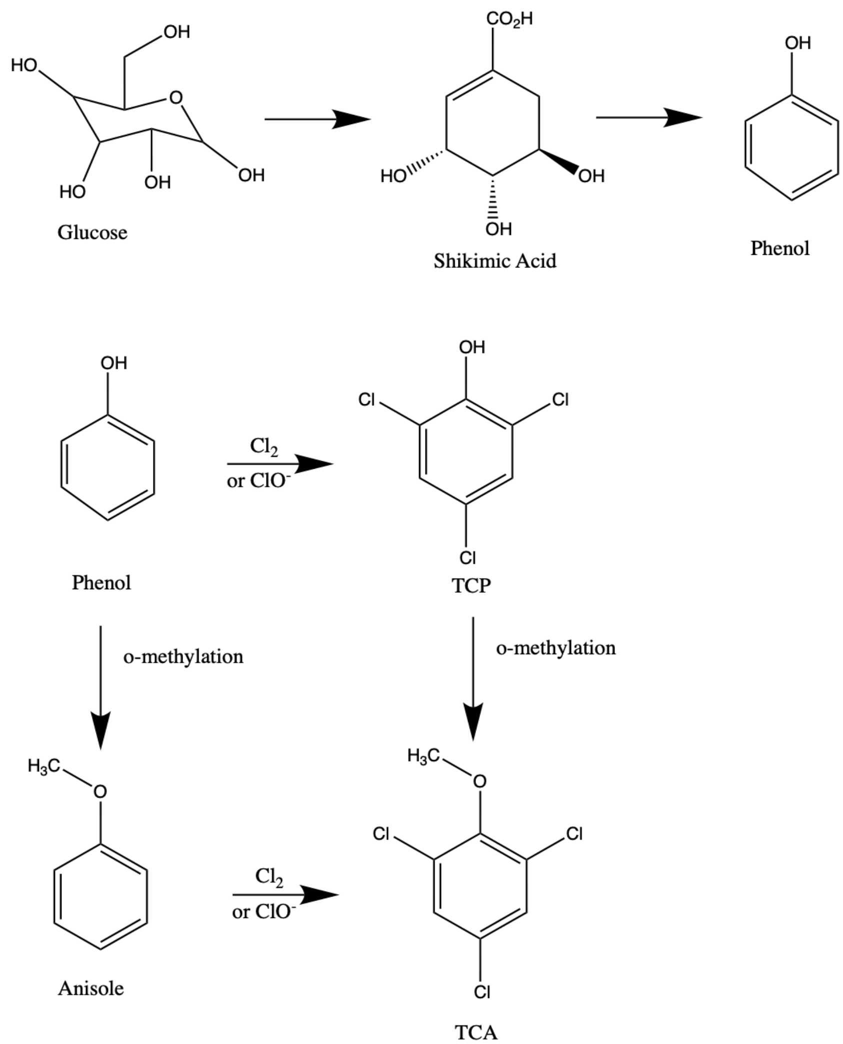

Figure 4: Reaction scheme of TCA from glucose and phenol found naturally in cork.

2.4 Wine Bottle Information:

The properties of wine bottles play a crucial role in designing an automated wine opening mechanism that provides an accessible, convenient, maintainable, and cost-effective method to remove a cork.

2.4.1 Properties of the wine bottle:

A typical wine bottle weighs approximately 2.65 pounds (1.2 kilograms), providing stability and durability during transportation and storage. In terms of size, the dimensions of a standard 750 milliliter wine bottle are as follows: it stands at a height of 30.48 centimeters (12 inches), with a base diameter of 7.493 centimeters (2.95 inches). At the top, the bore diameter starts at 1.85 centimeters (0.728 inches) and gradually increases to 2.1 centimeters over a length of 4.5 centimeters from the mouth of the bottle [9]. These dimensions are carefully designed to accommodate various wine bottling processes while ensuring ease of handling and pouring for consumers.

2.4.2 Composition of the wine bottle:

The composition of a wine bottle encompasses three primary natural resources: silica dioxide, soda ash, and limestone. Typically, a wine bottle consists of approximately 73% silica dioxide, derived from sand, 17% soda ash (Na_2O), and 9% lime (CaO). These materials, sourced from natural reserves, contribute to the bottle's structural integrity and transparency [14]. Additionally, a small percentage, usually between 1-3%, of coloring agents may be added to achieve specific aesthetic qualities [14]. This blend of materials forms the basis for the production of wine bottles, ensuring both functionality and visual appeal.

2.4.3 Motorized Cork Extraction Tester:

Mecmesin’s motorized cork extraction tester offers a reliable solution for conducting cork extraction tests on both natural and synthetic still-wine stopper corks. Designed to meet the requirements of ISO 9727, this tester provides accurate force measurements. The system features a cork extraction test rig that can accommodate bottles of different heights, ensuring secure positioning during testing. During the test, a tensile load is steadily applied at a rate of 300 mm/min until either a sudden drop in resistance occurs or the cork is fully extracted from the bottle.[15] The peak extraction force is prominently displayed on Mexmesin’s digital force gauge and can be easily printed for further analysis and evaluation. This system offers a straightforward and efficient method for conducting cork extraction tests with precision and reliability,

2.5 Recycling and Reuse

Recycling aims to transform waste or used materials into reusable resources. Wine bottles, primarily made of sand, soda ash, and limestone, are essentially glass, which is 100% recyclable. This makes it easy to dispose of wine bottles through local recycling or waste collection services. Recycling centers also typically accept glass items when properly sorted.

The recycling process for corks differs slightly. ReCork companies, found throughout various locations, specialize in recycling cork products exclusively. Corks are frequently repurposed into various items, such as floorboard underlays or components for shoe soles. Some town and city recycling centers may also accommodate cork recycling, although it's advisable to confirm their specific guidelines beforehand.

3. Project Strategy

This section outlines the current gaps in the market for wine bottle openers and presents a solution that effectively addresses and resolves many of these issues. Recognizing the cultural significance of wine drinking, our design process prioritizes these ideals. Additionally, the team emphasizes the importance of preserving the integrity of the wine and provides insights on how to ensure that the wine's quality is maintained throughout the opening process.

3.1 Initial Client Statement

As of now there is no wine opener on the market that is accessible to disabled demographics such as: people with motor skill disabilities, the visually impaired, or amputees. Additionally, current automated wine openers lack a convenient, cost effective, easy to use, and easily maintainable design. The automated wine opener will aim to be a more convenient and maintainable design that is accessible to a wide plethora of disabled demographics while remaining a cost effective option that will not contaminate wine.

3.2 Objectives and Constraints

The objectives of this project are multifaceted, aiming to cater to various needs. Firstly, it seeks to create an accessible and user-friendly option for opening wine, ensuring that individuals with disabilities can enjoy the process with ease. Moreover, maintaining the integrity of the wine is paramount, emphasizing the necessity to design a mechanism that does not taint or contaminate the beverage during the opening process. Additionally, practicality is considered, with a focus on creating a product that is easy to clean, enhancing convenience for users. Finally, cost-effectiveness is a crucial aspect, ensuring that the solution remains affordable and accessible to a wide range of consumers. Through these objectives, the project aims to address multiple aspects of wine opening, making it inclusive, efficient, and economical.

The project faces several constraints that must be navigated to achieve its objectives. Firstly, the speed of opening is a critical factor, requiring the development of a solution that balances efficiency with accessibility. Cleaning options are also limited to non chlorinated products as use of chlorinated products can result in the formation of TCA and other wine contaminants. Cost presents another challenge, demanding a cost-effective approach to ensure affordability without compromising quality. Additionally, while targeting disabled demographics is a priority, the solution must also be mindful of untargeted groups, ensuring inclusivity across a diverse range of users. Meeting these constraints will be crucial in the development of a successful and impactful product.

With wine drinking being a very popular part of American culture, the market for wine bottle openers can be very competitive with many different iterations of similar designs. As far as handheld wine bottle openers go, a very well known two-handed lever action device known as the "Rabbit" ranges from around $26 to $60 depending on the version selected. Moving along to the automated world of wine bottle openers, many iterations of similar designs exist. The two handed battery operated devices typically range from around $24 to $50 dollars.

The world of wine bottle openers is indeed diverse, offering a range of options to suit different preferences and budgets. The classic Rabbit lever-style opener has established itself as a staple for wine enthusiasts, offering efficient and reliable performance. Its popularity has led to various versions and price points to cater to different needs ranging from $26 at the lowest to $60 at the highest version. Transitioning to automated openers, a plethora of similar designs exist, typically priced between $24 to $50 for two-handed battery-operated models. It is imperative to have our product cost within a similar range of these competitors as the ideas and mechanisms are similar and of the same purpose.

3.3 Revised Client Statement

Table 4: Pairwise comparison of design objectives.

	Accessibility	Ease of Use	Maintenance	Cost	Speed	Total
Accessibility	-	0	+1	+1	+1	3
Ease of Use	0	-	+1	+1	+1	3
Maintenance	-1	-1	-	+1	+1	0
Cost	-1	-1	-1	-	+1	-2
Speed	-1	-1	-1	-1	-	-4

The pairwise comparison chart provides a comparison of design objectives based on their relative importance or priority. Each pair of objectives is compared, and a score is assigned to indicate which objective is more important in the context of the comparison. The scores range from -1 to +1, with negative values indicating that the objective in the column is less important than the objective in the row, and positive values indicating the opposite.

In the chart: for the "Accessibility" row, it is compared with other objectives. It receives scores of +1 when compared with "Maintenance," "Cost," and "Speed," indicating that it is considered more important than these objectives. The "Ease of Use" row also receives scores of +1 when compared with "Maintenance," "Cost," and "Speed," indicating its relative importance over these objectives. "Maintenance" receives a score of -1 when compared with "Cost" and "Speed," indicating that it is considered less important than these objectives. Similarly, "Cost" receives a score of -1 when compared with "Speed," indicating that it is considered less important than speed.

The total score for each objective is calculated by summing up the scores across all comparisons involving that objective. In summary, the pairwise comparison chart helps prioritize design objectives by highlighting their relative importance in the context of the design process. It provides valuable insights into which objectives should be given more emphasis during the design and development phases.

Table 5: Decision matrix for design decisions

Criteria	On the Market	Initial Design	Final Design
Accessibility	-1	+1	+1
Ease of Use	+1	+1	+1
Maintenance	0	+1	+1
Cost	0	-1	+1
Speed	+1	-1	+1
Total	1	1	5

The decision matrix chart outlines the evaluation of different design options based on specific criteria. Each criterion is assigned a weight or score, ranging from -1 to +1, with higher scores indicating better performance in that aspect. The criteria evaluated include Accessibility, Ease of Use, Maintenance, Cost, and Speed.

For the "On the Market" option, it received a total score of 1, indicating moderate performance across the criteria. The "Initial Design" option also received a total score of 1, suggesting similar performance to the "On the Market" option.

However, the "Final Design" option stands out with a total score of 5, indicating significantly better performance across the evaluated criteria. This suggests that the final design excels in terms of Accessibility, Ease of Use, Maintenance, Cost, and Speed compared to both the initial design and existing options on the market.

In summary, the decision matrix highlights that the final design outperforms both the initial design and existing options on the market across all evaluated criteria, making it the preferred choice for implementation.

3.4 Project Approach

A Gantt chart was created as depicted in table 6 to organize research in necessary fields, design and amend the wine opener itself, as well as write and edit a final report.

Table 6: Gantt chart of tasks to be completed.

Task	C-Term	D-term
Research existing devices		
Research of assistive technology		
Research of cork properties		
Research of cork production process		
Research of cork recycling		
Research on bottle properties		
Research of bottle recycling		
Research of corkscrew		
Initial CAD drawing		
CAD drawing amendments		
Finalized CAD drawing		
Rough draft of report		
Project presentation		
Final draft		

4. Design Process

Our innovative wine opener prioritizes user needs and functionality, while complying with important industry standards. This section goes deep into the design process, exploring each step in detail and highlighting how standards were incorporated throughout. Our design began with a comprehensive needs analysis. Through a literature review and a patent search, we identified key objectives. First being the design should prioritize one-handed operation for users with limited hand strength or dexterity. This meant exploring mechanisms that minimize effort and eliminate the need for twisting or gripping the bottle. Our next priority was creating a product accessible to a wide range of consumers. Material selection, manufacturing processes, and design complexity were all considered to achieve this goal. Finally the opener needed to extract the cork entirely and efficiently, lowering the risk of damage or contamination considering TCA (TriChloroanisole) contamination.

Based on these identified needs, we established the following design requirements and functions, while keeping industry standards in mind which is essential. Mechanisms that utilize levers, buttons, or automatic features were explored while considering ADA (Americans with Disabilities Act) guidelines for accessibility. The opener needed to accommodate various standard wine bottle sizes (750ml, Magnum, etc.). This meant the design of the clamping mechanism had to be adjustable to comply with industry standard bottle dimensions. Furthermore, we had to minimize risk of cork damage or contamination through a controlled method of extraction. Materials used for the corkscrew itself are intended to meet food contact surface standards to prevent contamination. Leading to compliance with regulations set by the FDA (Food and Drug Administration). This ensures non-toxicity and prevents harmful chemicals contaminating the wine. Then we selected high-quality materials that are strong, corrosion-resistant, and easy to clean (e.g., stainless steel) [17]. These materials must comply with general safety standards and promote long-lasting performance of the product.

To begin our actual design, we started with detailed paper sketches. We explored a wide range of design ideas. This initial phase focused on functionality, user-friendliness, and helped us brainstorm various solutions in compliance with the identified standards. Sketches were reviewed keeping in mind ease of use, manufacturability, and material requirements to meet industry standards. We developed a secondary design concept, potentially catering to users with more extensive limitations using an electric motor. This design was also evaluated based on industry standards and user needs. As time went on, both paper sketches and Solidworks CAD (Computer-Aided Design) models were utilized to refine the design and ensure functionality. The CAD model allowed for more precise visualization, testing of mechanics, and verification of compliance with relevant standards. Material properties and dimensions could be incorporated into the CAD model to ensure the design meets industry standards.

4.1 Design Requirements

Our design specifications call for a strong and sturdy base that ensures stability during operation, whether through weighting or suction mechanisms to secure it firmly to the table. This stability is crucial to prevent any unintentional lifting or movement of the device. Additionally, we aimed to incorporate a user-friendly control system, seen in the form of a lever, to provide effortless operation for individuals with disabilities. Furthermore, our design includes features for users with visual impairments, such as textured grip and base to provide tactile guidance for bottle placement and device handling. Moreover, a protective cover was added to safeguard users in the event of a bottle breakage, containing any shattered glass and preventing injuries. This comprehensive approach prioritizes both functionality and user safety, ensuring an easy to use and accessible wine-opening experience for all individuals.

The American with Disabilities Act (ADA) outlines specific design requirements to ensure buildings, facilities, and products are accessible and usable for individuals with disabilities. In the context of this user-centered wine opener design, some important ADA requirements to consider include, single-handed operation to accommodate users with limited hand strength or dexterity, minimal gripping force to ensure ease of use for those with limited hand strength, and stability during operation to prevent the need for bracing or additional support [18]. By incorporating these principles into the design, we created a more inclusive product that can be used by a wider range of users, including those with disabilities.

4.2. Important Standards

While functionality and user-friendliness were very important, our design adheres to several important standards to ensure safety, compatibility, and responsible manufacturing. All materials used will comply with relevant safety standards for food contact surfaces. Our design adheres to ISO drafting standards to ensure consistency throughout the manufacturing process. This includes following guidelines for dimensioning, line styles, and views, creating a universally understood blueprint for our wine opener. During the manufacturing phase, we thoroughly researched and incorporated specific regulations on materials set by the FDA (Food and Drug Administration) [19]. This makes sure the materials are non-toxic and don't risk harmful chemicals into the wine. We selected high-quality materials that are strong, corrosion-resistant, and easy to clean. All parts are intended to be 316 Stainless Steel and aluminum which comply with general safety standards. The design incorporates a mechanism suitable for various standard wine bottle sizes. Ensuring compatibility with 750ml bottles, Magnums, and other common sizes to maximize the usability of the opener. This design prioritizes features aligned with the Americans with Disabilities Act (ADA) guidelines for usability by individuals with disabilities [18]. To adhere to these guidelines we include features like single-handed operation, automatic functions, and a stable base that minimizes the use of other body parts. By adhering to these important standards, we ensure our design is not only functional and user-friendly but also safe and compatible not only with wine bottle sizes but people too. This focus on responsible design practices ensures a high-quality product that can be used time and time again with confidence.

4.3 Conceptual Designs

Our design addresses the limitations of existing wine openers and prioritizes ease of use, especially for people with disabilities. Here's a breakdown of our concept:

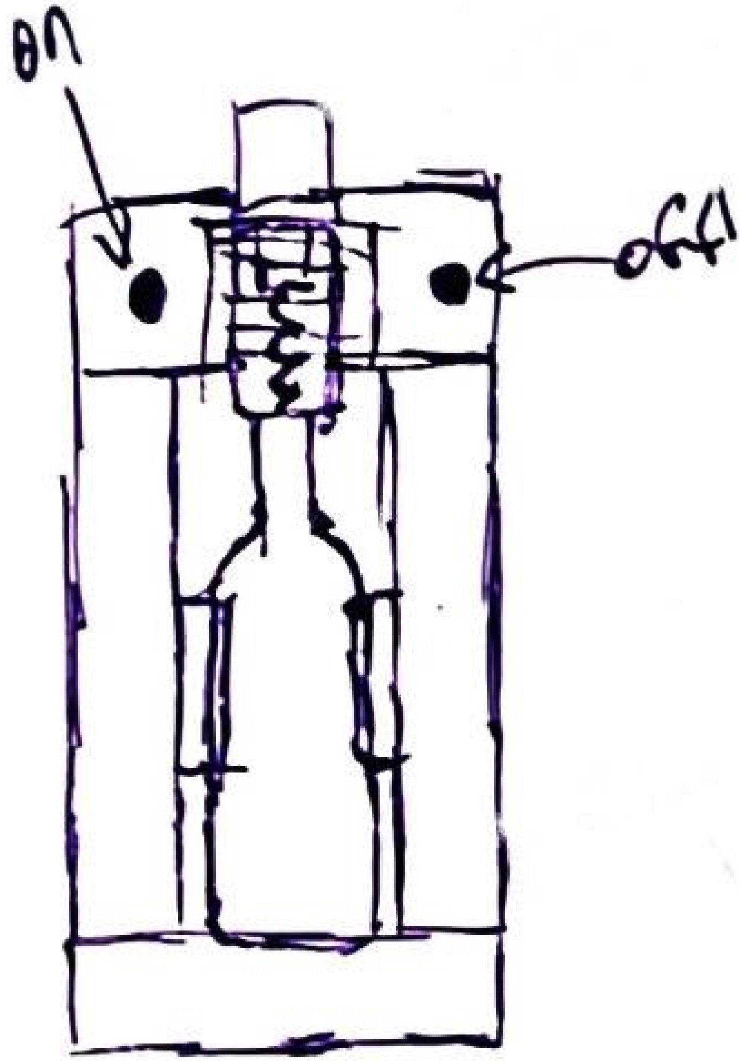

Figure 5: Concept sketch for potential design.

We considered an electric concept to further enhance accessibility shown above in Figure 5. This version incorporated a motor to automate the operation of the rack and pinion mechanism. Users would simply press an "Up" button to activate the motor in order to extract the cork, followed by a "Down" button to return the corkscrew to its original position. There is also a power switch to turn the device on and off. While this electric concept offered the most ease of use for individuals with limited hand strength or dexterity, it did introduce a higher production cost due to the use of the motor and electronic components. Therefore, we decided a user-friendly manual design with a focus on affordability was more important to us, while acknowledging the potential benefits of an electric version for future exploration.

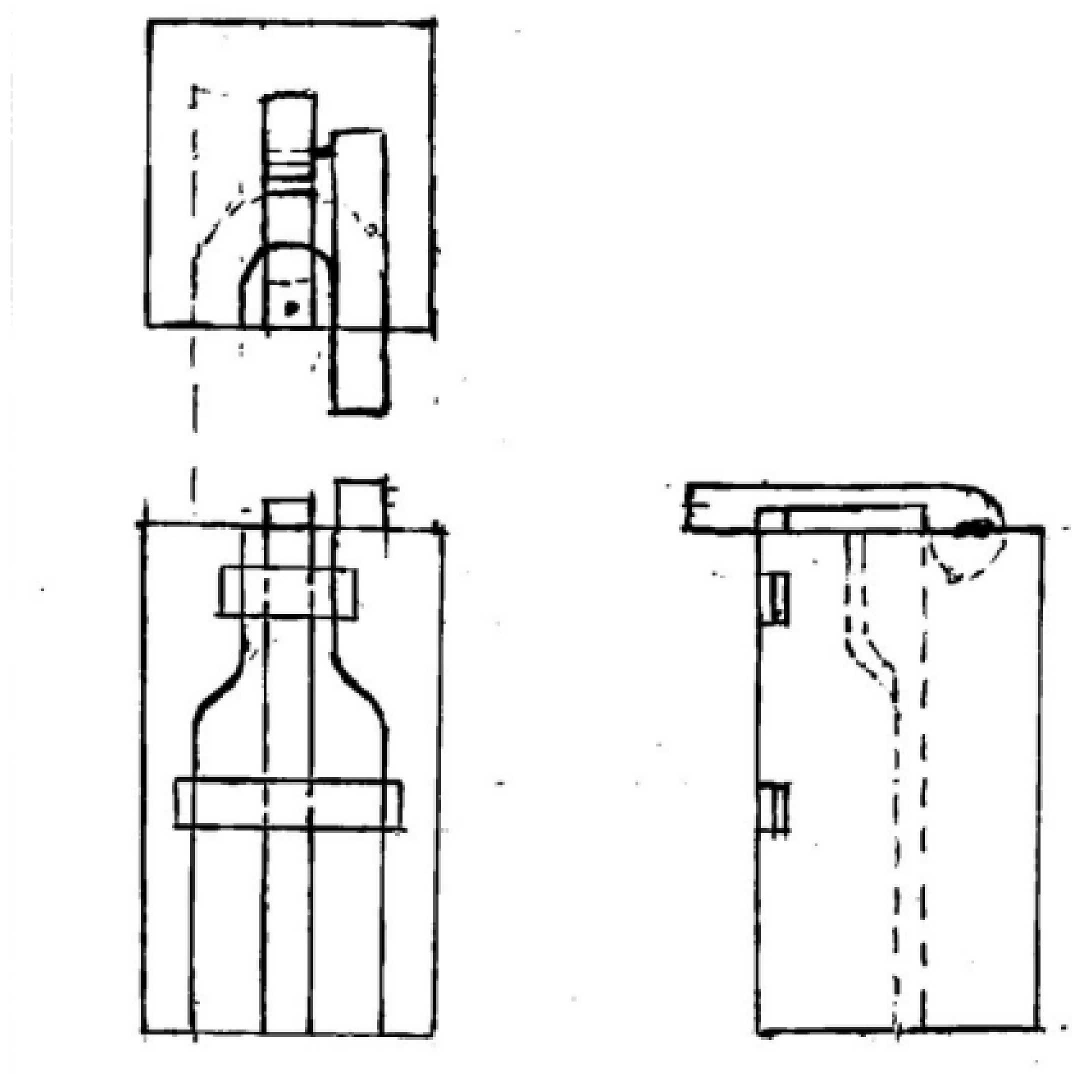

Figure 6: Conceptual sketch of an automated wine opener.

We also explored a design iteration that utilized a lever-operated rack and pinion mechanism, similar to the final design direction shown above in Figure 6. This concept aimed to achieve user-friendliness through a manual operation system. However, there was a critical stability issue with this design. The initial placement of the rack and pinion mechanism was positioned on top of the device. This high center of gravity made the opener prone to tipping during cork extraction, especially when using one hand to push the lever up. Additionally, the concept used clamps to secure both the body and the neck of the bottle. While this approach intended for a secure hold, it added a lot of complexity to the bottle insertion and removal process, potentially causing inconvenience for users with the bottle potentially getting stuck. These limitations revealed the need to refine the placement of the rack and pinion mechanism for better stability and to create improved clamping solutions that ensured bottle security without preventing ease of use. By creating these alternate designs, we were able to arrive at the current design that prioritizes both functionality for the best user experience.

4.4 Alternative Designs

Prior to selecting our final design, our team thoroughly explored various viable alternatives and options. Understanding the importance of incorporating a lever handle to cater to individuals with disabilities and adopting an assistive technology approach, we carefully considered multiple design possibilities. Among these alternatives, we toyed with the ideas of a fully motorized design as well as a four-bar linkage design. While both options offered potential benefits in terms of automation and ease of use, we ultimately decided against them for specific reasons. For the fully motorized design, although it promises complete automation, we found that it doesn't have the tactile feedback that is experienced when opening wine and there was the potential that individuals with disabilities might not be able to use the small buttons. Additionally, concerns regarding the additional cost of electrical components led us to explore alternative solutions. Similarly, the four-bar linkage design which offered mechanical simplicity and efficiency, we saw potential limitations with the adjustability and adaptability of our device to different bottle sizes and shapes. After careful consideration and analysis, we determined that a lever-operated design would best meet our objectives of accessibility, ease of use and reliability. Presented in Figure 7 is an engineering drawing depicting the initial version of the automated wine opener, which has most of our design exploration process features.

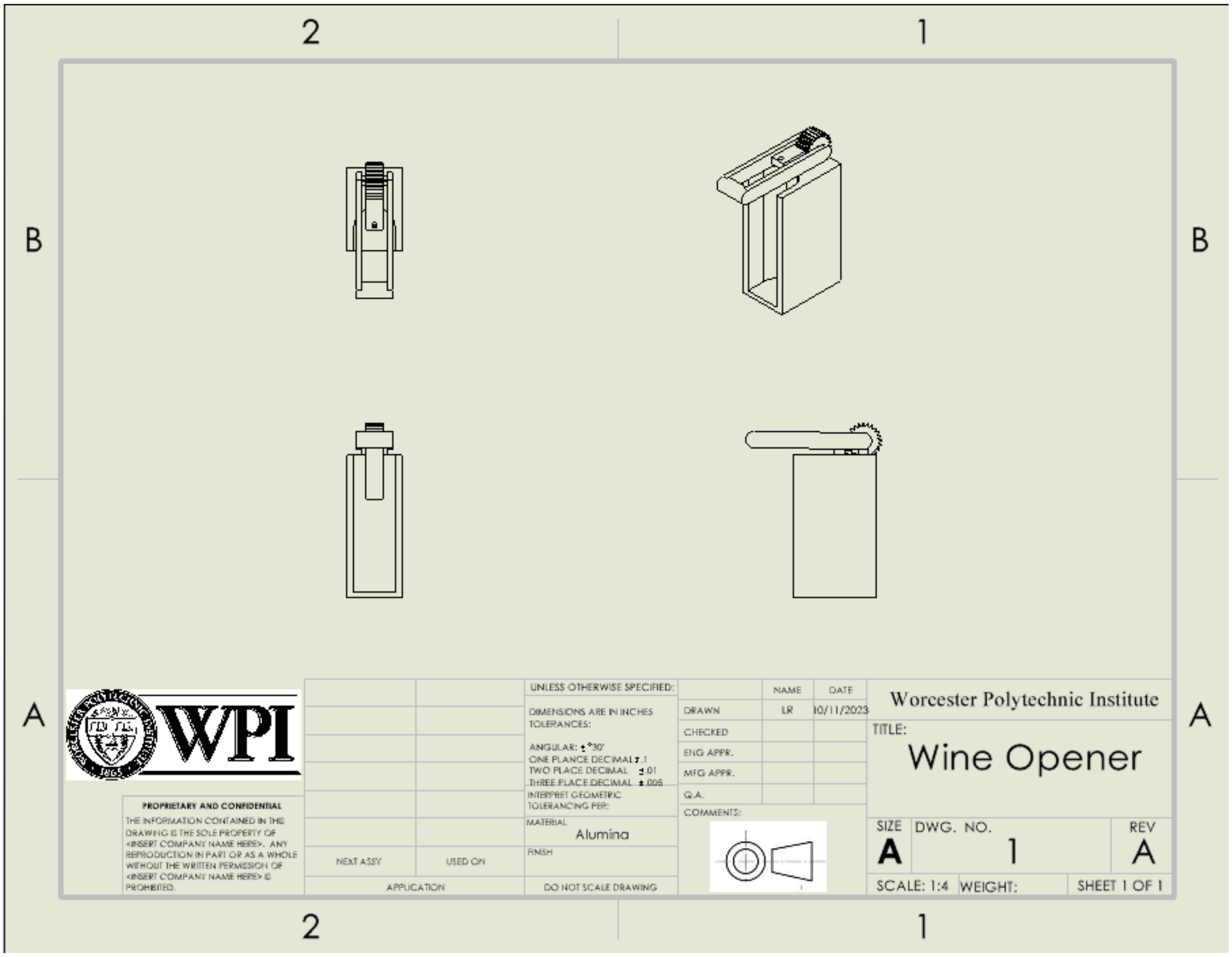

Figure 7: Engineering drawing of alternate lever design.

Our initial design exploration utilized SolidWorks CAD software to model a lever-operated rack and pinion mechanism as seen below in figures 8 and 9. With this prototyping environment, we could test the design's functionality and identify any potential issues. Through this digital modeling process, we further visualized a critical stability concern. The initial placement of the rack and pinion mechanism was positioned too high on the device. SolidWorks allowed us to simulate the center of gravity and visualize how this high placement could cause the opener to tip during bottle insertion and extraction, particularly for single-handed users. Additionally, the initial design featured a pinion gear with a relatively small diameter. While this design choice aimed to minimize the overall size of the opener, SolidWorks simulations revealed that a larger pinion gear would be necessary to achieve a smaller range of motion in the lever. A smaller range of motion on the lever translates to less effort required for operation, which aligns better with ADA accessibility guidelines. By making the most of the capabilities of SolidWorks, we were able to identify and address any shortcomings early in the design phase, leading the way for a more stable and user-friendly final design.

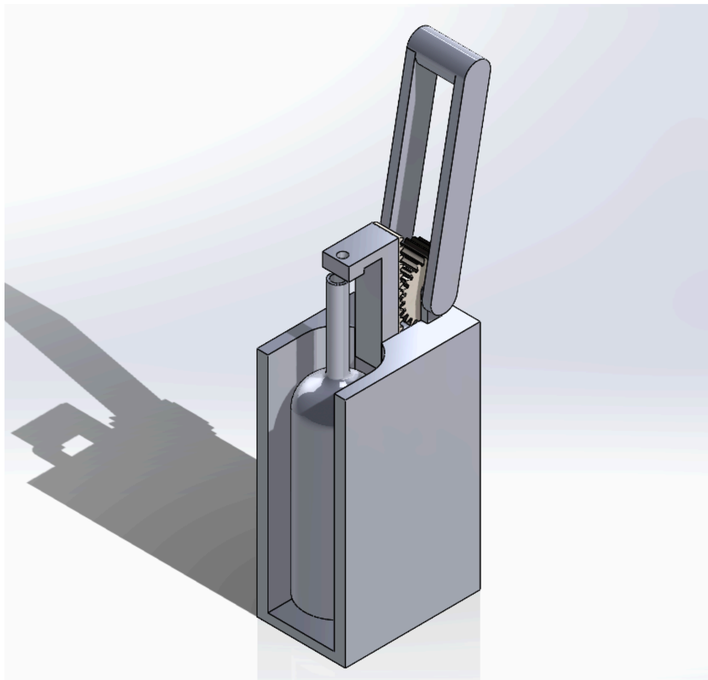

Figure 8: Solidworks CAD drawings of lever in upward position.

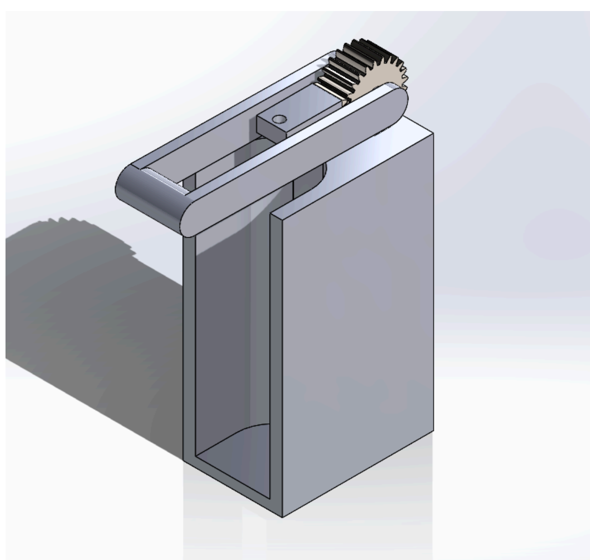

Figure 9: Solidworks CAD drawings of lever in downward position.

In addition to exploring alternative designs, the team has drafted potential attachments to enhance inclusivity for individuals with disabilities. The primary objective of this project is to address limitations found in other wine openers, notably the requirement for two firm hands to operate. Our design prioritizes usability for those with disabilities. Given the mechanical reliability of a lever action mechanism, it was logical to develop additional attachments or styles that can accommodate users of all abilities.

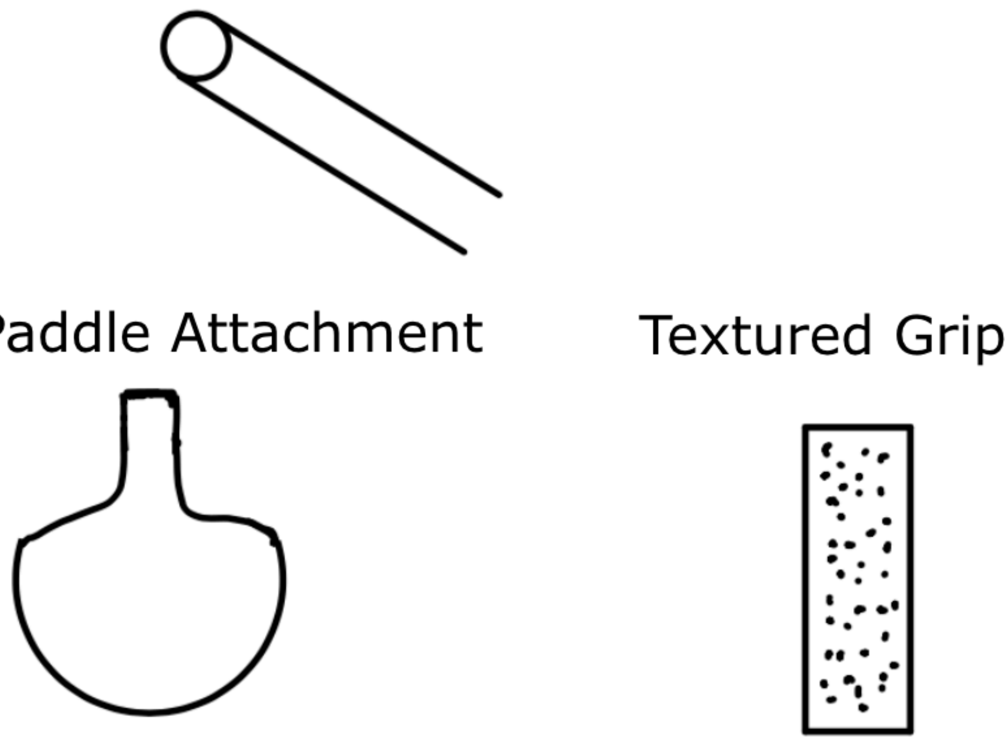

Figure 10: Potential handle attachments for use of people with various disabilities.

Above in figure 10, potential drafts of handles and attachments are presented, aimed at broadening the client base and enhancing inclusivity for individuals with disabilities who enjoy wine. One design features an extension for the lever, providing increased leverage for those needing to use their armpit or elbow crease. Another option is a paddle extension, enabling users to operate the opener with a fist, elbow, or foot. Lastly, a textured grip attachment is proposed, offering enhanced grip for individuals with arthritis or grip strength issues.

4.5. Final Design and Model

The final design consisted of eleven total parts as depicted in Figure 11 and Table 5 below. The design features a minimalized housing that holds the internals and wine bottle itself. A plastic cover along with clamps to hold various sized wine bottles. Clamps will apply pressure to the bottle at the base and at the neck. The clamps at the neck will also act as a trap for the removed cork allowing for removal of the cork from the corkscrew. The rack attached to the rack arm is then operated via a lever that is fixed to the pinion that will raise the rack with the rack arm. The corkscrew which is attached to the corkscrew head. This assembly is attached to the rack arm and is allowed to move slightly in the z-axis on the rack arm allowing the user to position the corkscrew perfectly centered on the cork. This also makes the corkscrew assembly detachable for easy maintenance.

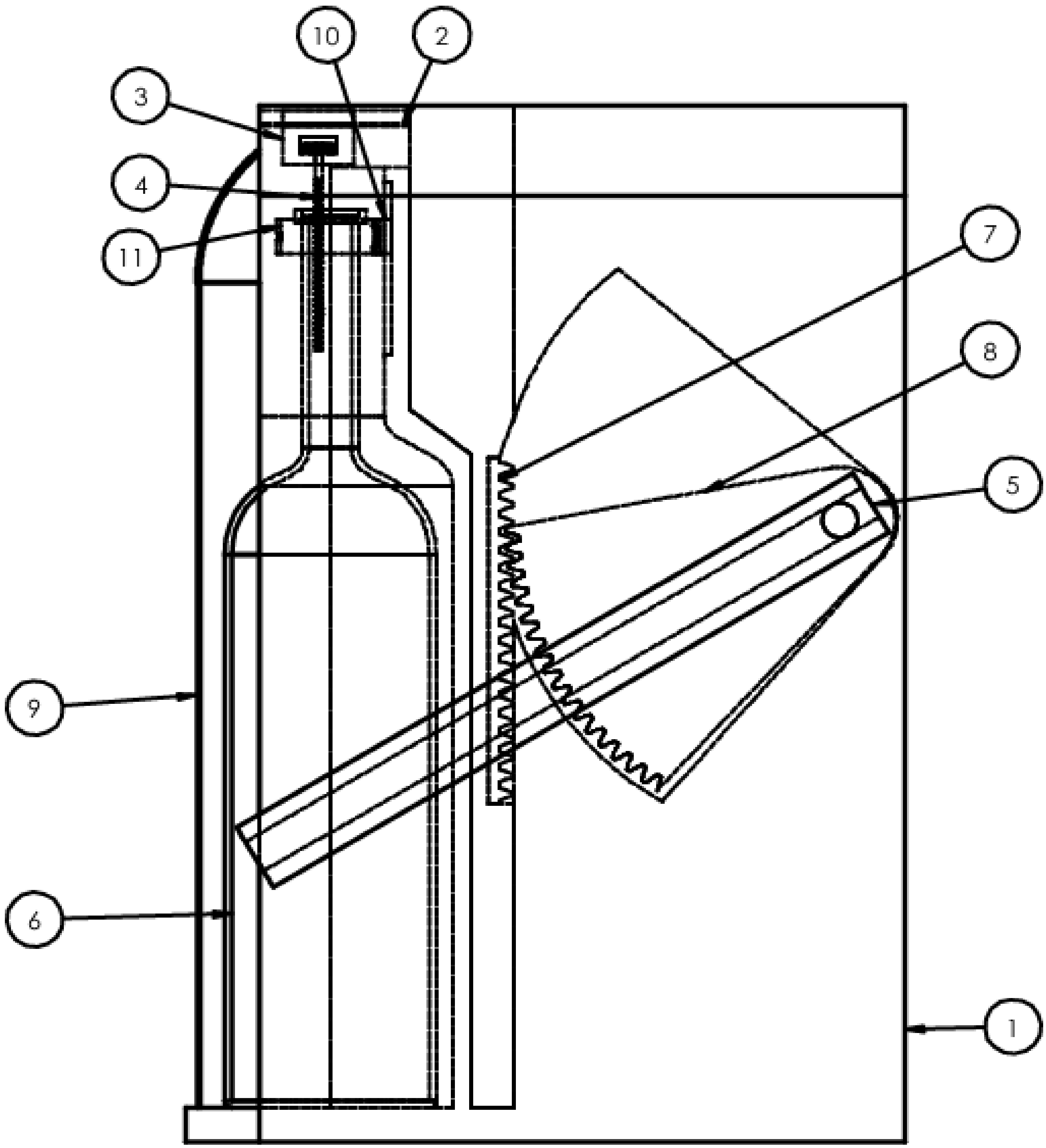

Figure 11: Side view of the final design for an automated wine opener.

Table 7: Parts list, description, and quantity of each part.

Item No.	Part	Description	QTY.	Cost ($)
1	Wine Opener Body	Housing for all parts	1	15.98
2	Rack Arm	Connects rack and pinion to the corkscrew head	1	2.94
3	Corkscrew Head	Adjustable and contains the corkscrew	1	0.22
4	Corkscrew	Free to move up and down but only spin when pushed	1	0.0086
5	Handle	Handle is fixed to the pinion	1	2.44
6	Wine Bottle	Standard wine bottle	1	N/A
7	Rack	Custom rack to to move the rack arm up and down	1	0.086
8	Pinion	Custom pinion to move the rack with limited movement	1	5.16
9	Bottle Cover	Prevents injury and contamination	1	0.01
10	Clamp	Clamp for the bottle	1	0.0071
11	Clamp Arms	Spring loaded to hold bottle neck and remove corks	2	0.0086

We considered multiple material types when designing our wine opener. For the parts we made in stainless steel, we considered high carbon steel for its strength and affordability but the downside to this is high carbon steel is not food safe since it is prone to rust. We also considered nylon for its strength and lightweight but decided against it because of wear overtime. We opted for 316 stainless steel due to its durability and its exceptional corrosion resistance. The rack and pinion was designed to be 316 stainless steel. Stainless steel offers durability sufficient for the design. Stainless steel is a material that can withstand many more cycles and applied loads than plastic or pvc alternatives. The use of stainless steel for the pinion was chosen to provide a long lasting and durable operating mechanism and therefore product. Additionally, 316 stainless steel is a corrosive resistant option. This is crucial as some of these parts like the corkscrew assembly come into direct contact with wine and moisture during use. For the parts made of aluminum, we considered ABS plastic, a cost-effective and lightweight plastic with good chemical resistance. We also had the idea of using a magnesium alloy which offers a good balance of strength and weight, but can be a lot more expensive. We chose aluminum for the body and clamp (excluding spring) due to its balance of affordability, weight, and corrosion resistance. The weight consideration is important, as the overall weight of the opener should be manageable for users with limited hand strength. While magnesium alloy offers improved strength, the cost increase is not necessary for these components. ABS plastic is a budget-friendly option but may raise concerns about long-term durability, especially if the opener encounters frequent use. The total price in raw materials for one wine opener would be $26.86 which is based on the current 316 stainless steel price per pound and aluminum price per pound [16].

The wine opener utilizes a clamping system made of stainless steel to secure the bottle. Two clamp arms and one clamp piece work together, fastened by pins. This spring loaded clamp applies pressure to hold the rim of the bottle around the cork, preventing it from moving upwards. This entire clamp assembly can be adjusted up and down to accommodate different bottle sizes. The clamp can also catch the cork after the bottle is removed. When the handle is lowered, the cork is held by the clamp, and then released when the handle is raised. The wine opener body (made of aluminum) serves as the central unit, housing the bottle and all the other components. The corkscrew and corkscrew head (both stainless steel) work together to extract the cork. This assembly can be adjusted for various bottle depths by moving it forward or backward on the rack arm (aluminum). An interesting feature is the friction between the corkscrew and the head. This allows the corkscrew to spin freely when inserted but provides more resistance when pulling the cork out, aiding in its extraction. The corkscrew is also Teflon-coated, to reduce friction with the cork. The rack arm connects the corkscrew assembly to the rack and pinion mechanism (stainless steel). This rack and pinion system is key: it translates the rotational motion of the lever (aluminum) into linear motion that powers the corkscrew. The lever provides the user with mechanical advantage, making it easier to extract the cork. Finally, a plastic cover is included, for safety purposes to prevent injuries and to minimize contamination of the wine. Final engineering drawings of the automated wine opener can be found below in figures 12 and 13.

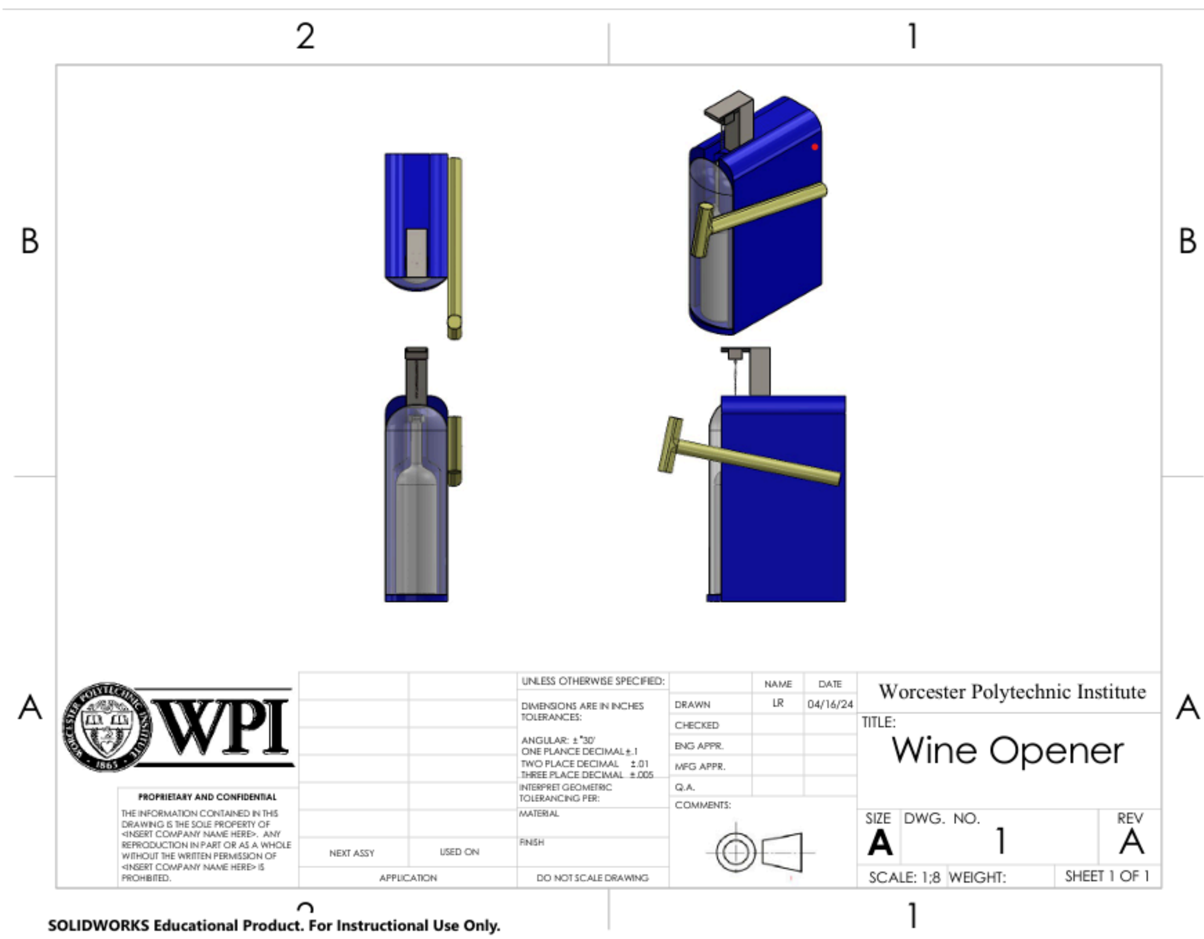

Figure 12: Engineering drawing of the final design for an automated wine opener.

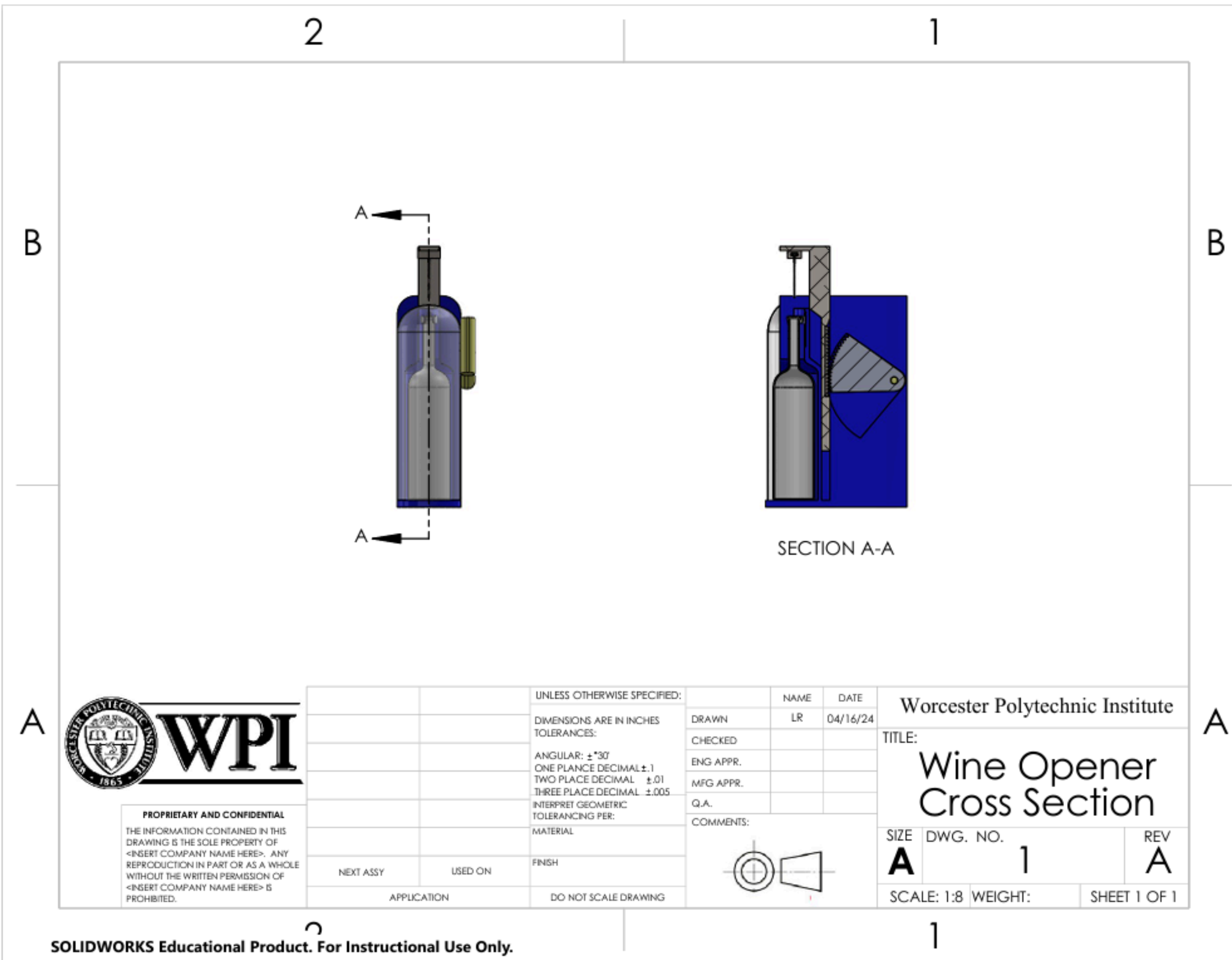

Figure 13: Cross sectional engineering drawing view for an automated wine opener.

Design Features:

- **Base with Suction Cups:** A wide, stable base equipped with secure suction cups allows for hands-free operation. The user simply positions the opener on a flat surface and presses down to create a strong suction grip. (The additional weight of the wine bottle on top will also contribute to stability.)
- **Automatic Clamps:** A spring loaded clamp firmly grips the bottle neck. This eliminates the need for twisting or manual gripping, making it ideal for users with limited hand strength or dexterity.
- **Rack and Pinion Corkscrew with Lever:** A rack and pinion mechanism translates a rotating motion into a linear one, smoothly extracting the cork with minimal effort. This

mechanism is easy to use with one hand and applies gentle, controlled pressure on the lever.

- **Cork Ejection System:** The built-in clamp will automatically eject the cork from the screw once extraction is complete. This eliminates the need to manually remove the cork and reduces the risk of dropping the cork.
- **Durable and Hygienic Materials:** The device will be constructed from high-quality, easy-to-clean materials that are resistant to corrosion and staining.

5. Final Design Verification

After selecting a final design calculations were required to thus verify the design. Through a series of derivations and iterations of equations the dimensions, geometry, and materials were able to be finalized.

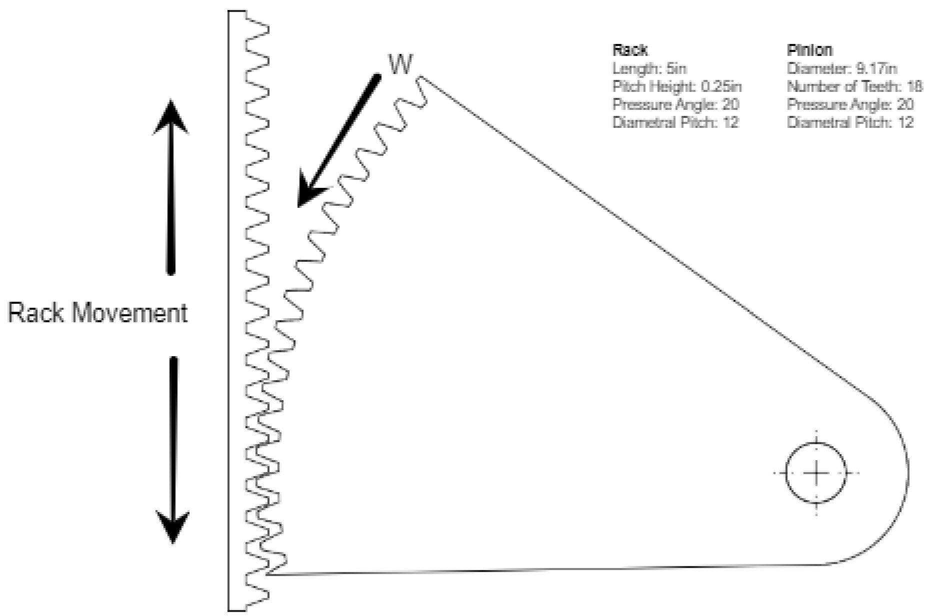

Figure 14: Close up of rack and pinion engineering drawing.

The velocity vector of the rack and pinion mechanism is determined by:

$$v = \omega x r = ||\omega||||r||sin\theta e_{\lambda} \qquad \text{Equation 1}$$

Where ω is the angular velocity of the pinion, r is the radius of the pinion, and θ is the angle between ω and r. In equation 1, the unit vector, e_{λ}, is determined by:

$$e_{\lambda} = \frac{\omega x r}{||\omega x r||} \qquad \text{Equation 2}$$

Both the angular velocity, ω, and the radius, r, of the pinion are perpendicular to the velocity.

If the effective mass of the rack pinion is m, the momentum, p, is equal to:

$$p = mv \qquad \text{Equation 3}$$

The resulting forces acting on the rack-pinion equals to the rate of change of the momentum, p. The rate at which work is done by the pinion and the rack is equal to the power. Then we can define the mechanical advantage as the power output, P_{out}, over the power input, P_{in}. In this case, the power output is the torque output multiplied by the angular velocity. The power input thus equals the power output plus the loss of power, P_{loss}. If there is no loss of power, the power input equals the power output. [20] Therefore the mechanical advantage will equal the torque output divided by the torque input multiplied by the radius in and the radius out.

The angular momentum, L, is the vector cross product of the vector radius, r, and linear momentum, p as seen in equation 4 below.

$$L = rxp \qquad \text{Equation 4}$$

For the force that comes out during the operation of the rack-pinion, the mechanical advantage can also be determined. It equals the force output over the force input. We also know that torque, τ, is the vector cross product of the radius, r and the force, F. This is equivalent to the rate of change of angular momentum.

$$\tau = rxF \qquad \text{Equation 5}$$

Relative position, velocity, and acceleration, can be derived from dynamic quantities; force, torque, and momentum. This calculation contributed to the selection of geometry, dimensions, and materials for the proposed design of the automated wine opener. The calculations also guide the design process to meet the desired specifications. The mechanical advantage enabled the team to establish tolerances to reduce components of the product and ease of manufacturing.

After deriving the necessary equations to define the force properties of the lever a dynamic analysis was performed on the SolidWorks CAD software. As stated within the literature review, it takes approximately 300-400 N of force to remove a corkscrew. This being said, the rack-pinion mechanism will be tested at three varying applications of force on the plane that would receive the force. These force trials were for 300 Newtons, 350 Newtons, 400 Newtons, 450 Newtons, and 500 Newtons of applied force. Below in table 8, the data collected from the linear dynamic analysis is highlighted.

Table 8: Data gathered from linear dynamic analysis on the rack-pinion mechanism

Number	Force (N)	Minimum (mm)	Intermediate (mm)	Maximum (mm)	Average (mm)
1	300	1.361e+04	1.362e+04	1.363e+04	1.362e+04
2	350	1.588e+04	1.589e+04	1.590e+04	1.589e+04
3	400	1.815e+04	1.816e+04	1.817e+04	1.816e+04
4	450	2.042e+04	2.043e+04	2.045e+04	2.0433e+04
5	500	2.269e+04	2.270e+04	2.272e+04	2.270e+04

As seen in the table above, three force values were analyzed and applied on the pinion. The table consists of the acting forces on the rack-pinion design whilst opening the lever. The minimum, intermediate, and maximum values are the amount of deflection caused by the applied forces of 300N, 350N, 400N, 450N, and 500N. Since the teeth of the pinion are meshed with the rack teeth, the values are the same for the rack.

Below in Figure 16, is a solidworks CAD file of the linear dynamic analysis on the rack-pinion mechanism with 300 N of applied force. (The trials for 350 N to 4 can be found in Appendix C). Figure 16 shows the distribution of deflective forces when a force is applied on the rack-pinion mechanism. The analysis showed that the rack-pinion mechanism could withstand the forces required to remove the wine cork from the bottle. The top left image describes the rack-pinion with the forces being deflected across the part. The top right image depicts the mesh layer surrounding the rack-pinion mechanism. Bottom left image is the displacement and distribution of the acting forces. The bottom right image is the solid CAD file created by the team with no mesh and no acting forces.

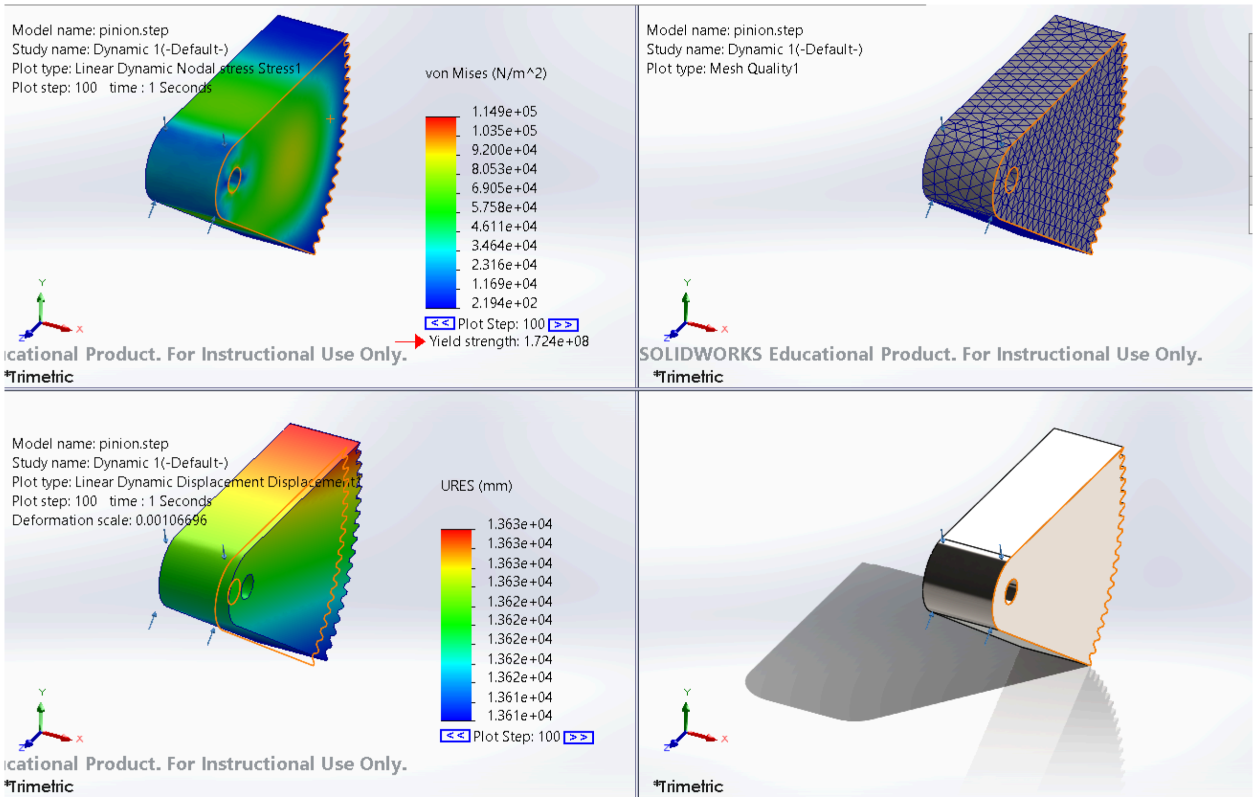

Figure 16: Linear dynamic analysis on the pinion for a 300 N applied force.

6. Final Design Validation

This section details how our design choices effectively address the identified needs and objectives of the project. We've followed a logical sequence of tasks to achieve a functional and user-friendly wine opener, particularly for individuals with limitations.

Addressing Needs Through Design Features:

- Safe and Efficient Cork Removal:
  - Rack and Pinion Corkscrew: This mechanism ensures smooth and controlled extraction, minimizing the risk of damaging the cork or the bottle.
  - Automatic Clamp: The secure clamp prevents the bottle from getting pulled up or wobbling during operation, promoting safety.
- Ease of Use:
  - Suction Cup Base: This feature allows for hands-free operation, ideal for users with limited hand strength or dexterity. (Along with the weight of the wine bottle, the device would be secure and should not tip over.)
  - Lever-operated Rack and Pinion: The lever mechanism minimizes the effort required to extract the cork, making it easy to use with one hand.
  - Automatic Cork Ejection: Eliminates the need to manually remove the cork, reducing the risk of dropping or fumbling.
  - T-Shaped Lever: This ‘T’ Shaped lever allows for an individual to use the crease of their elbow, wrist or their arm as a hook to operate the mechanism. Similarly, an individual with arthritis, cerebral palsy, or any other hand disability could use this hook feature as it requires significantly less grip strength compared to a handle.
- Affordability: The total cost for the design was calculated to be $26.86. Our design prioritizes the use of readily available materials and a relatively simple mechanism to keep production costs down.
- Durability and Hygiene: The use of high-quality durable materials like 316 stainless steel and aluminum allows for a durable operating mechanism in the design and therefore a long lasting wine opener. Additionally, non corrosive and food safe materials in

easy-to-clean, and non corrosive materials ensures long-lasting performance and minimizes the risk of bacterial growth.

Standards and Considerations:

- Wine Bottle Compatibility: The design incorporates a clamp and mechanism suitable for various standard wine bottle sizes and is adjustable to different bottle heights. The corkscrew assembly can shift on an x-axis allowing the corkscrew to be centered wherever the cork is located depending on the size of the bottle. This allows for bottles as small as 350 ml and as large as 1000 ml and of course the standard 750 ml wine bottle.
- Material Selection: The chosen materials of stainless steel and aluminum will comply with relevant safety standards for food contact surfaces. Further research will be required to identify specific standards during the manufacturing phase.
- Accessibility: The design prioritizes features aligned with ADA (Americans with Disabilities Act) guidelines for usability by individuals with disabilities.

Validation through Future Work:

- Prototype Testing: Building and testing a functional prototype will allow for real-world user feedback and refinement of the design.
- Manufacturability: Consulting with potential manufacturers will ensure the design can be translated into a cost-effective and scalable production process.

Our group was to 3-D print multiple components using the 3-D printers available on WPI's campus. To do this, we converted our CAD files to STL files which are compatible with the 3DPrinterOS slicing software. Once our files were uploaded to this software, the parts were positioned on the build plate to have an optimal print position and time. The settings we used were 0.2mm layer height, 0.8mm wall thickness, and a 7% infill density. These settings did not produce a very strong prototype, but let us further visualize our final product. Provided below in figure 17 is a blowout of the SolidWorks CAD design to show how the parts piece together.

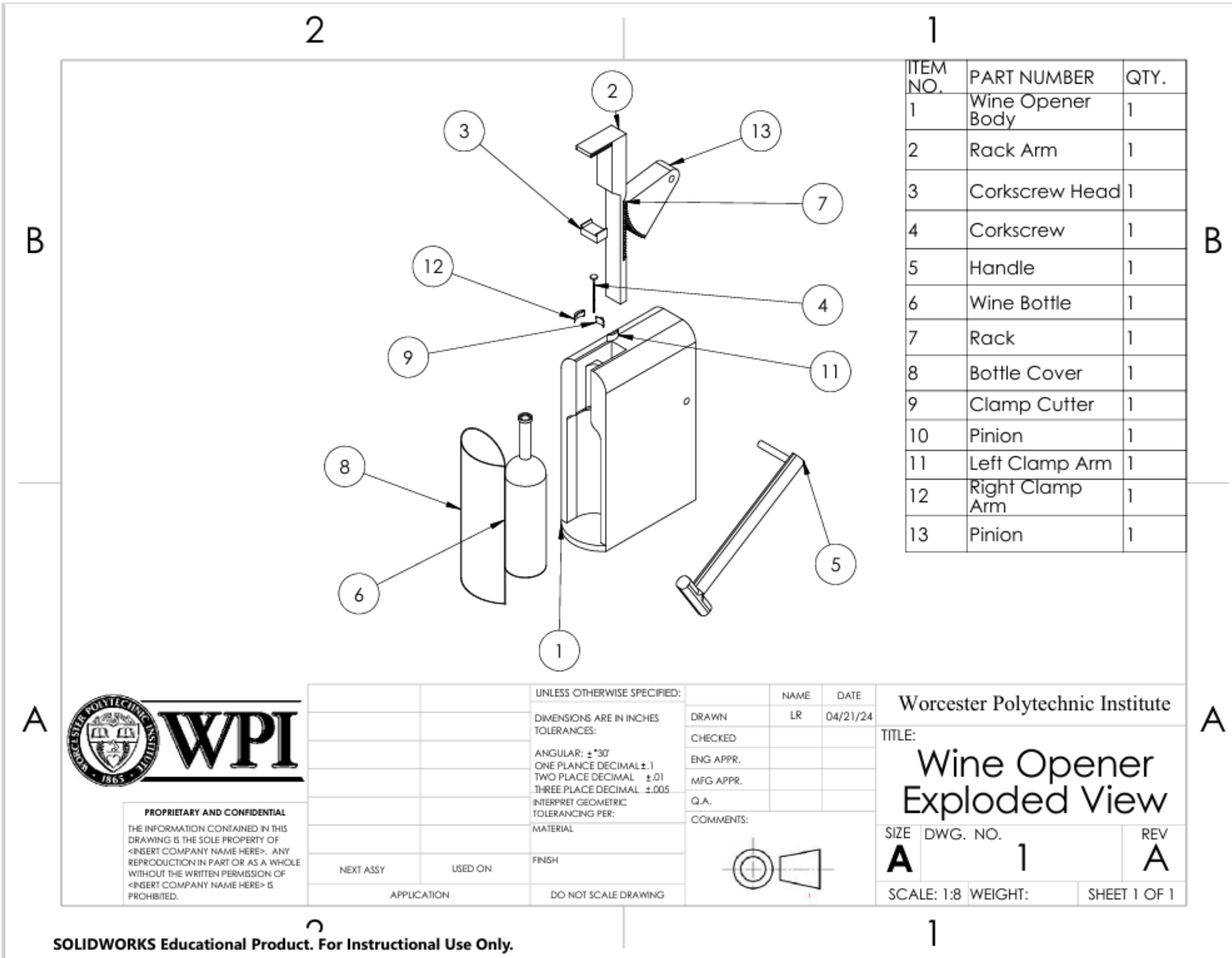

Figure 17. Exploded view of Solidworks CAD design.

Our wine opener takes a user-centered approach, offering several advantages over existing designs. Firstly, it prioritizes ease of use. The combination of a suction cup base, automatic clamps, and a rack and pinion mechanism minimizes the effort required to open a bottle. This feature is particularly beneficial for users with limited hand strength, dexterity, or upper body mobility. Furthermore, all functions can be performed with one hand, making it perfect for individuals with limited use of one arm. Our design also ensures gentle cork extraction. The controlled pressure exerted by the rack and pinion mechanism reduces the risk of damaging fragile or crumbly corks, a common concern with traditional corkscrews. Improved safety is another key benefit. The secure suction base and automatic cork ejection minimize the risk of dropping or fumbling the bottle or cork. Additionally, the use of smooth, easy-to-clean materials promotes hygiene and reduces the risk of bacterial growth. Finally, our versatile design can accommodate bottles of various sizes and is suitable for most cork types. Compared to existing solutions, our design offers significant advantages. Unlike waiter's corkscrews or winged corkscrews, it eliminates the need for strength or twisting motions, making it superior for users with limitations. While lever corkscrews offer ease of use, our design incorporates single-handed operation and automatic features for enhanced accessibility. Electric and pneumatic openers, while convenient, come with drawbacks. Our design offers a more affordable and space-saving alternative while still providing ease of use. Moreover, it avoids the risks of damaging corks associated with electric openers and the ongoing cost of compressed air cartridges required by pneumatic models. By following this logical design sequence and focusing on user needs, we have created a wine opener concept with the potential to improve the wine-drinking experience for a wider audience, especially those with limitations. The upcoming stages of prototyping, user testing, and manufacturability analysis will further validate the design's effectiveness and marketability.

6.1 Economics

The design was meticulously crafted to provide an affordable solution accessible to the general public, ensuring that cost constraints do not hinder its adoption. Consequently, its entry into the market is expected to yield only marginal effects on the broader economy, primarily fostering increased competition within the wine opener market segment. However, this infusion of competition is poised to stimulate innovation and drive product refinement, potentially leading to broader economic benefits such as enhanced consumer choice, improved product quality, and potentially lower prices across the industry. Thus, while the immediate economic impact may appear modest, the long-term implications of fostering a competitive market environment could be substantial, driving growth and innovation within the wine opener industry.

The cost of the proposed design is currently approximately \$26.86 of raw materials. Oddly enough, the market for handheld wine bottle openers range from around \$26 - \$60 with automated handheld devices ranging from around \$24 - \$50. With this comparison our device fits within the competitive scenery that is wine culture. Our design was intended to be reliable, accessible, and easy to use as the main concerns with the target audience being disabled individuals. The cost was the least important design consideration for the team as inclusivity to disabled individuals and the focus on assistive technology played a large role.

6.2 Environmental Impact

The environmental footprint of the design extends beyond its production phase, with considerations for its entire lifecycle. While the production process is optimized to minimize environmental impact, the ongoing use of the product necessitates the consideration of waste generated during its operation. Specifically, the disposal of corks and empty wine bottles both contribute to waste generation that could potentially be released into the environment, highlighting the importance of responsible waste management practices. Both the bottle and cork have the capability to be recycled which will mitigate the environmental impact of these waste products along with the environmental impact in producing more cork stoppers or wine bottles. By addressing not only production but also waste generation, the design strives to uphold environmental stewardship principles, fostering a more sustainable approach to wine consumption.

6.3 Societal Influence

The design's most significant impact on society lies in its pioneering approach to wine opening, revolutionizing accessibility for a diverse range of disabled demographics. By providing a novel and inclusive method for opening wine, it transcends traditional barriers and empowers individuals with disabilities to fully participate in wine-related experiences, a cornerstone to many cultures globally. This not only enhances their quality of life by enabling them to engage in social activities more independently but also fosters a more equitable and inclusive society. Moreover, the design's innovative features have the potential to inspire broader societal shifts towards greater inclusivity and accessibility across various industries, serving as a catalyst for positive social change.

6.4 Political Ramifications

The introduction of this product to the market carries significant political implications, primarily leading to a more diverse and competitive landscape for wine openers. Additionally, across numerous cultures, wine holds a central and revered position, making accessibility to it essential. By providing a user-friendly option, particularly tailored for disabled demographics, this innovation aims to enhance inclusivity within these cultural practices. Nevertheless, it's anticipated that some may adhere to traditional wine-opening methods and thus may not readily embrace this new product.

6.5 Ethical Concerns

A main ethical concern is the issue of accessibility. While the design can provide convenience for many, it may inadvertently exclude individuals with more severe disabilities who may struggle to operate such devices. Ensuring that automated wine openers are designed with inclusivity in mind and are accessible to all users is crucial to mitigate this ethical concern. Another aspect to consider is the environmental impact. The production and disposal of automated wine openers could contribute to electronic waste and carbon emissions. Manufacturers should prioritize sustainable practices in the production process and consider the lifecycle impact of their products to minimize environmental harm. Moreover, there are potential ethical implications regarding cultural heritage and tradition. Wine culture is deeply rooted in many societies, with rituals and practices associated with the opening and serving of wine. The widespread adoption of automated wine openers could disrupt or diminish these cultural traditions, raising questions about the preservation of cultural heritage in the face of technological advancement. As a result a demographic of people that reserve traditional wine opening methods may outright reject the product.

6.6 Health and Safety Concerns

We have meticulously chosen premium-grade materials renowned for their durability, resilience to corrosion, and ease of maintenance, such as stainless steel or food-grade plastics.

These materials not only meet strict safety standards but also ensure the longevity and reliability of our product. Furthermore, our design incorporates a protective screen surrounding the wine bottle within the device, providing an additional layer of safety in the event of a bottle breakage. This innovative feature effectively contains any shattered glass or debris, preventing potential harm to users and minimizing cleanup efforts. Additionally, we advise using chlorine-free cleaning agents to maintain the integrity of the wine and prevent any unwanted contamination. Residual chlorine from cleaning products can react with microorganisms present in the cork, resulting in the formation of TCA, which can transmit an undesirable taste or odor to the wine. By prioritizing material quality and cleaning practices, we ensure the optimal performance and safety of our wine-opening device.

6.7 Manufacturability

This section talks about the key components of our wine opener design and analyzes their manufacturability, with a focus on balancing cost-effectiveness with functional integrity. Our design incorporates several aluminum components, including the spring-loaded clamp, the wine opener body, and the lever. Aluminum offers distinct advantages for these parts. Its lightweight nature makes the opener easy to handle, especially for users with limited hand strength. Additionally, aluminum is readily machinable, allowing for efficient shaping during the manufacturing process. Furthermore, aluminum exhibits good corrosion resistance, ensuring the opener's longevity. For the clamp, a critical component that secures the bottle neck, die casting is recommended as a suitable and cost-effective option, particularly for high-volume production. This process allows for the creation of complex shapes with high precision. However, tolerances achieved through die casting may need to be reviewed to ensure a perfect fit with various bottle neck sizes. Die casting is preferred due to the size of this part. The wine opener body can also be cast in aluminum or food grade plastic. Processes like CNC machining or investment casting could be suitable. CNC machining provides superior precision for intricate designs, while investment casting allows for more complex shapes. However, both options may be more expensive for high-volume production compared to die casting. Similarly, the lever can be constructed from aluminum. Extrusion offers a cost-effective solution for high-volume production of levers with simple profiles. For more complex lever designs, CNC machining may be necessary but with a more simple lever, die casting is possible.

Certain components within the opener demand a higher degree of strength and durability. Stainless steel is the ideal material for the rack, the pinion, and the corkscrew attachment. The rack, which interacts with the pinion gear to generate the corkscrew's pulling force, requires high strength to withstand the extraction pressure. Stainless steel's strength and resistance to corrosion make it the perfect choice for this important component. Machining or stamping are common processes for rack production. While machining offers superior precision, it may be more expensive for high volumes. Stamping presents a faster and more cost-effective option for high-volume production of simple rack designs. The corkscrew attachment, responsible for penetrating and extracting the cork, also benefits from the strength and durability of stainless steel. CNC machining is likely the most suitable option to create the precise helical shape of the corkscrew, ensuring efficient and smooth cork removal. The design likely incorporates a plastic cover for aesthetic and safety purposes. The type of plastic depends on factors like desired strength, clarity, and overall cost. Injection molding is a common and cost-effective process for high-volume production of plastic parts. The design of the cover should be optimized for efficient molding to minimize material waste and production costs.

The chosen manufacturing processes will ultimately depend on the target production volume and desired cost point. For high-volume production, die casting and extrusion offer lower costs, while CNC machining allows for greater design flexibility but may be more expensive. Finding the right balance between cost and complexity is the most important factor in manufacturing.

6.8 Sustainability

Our commitment to sustainability is evident in every aspect of our product design and manufacturing process. By selecting high-quality materials such as stainless steel or food-grade plastic, we prioritize durability and longevity, reducing the need for frequent replacements and minimizing waste. These materials are not only strong and corrosion-resistant but also easy to clean, promoting the reuse of the device for years to come. Additionally, our adherence to general safety standards ensures the safety of both users and the environment. Furthermore, our recommendation to use chlorine-free cleaning products reflects our dedication to minimizing harmful chemical residues that could potentially contaminate the wine or harm the environment. Moreover, the use of Teflon coating on the corkscrew enhances its efficiency and longevity, reducing wear and tear and further contributing to sustainability by extending the lifespan of the product. Overall, our focus on quality materials, responsible manufacturing practices, and user-friendly design aligns with our commitment to sustainability, ensuring the device not only meets the needs of our clientele (disabled) but also minimizes its environmental footprint.

7. Discussion

In today's market, handheld corkscrews typically demand both hands and a firm grip to extract the cork. The conventional metal helix and handle design necessitate one hand on the bottle and the other on the handle, pulling firmly upward to release the cork. Likewise, winged corkscrews require two-handed operation, with one hand on each arm for a downward motion to extract the cork.

While automated corkscrew devices excel at cork removal, their intricate designs and small motors often lead to durability issues. Like their handheld counterparts, these automated versions also require two-handed operation: one hand on the bottle and the other on the device, pressing a button to drive the corkscrew into the cork and another to reverse the cork off the corkscrew.

This design seeks to fill the gaps in the current market for wine openers accessible to individuals of all abilities. Our solution is an automated wine opener featuring a lever action rack and pinion mechanism. This lever design requires only one hand or body part to operate, accommodating various needs. Its shape enables users to utilize the crease of their elbow, wrist, or even foot for smooth up and downward motion, making it inclusive for individuals with disabilities such as arthritis, amputees, cerebral palsy, and many more.

This was achieved by prioritizing accessibility and inclusivity by designing it as an assistive device for individuals with disabilities. Recognizing the diverse needs of users, we aimed to develop a solution that would provide ease of use and independence for people facing mobility, sensory or other challenges, Our design process involved thorough research and consideration of the needs and preferences of individuals with disabilities, We incorporated features such as a standstill base with suction of weight mechanisms to prevent lifting, ensuring stability during operation. Additionally, we implemented a lever control system to facilitate effortless wine opening, catering to users with limited dexterity or strength. To aid visually impaired users, we included textured grips and bases to assist in positioning the wine bottle and operating the device. Furthermore, we integrated safety measures such as a protective cover to contain broken glass in case of bottle breakage, prioritizing user safety. By focusing on accessibility and inclusivity our automated wine opener serves as a practical and empowering solution for individuals with disabilities, enhancing their dining experience and promoting independence in everyday tasks.

The proposed design also offers a convenient, affordable, and maintainable design that many current wine openers, both automated and handheld, do not offer. The design allows for the cork to be removed simply by raising and lowering a lever that requires minimal effort to operate. This design provides a far more convenient approach than current wine openers that often require two hands and more user effort. Additionally, the proposed opener will not be expensive in manufacturing or retail allowing for an inexpensive and accessible wine opener option. Finally, the design offers a very maintainable approach where the corkscrew head can be replaced offering a clean corkscrew that ensures the integrity of the wine being opened.

8. Broader Impact

There are broader impacts to consider while creating a user-centered wine opener design. Ethical considerations guided the process, adhering to principles like public safety and social responsibility. The focus on secure features and minimal grip strength requirements promotes user safety and inclusivity for individuals with disabilities. However, the potential for increased wine consumption due to the design's ease of use presents an ethical consideration. Societal and global impacts encompass both positive and unintended consequences. On the positive side, the design empowers individuals with disabilities, fostering independence and social inclusion. Automatic features and a secure base minimize the risk of injuries, while the focus on ease of use enhances the overall user experience. An unintended consequence could be a potential rise in wine consumption due to the design's user-friendliness. Environmental impact is a key consideration. The use of durable materials like 316 stainless steel and aluminum promotes a long-lasting product, reducing waste. Additionally, the gentle cork extraction mechanism may help minimize cork breakage and wasted wine. However, the manufacturing process has an environmental footprint, and proper disposal or recycling practices will be crucial at the product's end-of-life. The design adheres to relevant codes and standards, including ISO Drafting Standards for clear communication during manufacturing, FDA regulated materials, and principles outlined in the Americans with Disabilities Act to promote accessibility. Economically, affordability is a key focus. The design prioritizes readily available materials and streamlined manufacturing to keep the product accessible to a wider audience. The intention of this design is to be the last wine opener someone will ever need to buy. In conclusion, the wine opener design prioritizes accessibility, safety, and ease of use. While there are potential ethical and environmental considerations, the design offers positive societal and economic impacts.

9. Conclusions and Recommendations

The team successfully developed a fully functional SolidWorks CAD model and design for an automated wine bottle opener. This design prioritizes inclusivity, catering to individuals with disabilities who wish to enjoy wine. Featuring a 'T' shaped lever action rack and pinion mechanism, users can operate it using the palm of their hand, the crease of their elbow, or even a foot. Furthermore, the design is adjustable to accommodate various sizes and heights of wine bottles.

While a one-handed design is beneficial for many individuals with disabilities, it doesn't cater to those who lack the ability to use both hands or arms. Future development could involve creating a fully automatic version that eliminates the need for a lever. With this advancement, a simple push of a button would activate a motor-driven rack and pinion mechanism inside the device. This expansion would not only broaden the client base but also increase inclusivity for individuals with disabilities who still desire to enjoy a glass of wine.

The design of this automated wine opener was created to be inclusive of those with ambulatory or visual disabilities. The simple lever action rack and pinion mechanism is an assistive technology that allows any disabled person(s) to operate the device.

This device has many alleys in which advancements could be made. Potential future developments include increasing and expanding the client base. This could be done by designing new handles or attachments to target any type of disability or handicap that a person may be dealing with. Additional attachments could include a paddle attachment, allowing users to operate the device with their elbow, fist, or foot. For those with arthritis or grip limitations, a wider handle attachment with textured surfaces could provide enhanced grip. The potential for diverse attachments allows for customization to accommodate a wide range of disabilities, promoting inclusivity for all.

Additionally, efforts can be made to facilitate an easy cleaning method free of chlorine products. Easier assembly of the parts would ensure a better cleaning of the product if needed. This will help prevent any contamination of the wine when opening, providing optimal taste and experience.

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Glossary

Accessibility - quality of being able to be used by anyone

Anisole - organic compound, colorless liquid

Anatomical - relates to structure of the body (study of anatomy)

Ambulatory - ability to walk around

Assistive Technology - rehabilitative devices for those with disabilities

Automated - operates for user via machine/motor

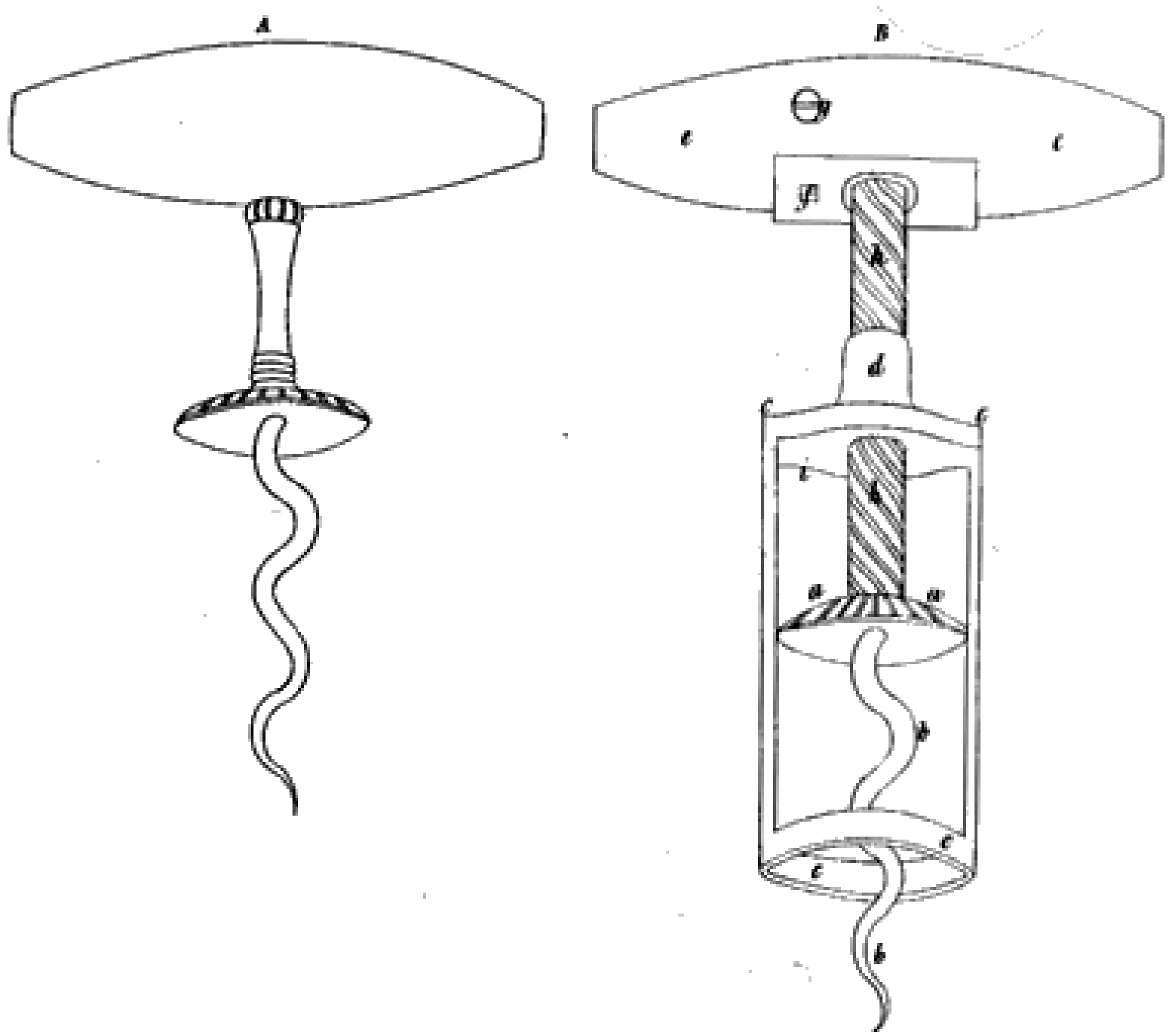
Cognitive - conscious mental activity

Orthotic - relates to a supporting device for ones feet

Appendix

Appendix A. Patent Search

Appendix A.1: Samuel Henshall Corkscrew Patent Via Directory of American Tool and Machinery Patents



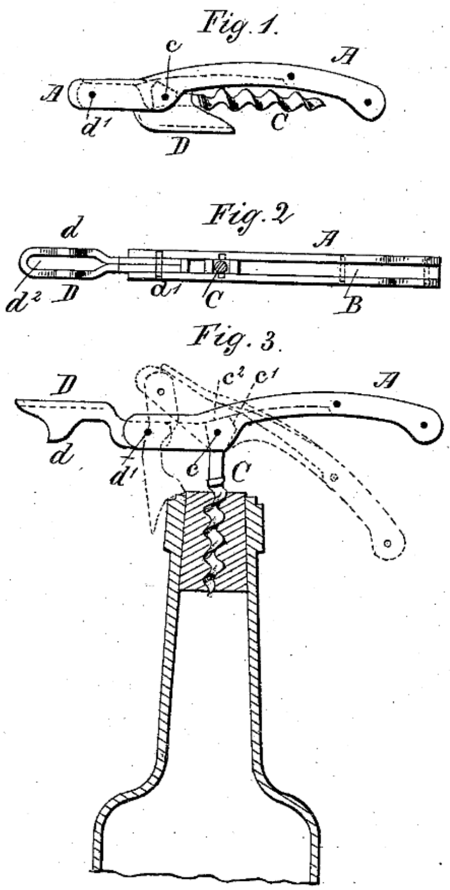
Appendix A.2: United States Patent for Carl F.A. Wienke Lever Corkscrew

(No Model.)

C. F. A. WIENKE.

LEVER CORKSCREW.

No. 283,731. Patented Aug. 21, 1883.



Witnesses.
William S. Boulter.
G. W. Knotts

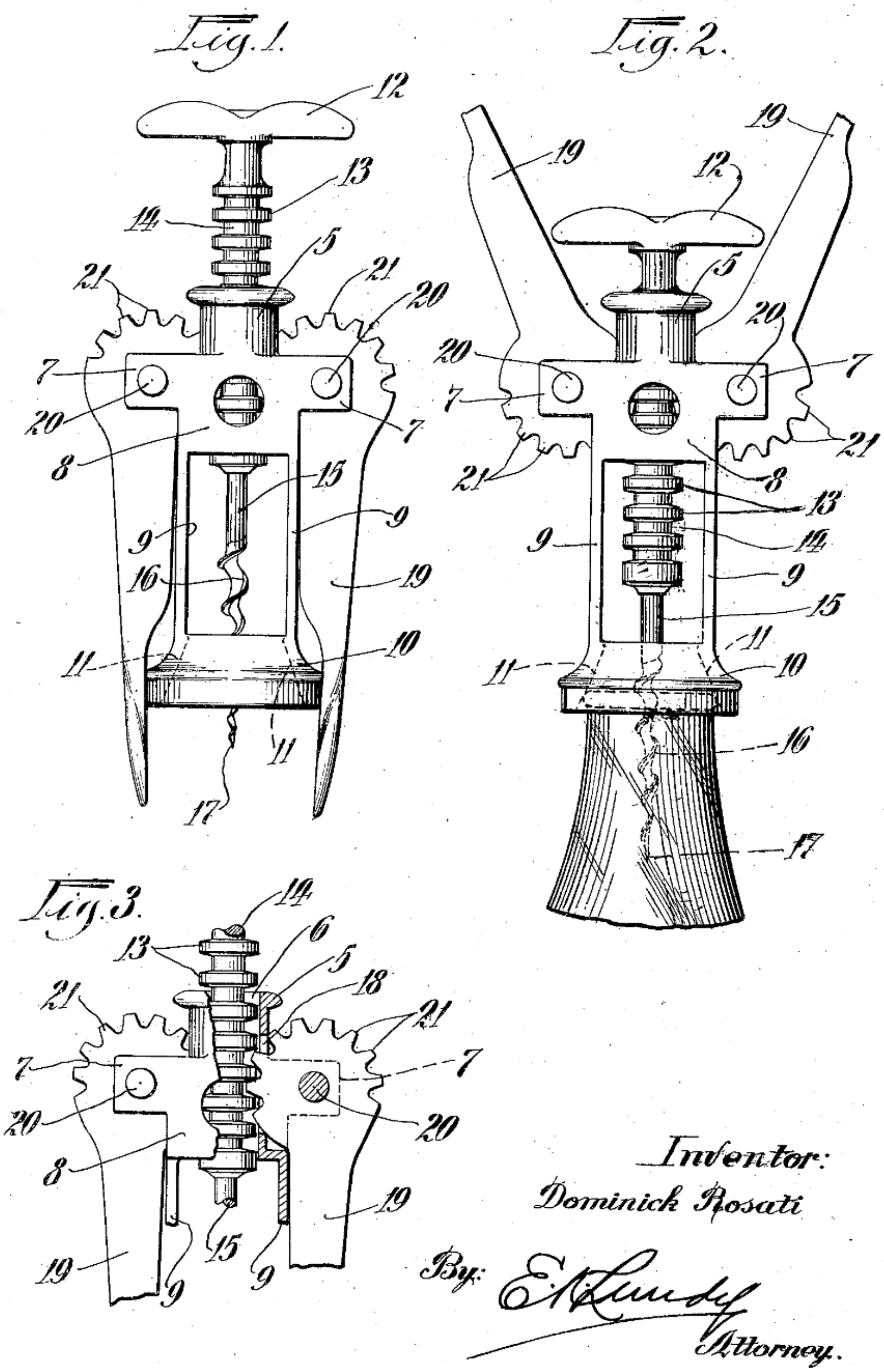
Inventor
Carl, F. A. Wienke
per Henry Orth
his att'y

Appendix A.3: United States Patent for A1 Heeley Double Lever Patent by Dominick Rosati

April 1, 1930. D. ROSATI **1,753,026**

CORK EXTRACTOR

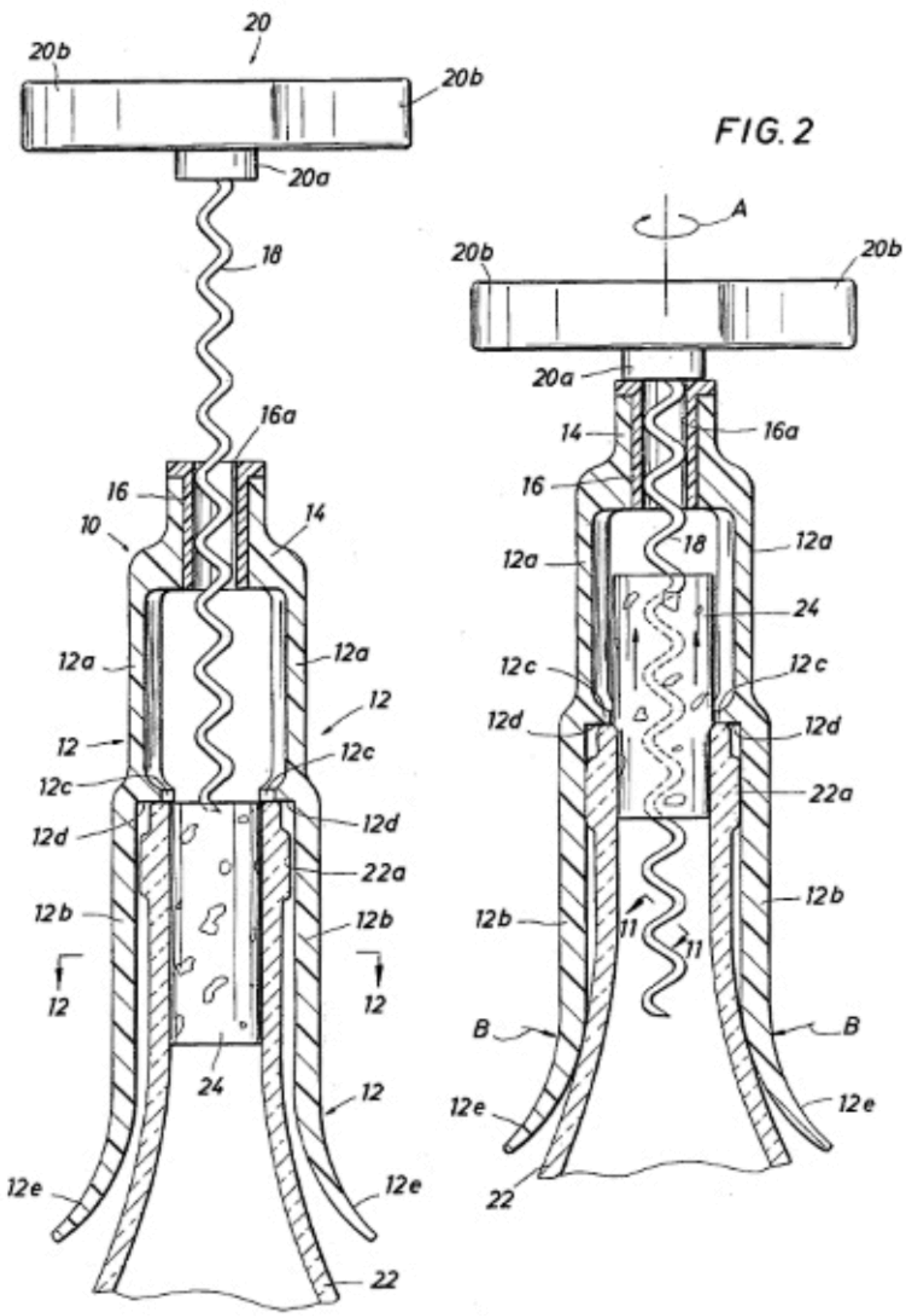
Filed Oct. 29, 1928



Appendix A.4: United States Patent for Herbert Allen's Screwpull Corkscrew

U.S. Patent Jul. 7, 1981 Sheet 1 of 4 4,276,789

FIG. 1



Appendix A.5: United States Patent for Herbert Allen’s Self Pulling Design

U.S. Patent Mar. 3, 1981 Sheet 1 of 9 4,253,351

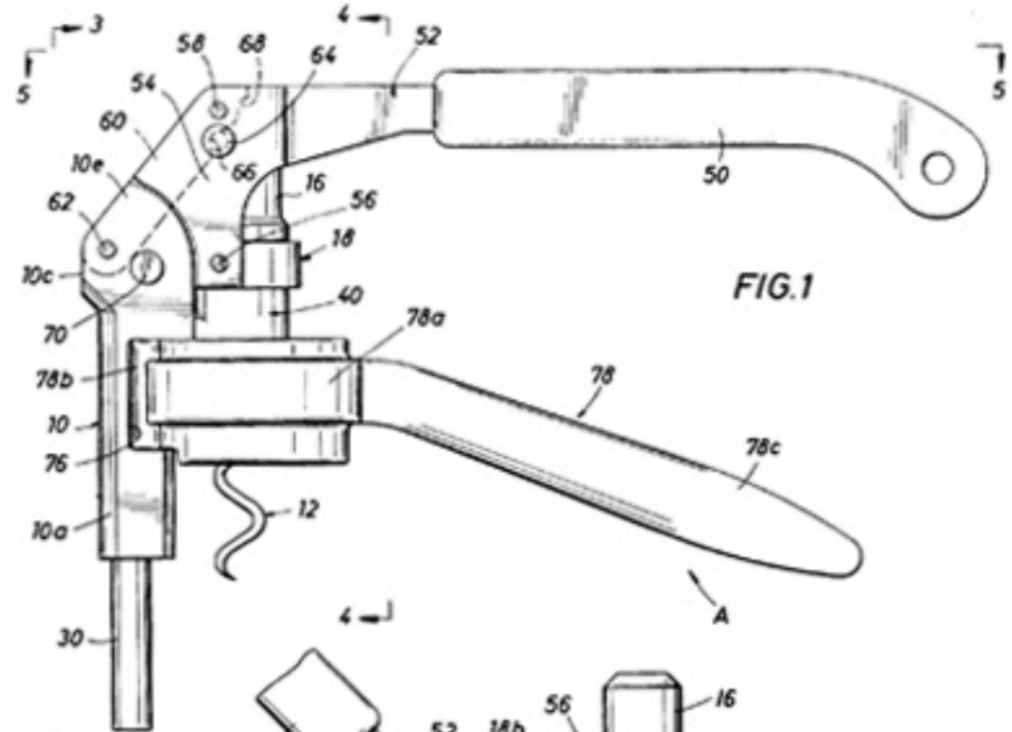


FIG.1

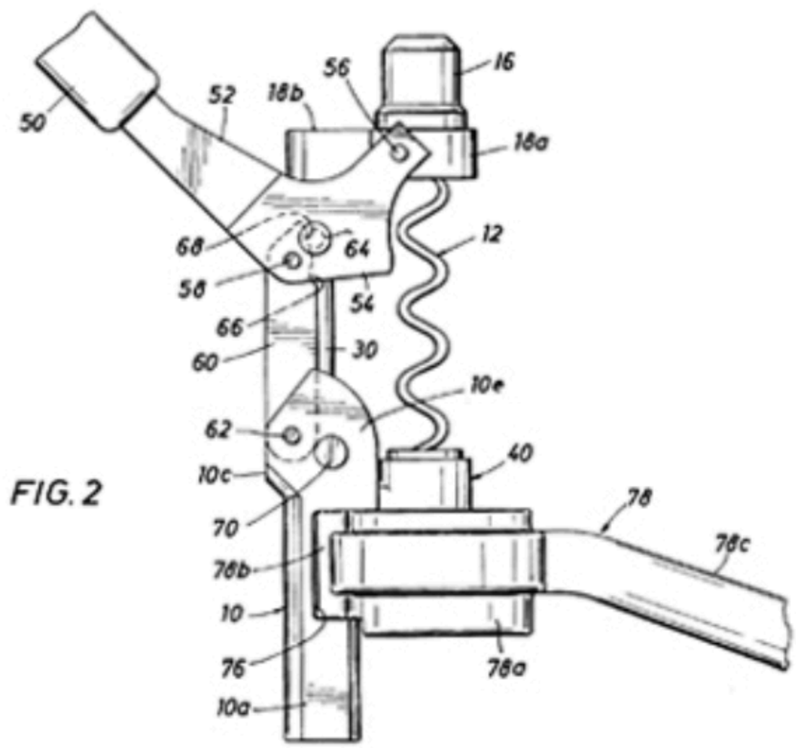


FIG. 2

Appendix A.6: United States Patent for the Rabbit

U.S. Patent Mar. 19, 2002 Sheet 1 of 14 US 6,357,322 B1

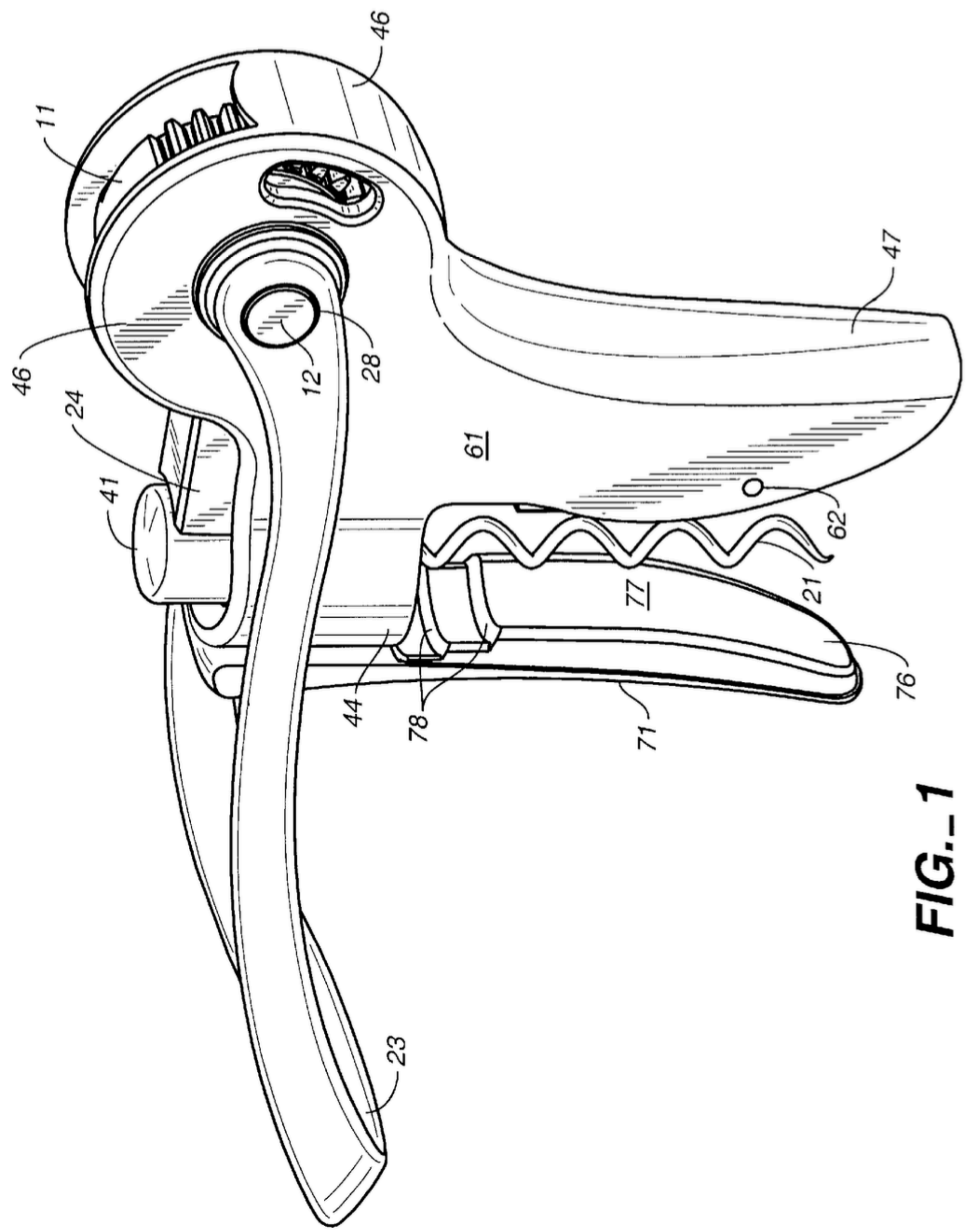
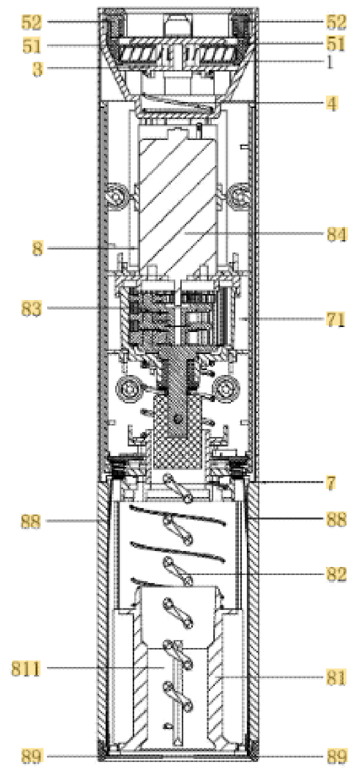
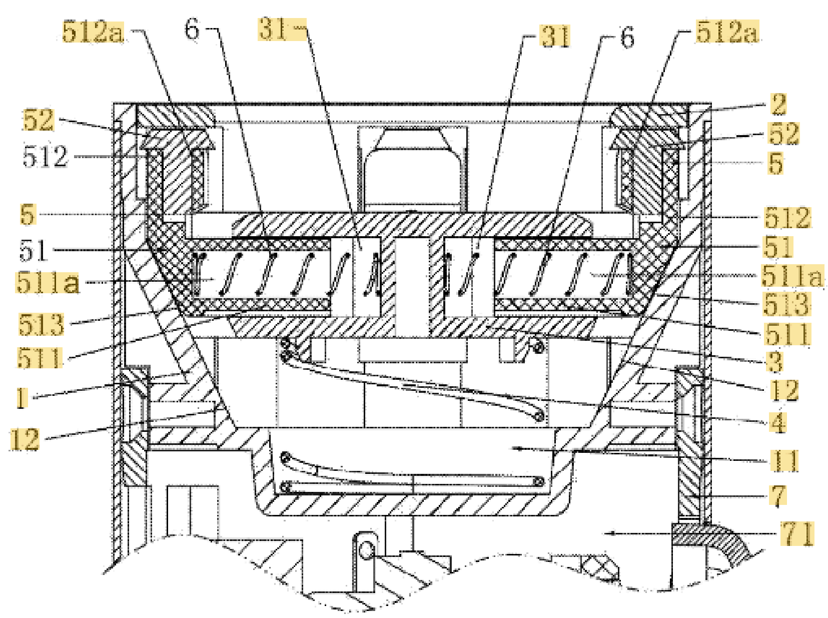


FIG._1

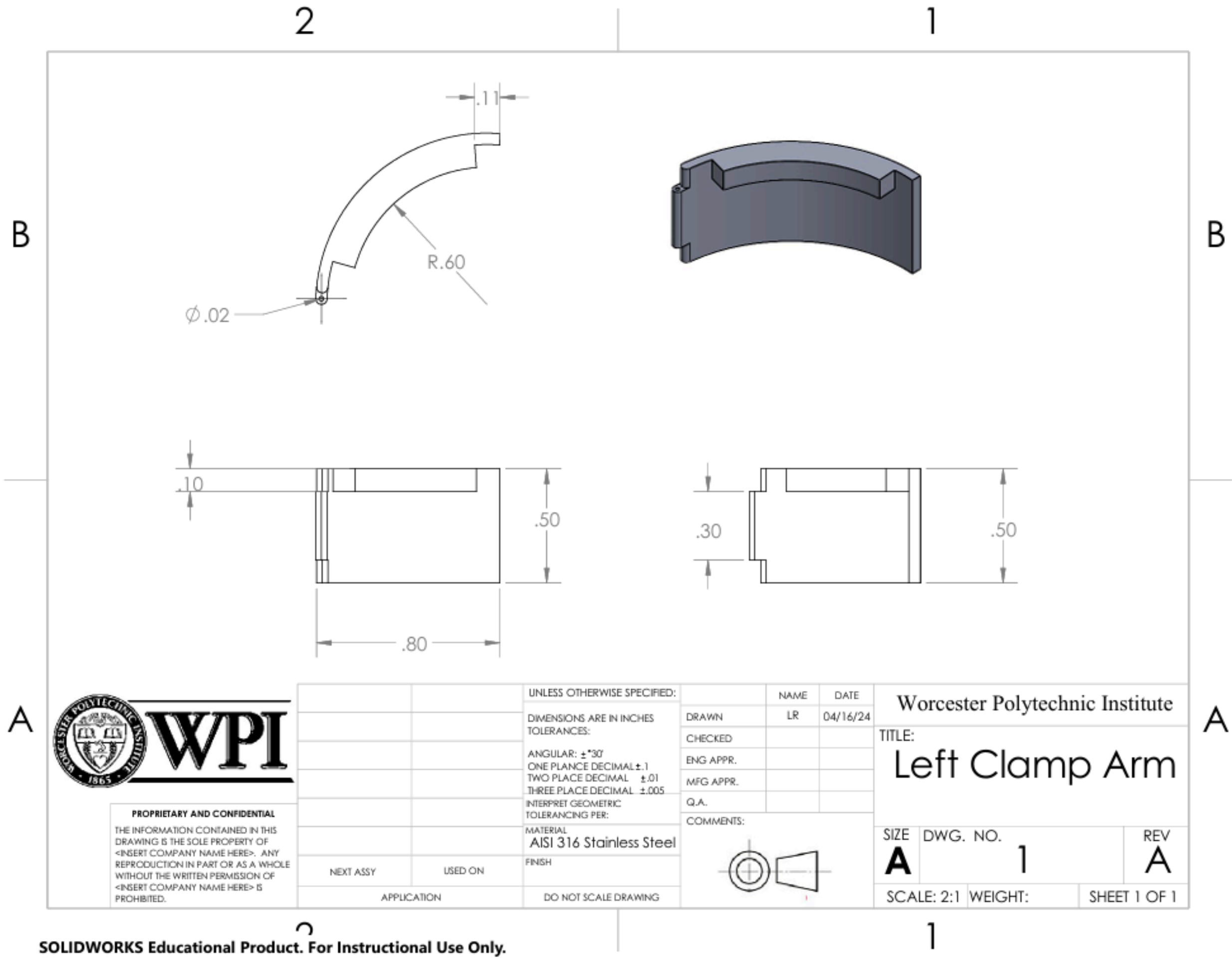
Appendix A.7: United States Patent for the Multifunctional Electric Wine Opener



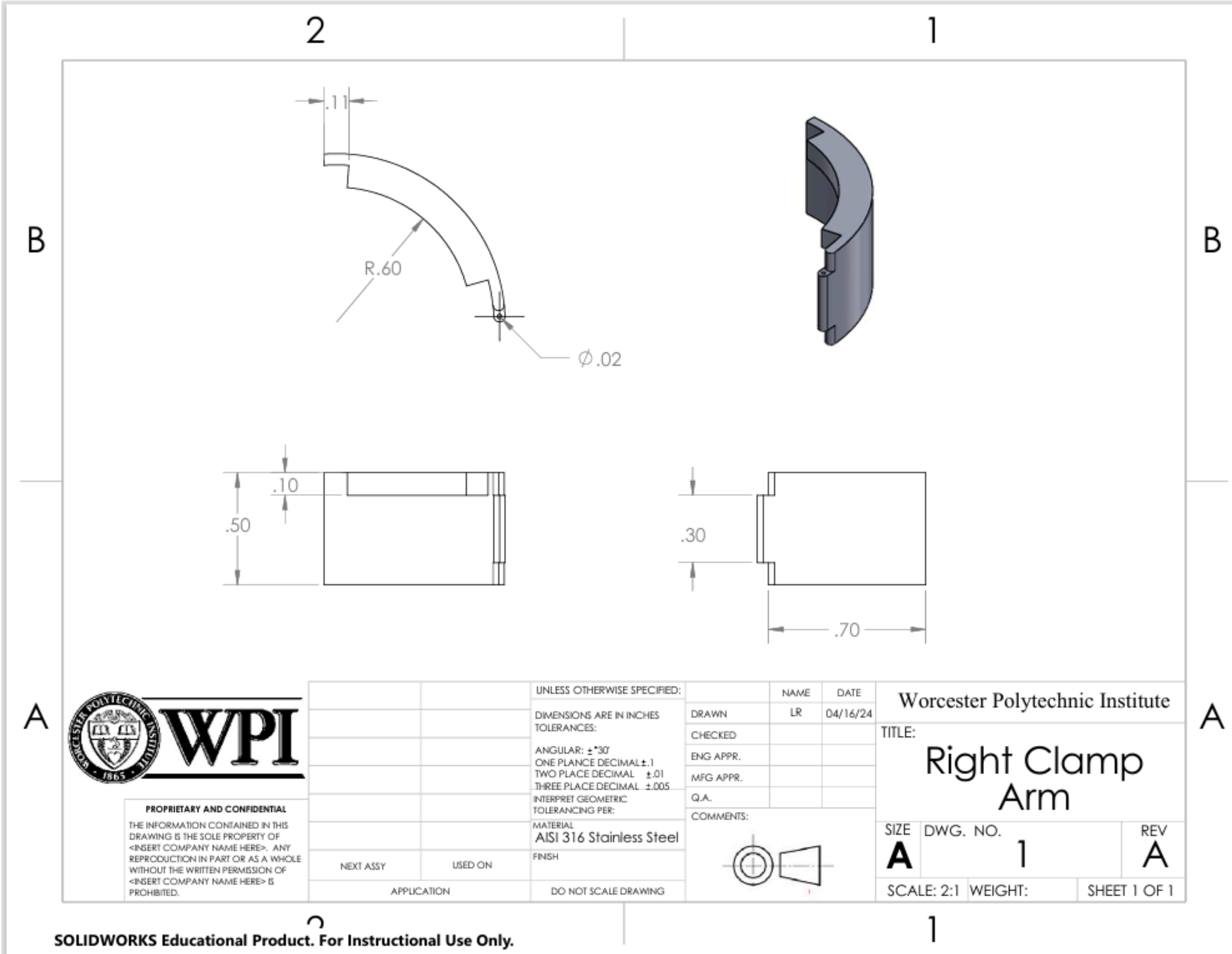


Appendix B. Engineering Drawings of Parts

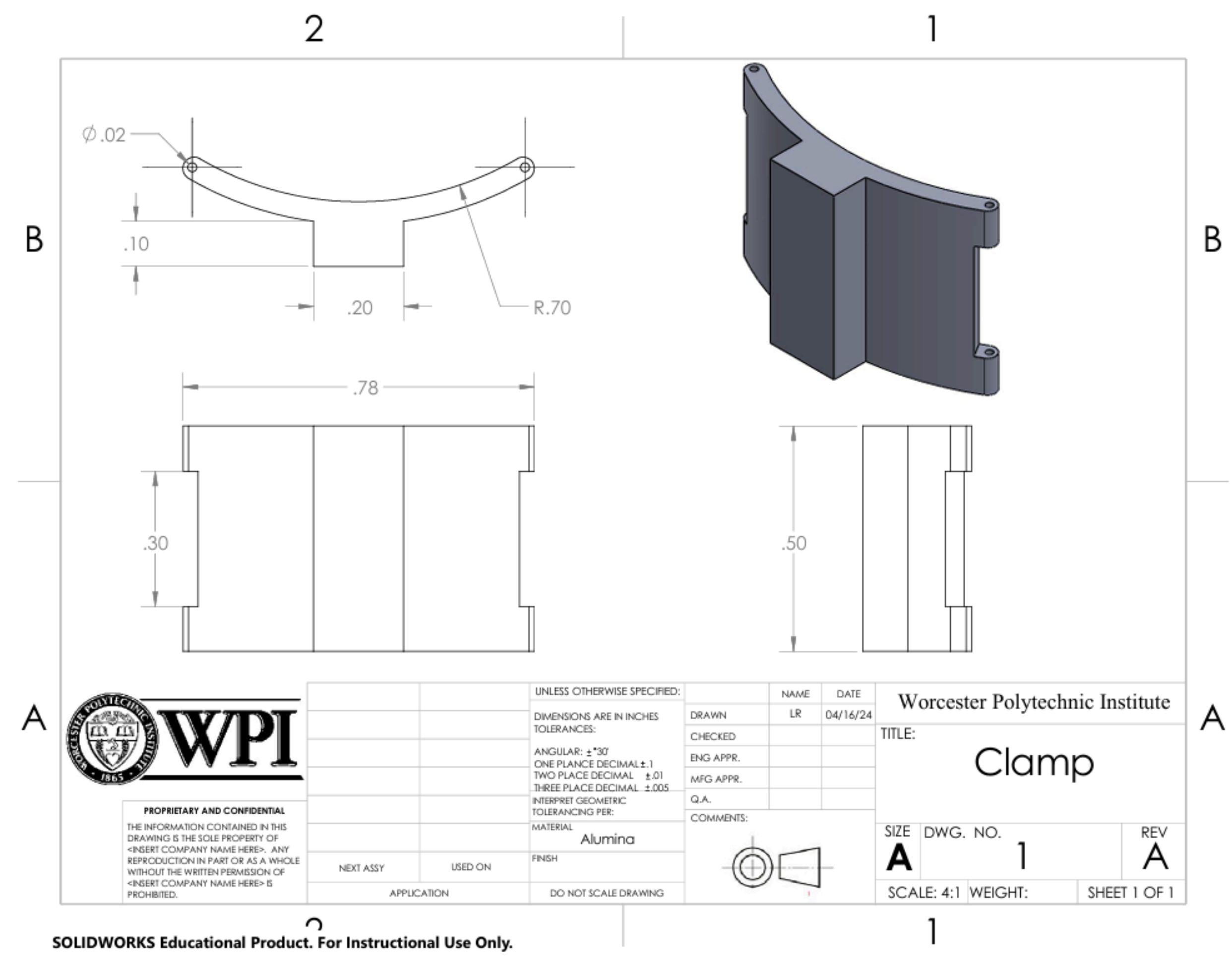
Appendix B.1: Engineering drawing of left clamp arm.



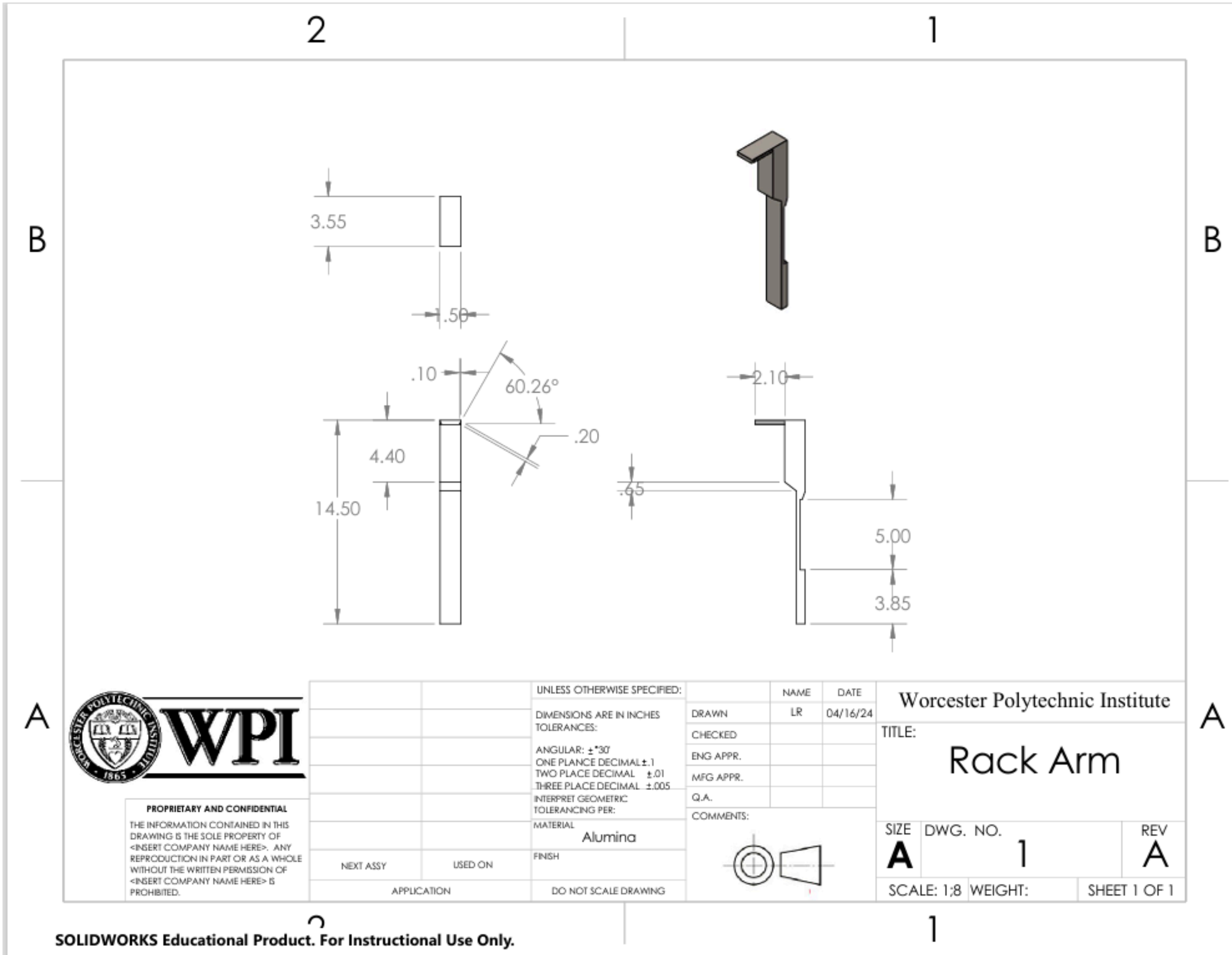
Appendix B.2: Engineering drawing of right clamp arm.



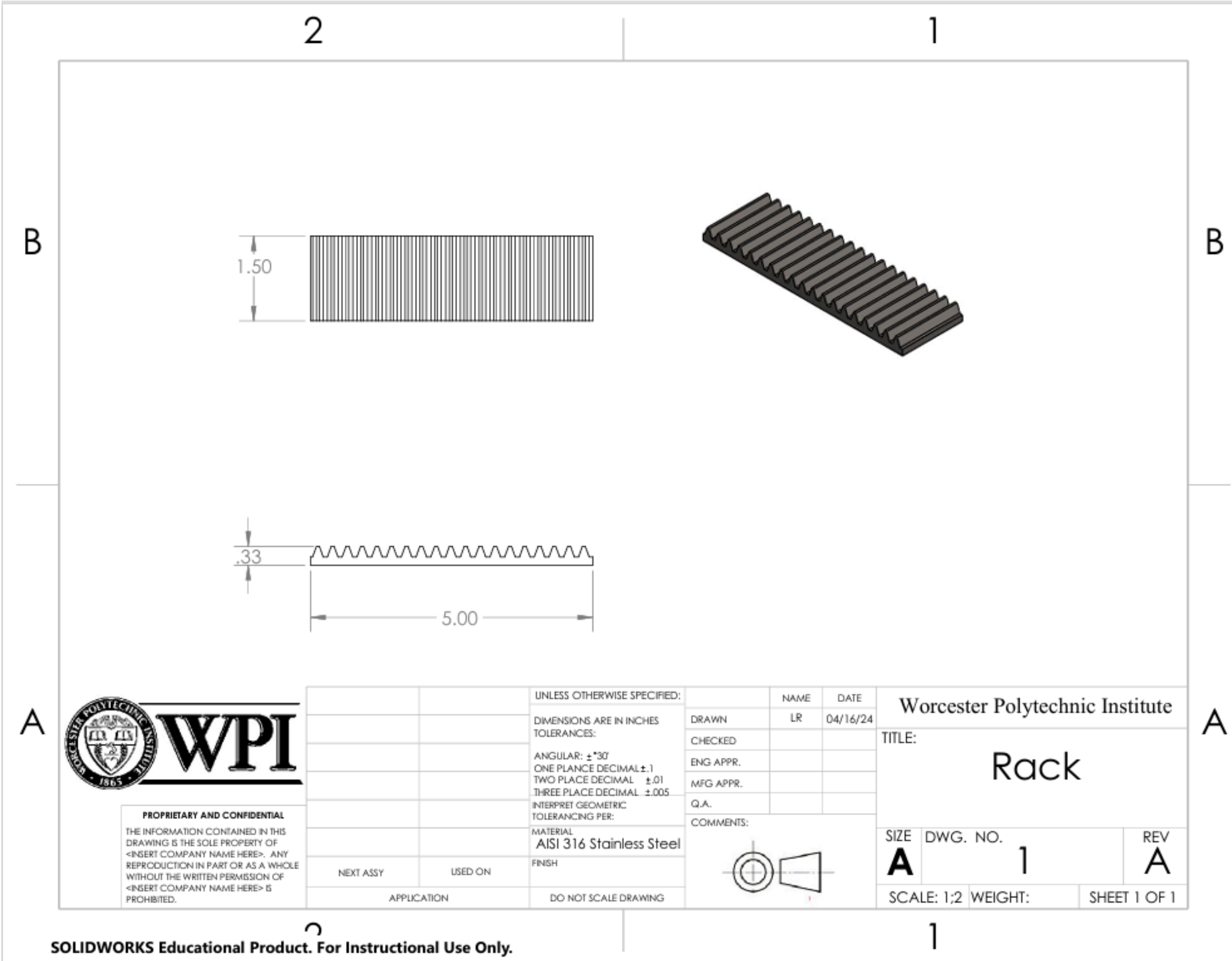
Appendix B.3: Engineering drawing of clamp.



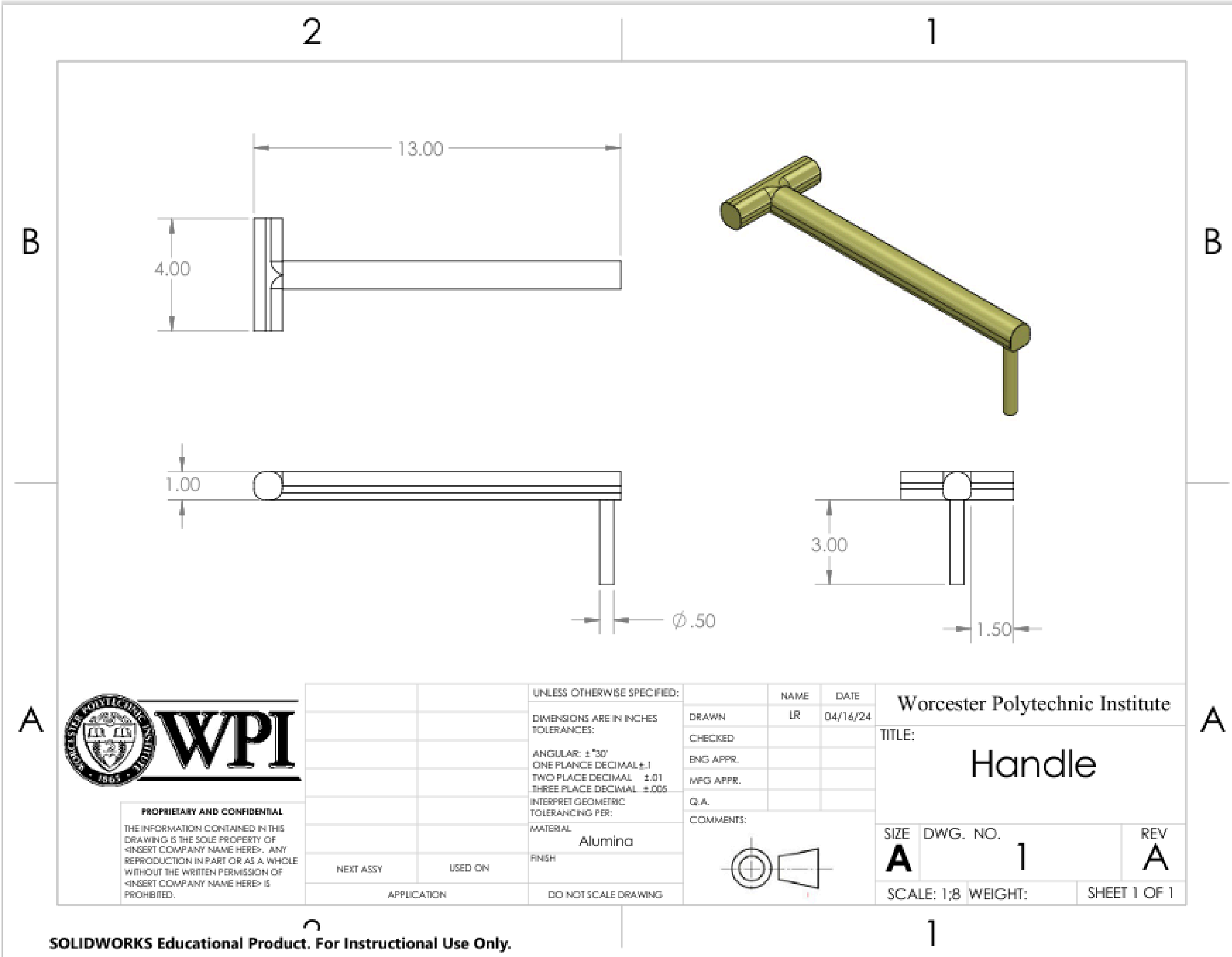
Appendix B.4: Engineering drawing of rack arm.



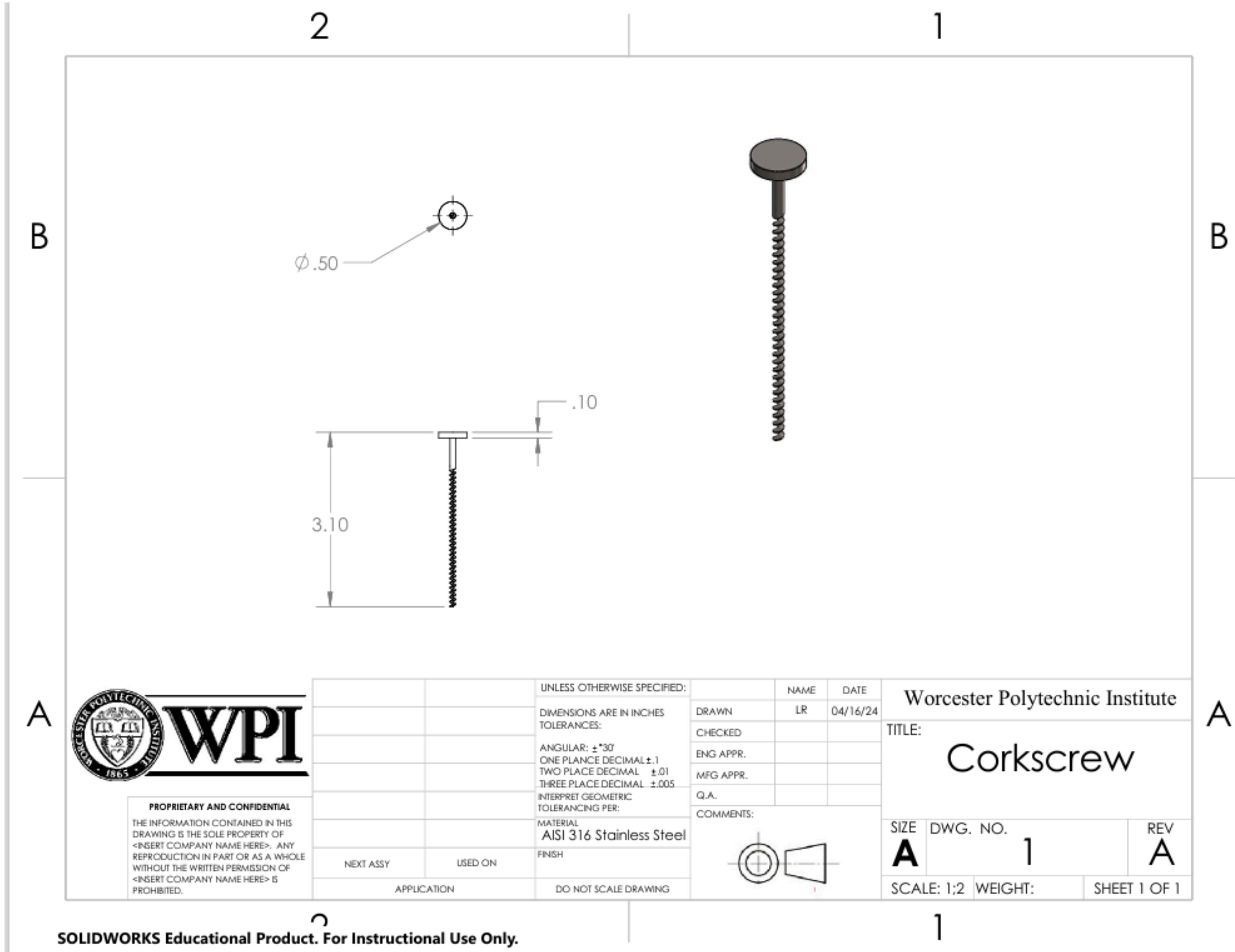
Appendix B.5: Engineering drawing of rack.



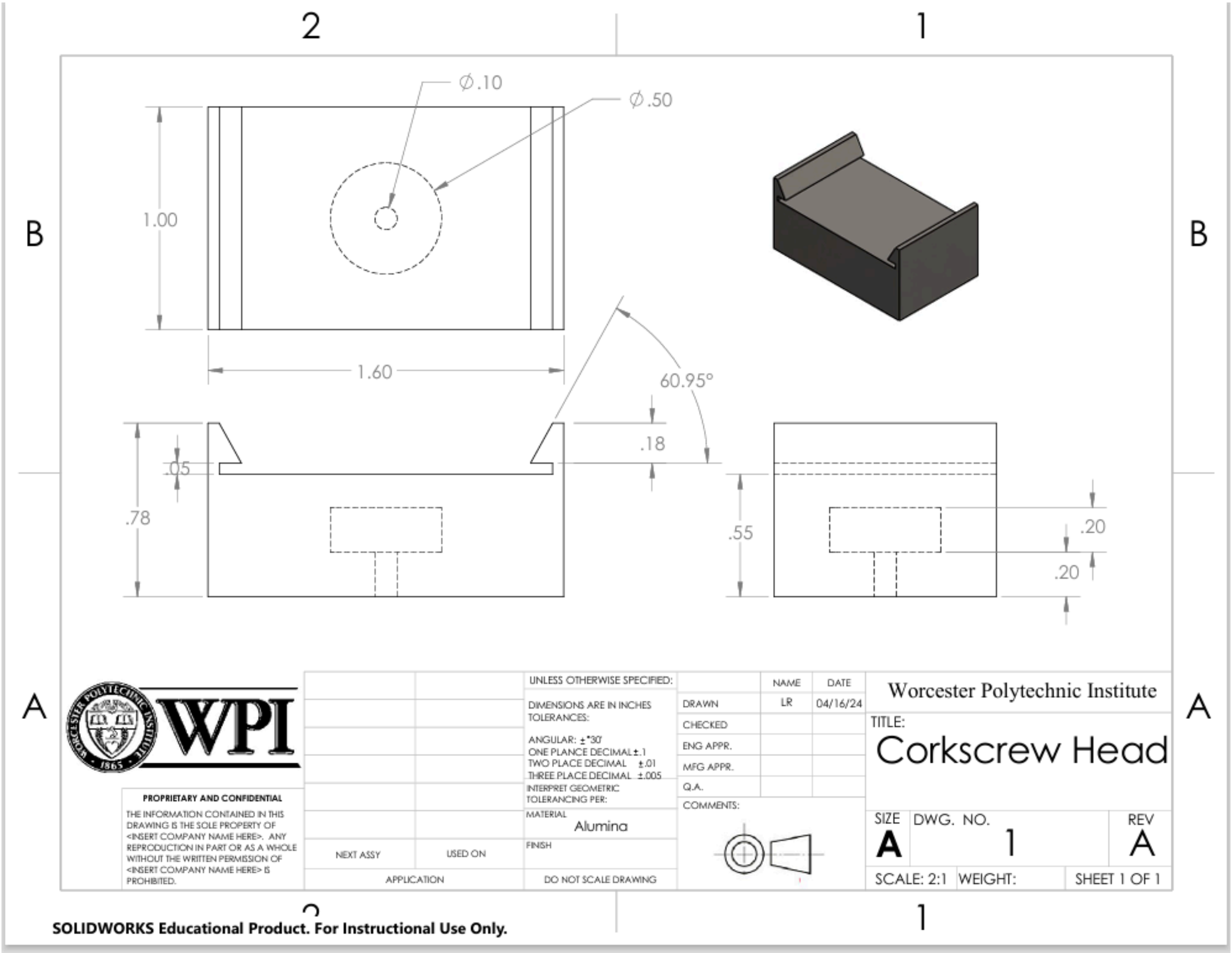
Appendix B.6: Engineering drawing of handle.



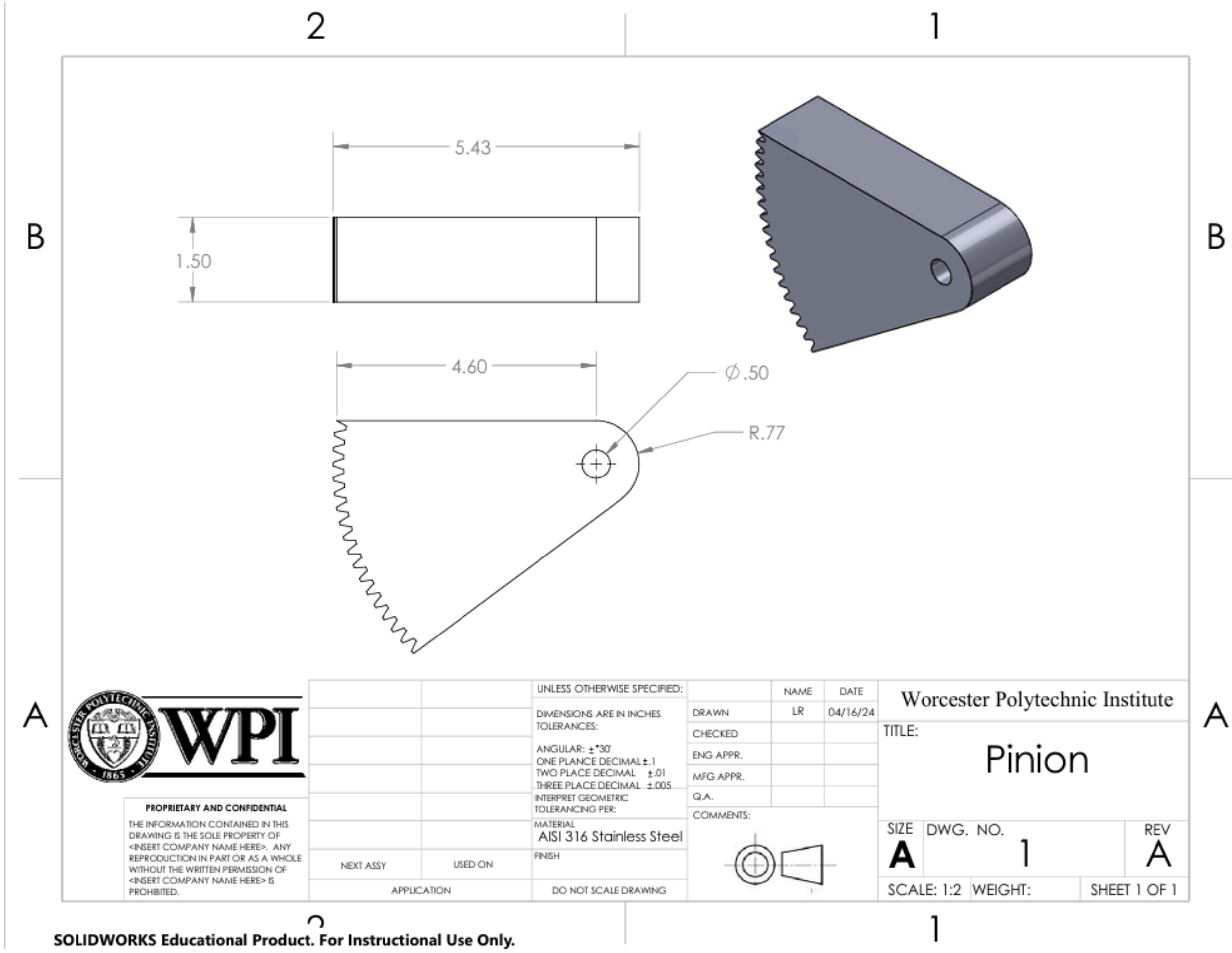
Appendix B.7: Engineering drawing of corkscrew.



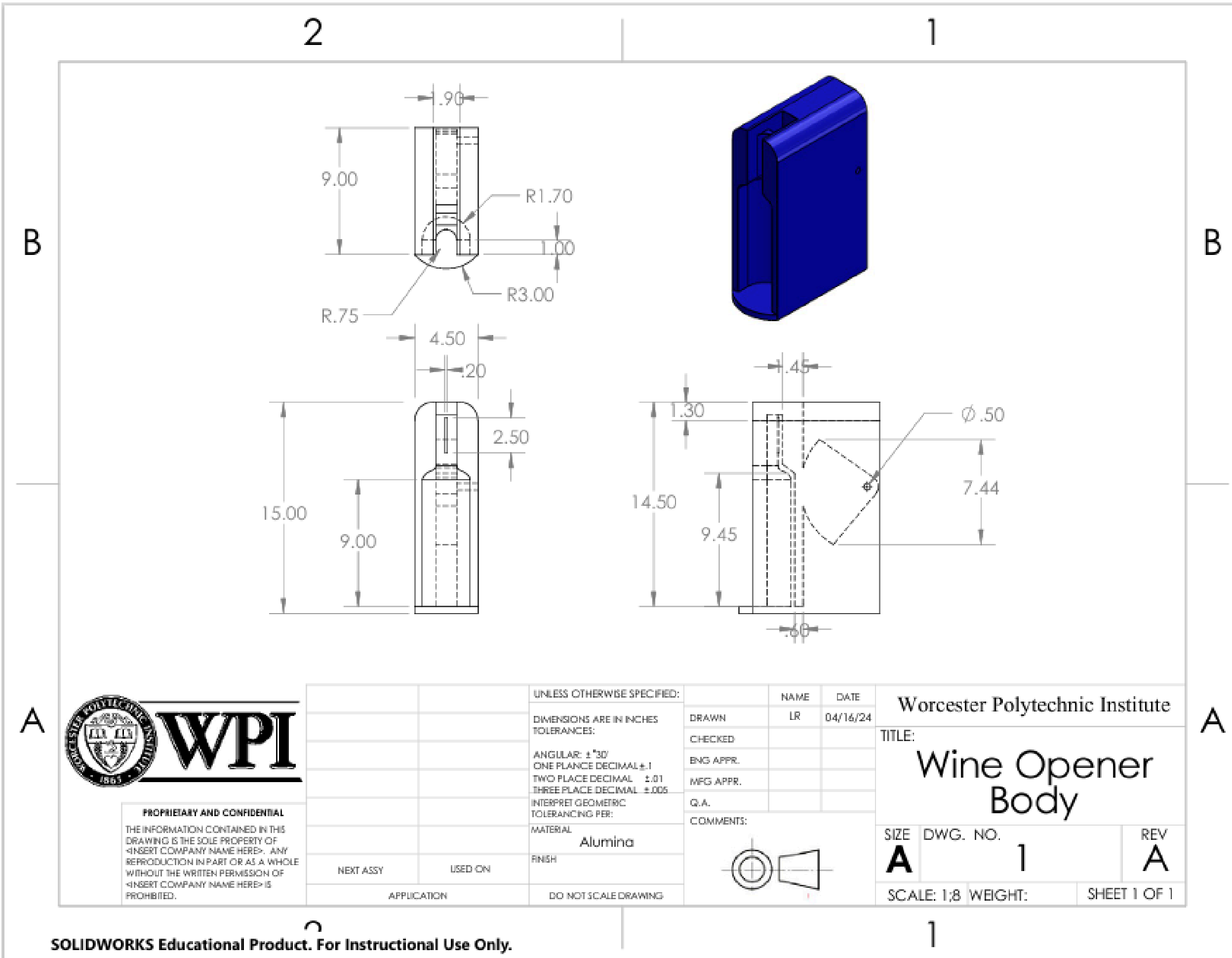
Appendix B.8: Engineering drawing of corkscrew head.



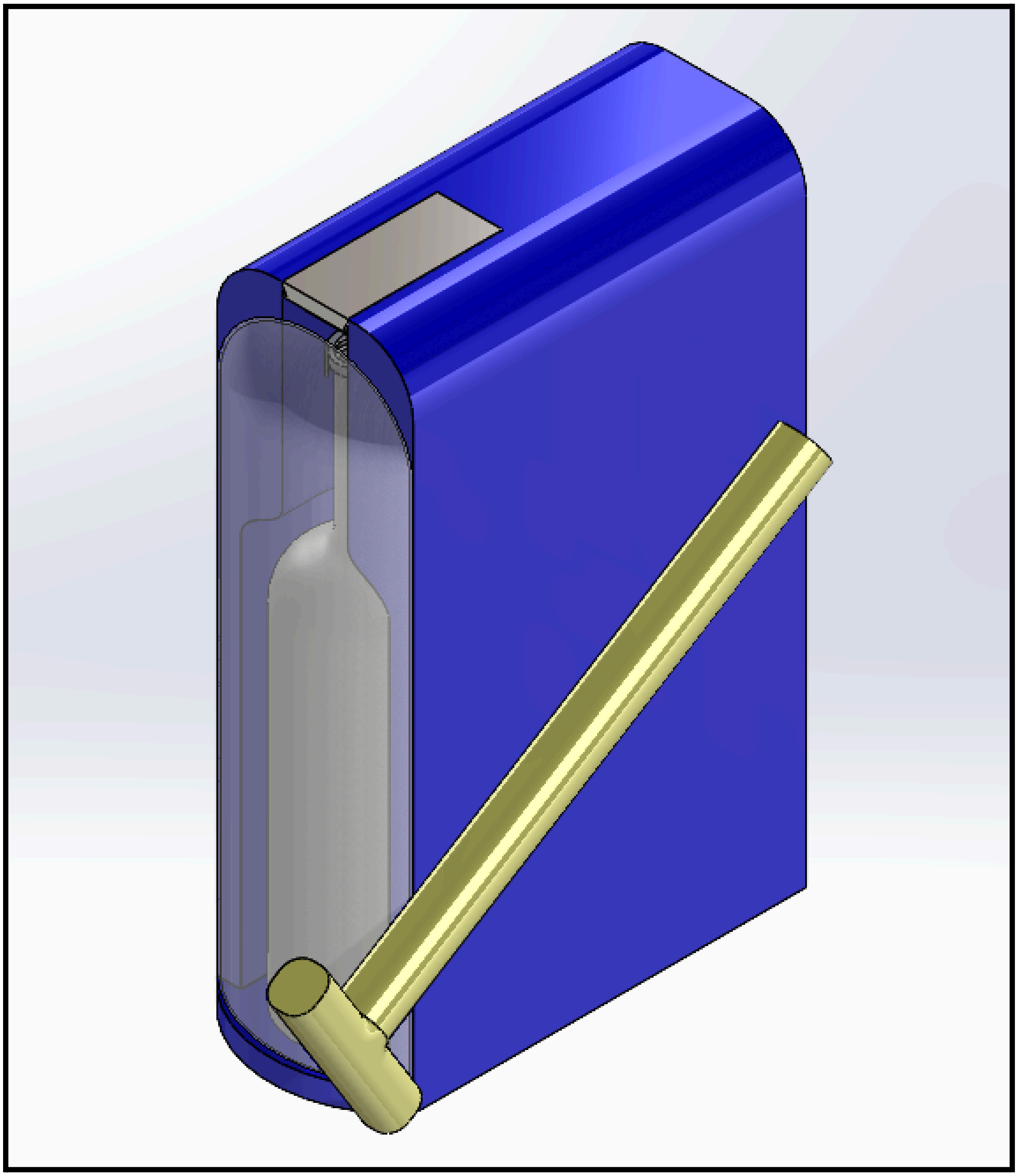
Appendix B.9: Engineering drawing of pinion.



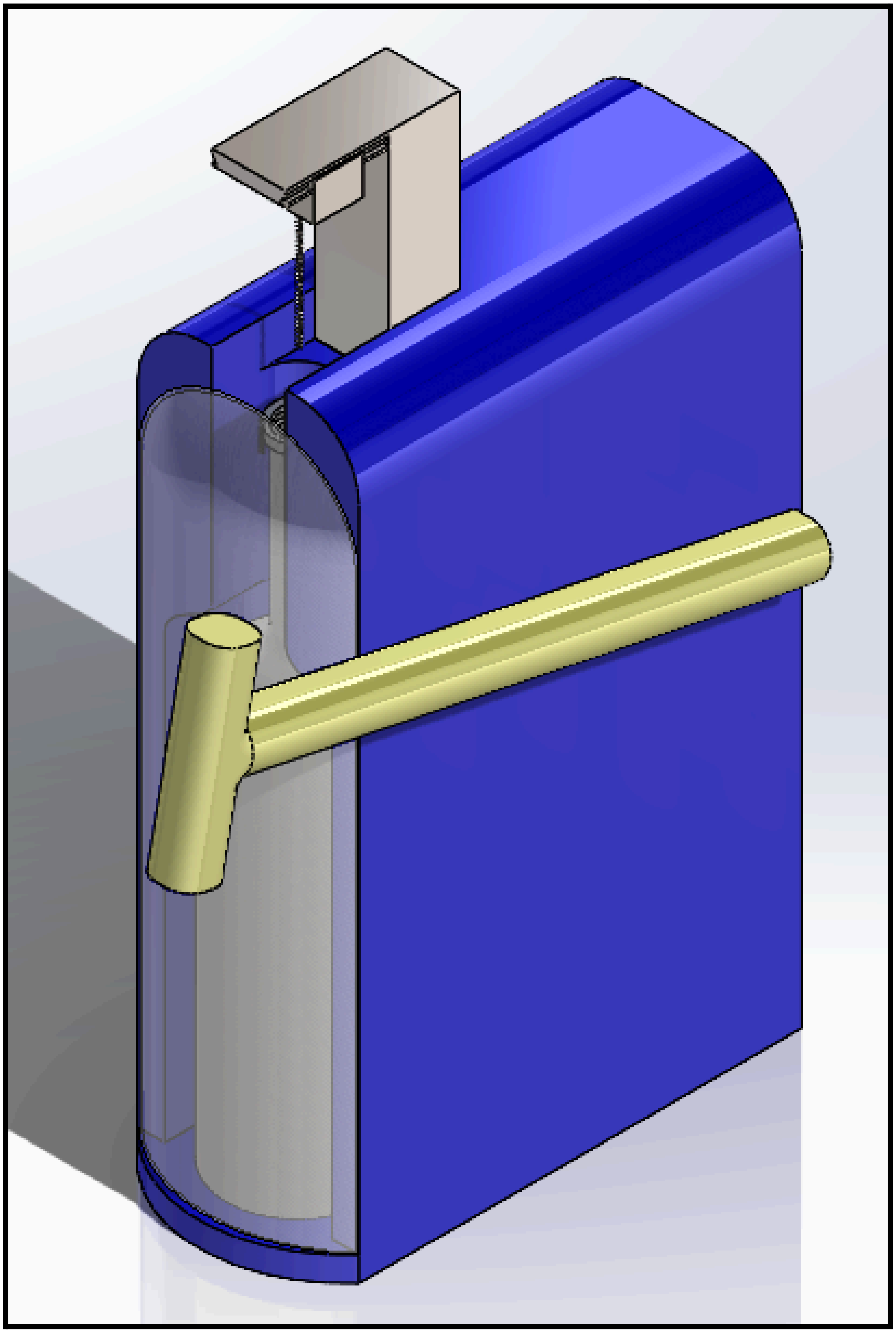
Appendix B.10: Engineering drawing of .



Appendix B.11: Solidworks CAD screenshot of final design.

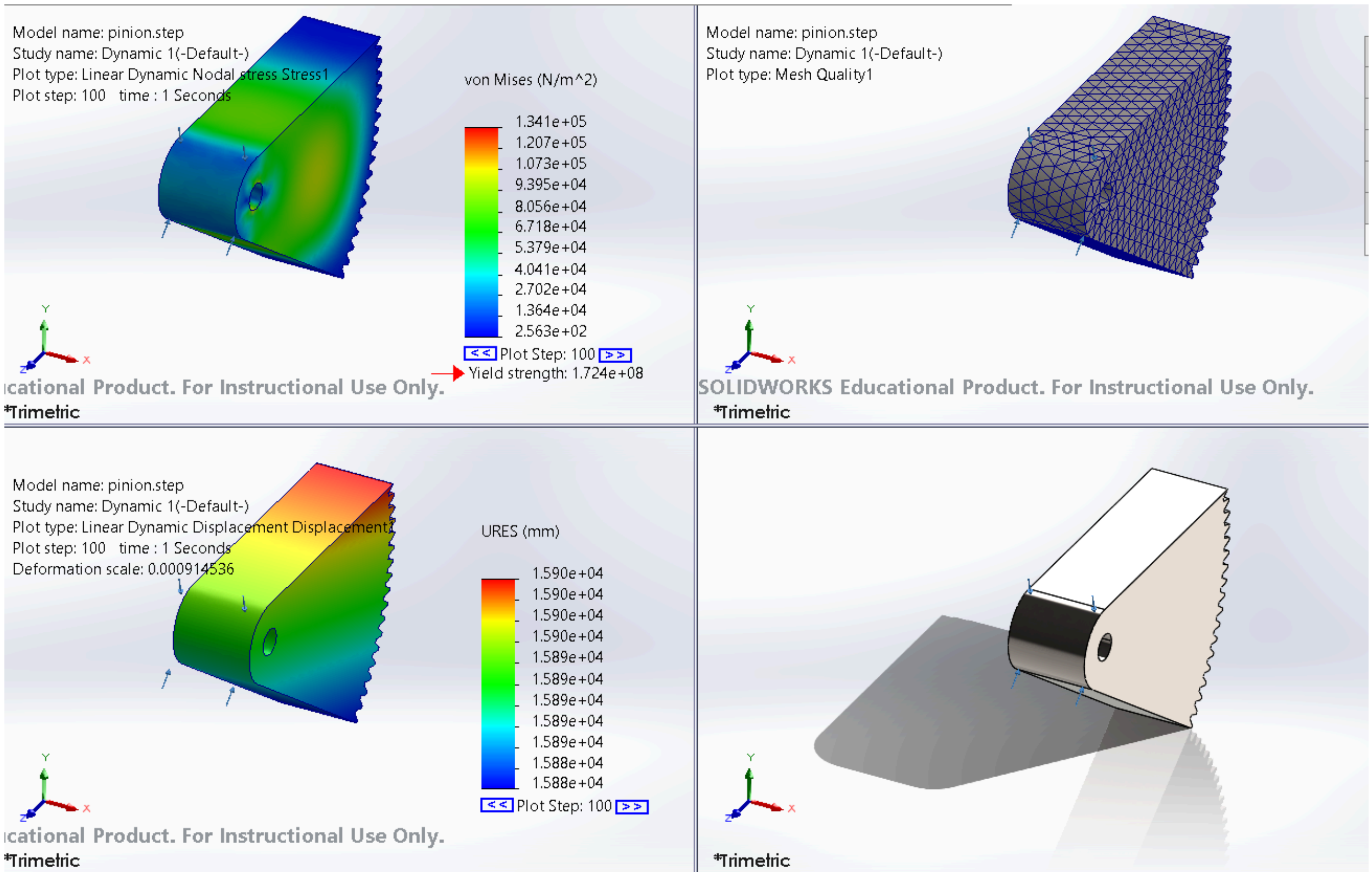


Appendix B.12: Solidworks CAD screenshot of final design.

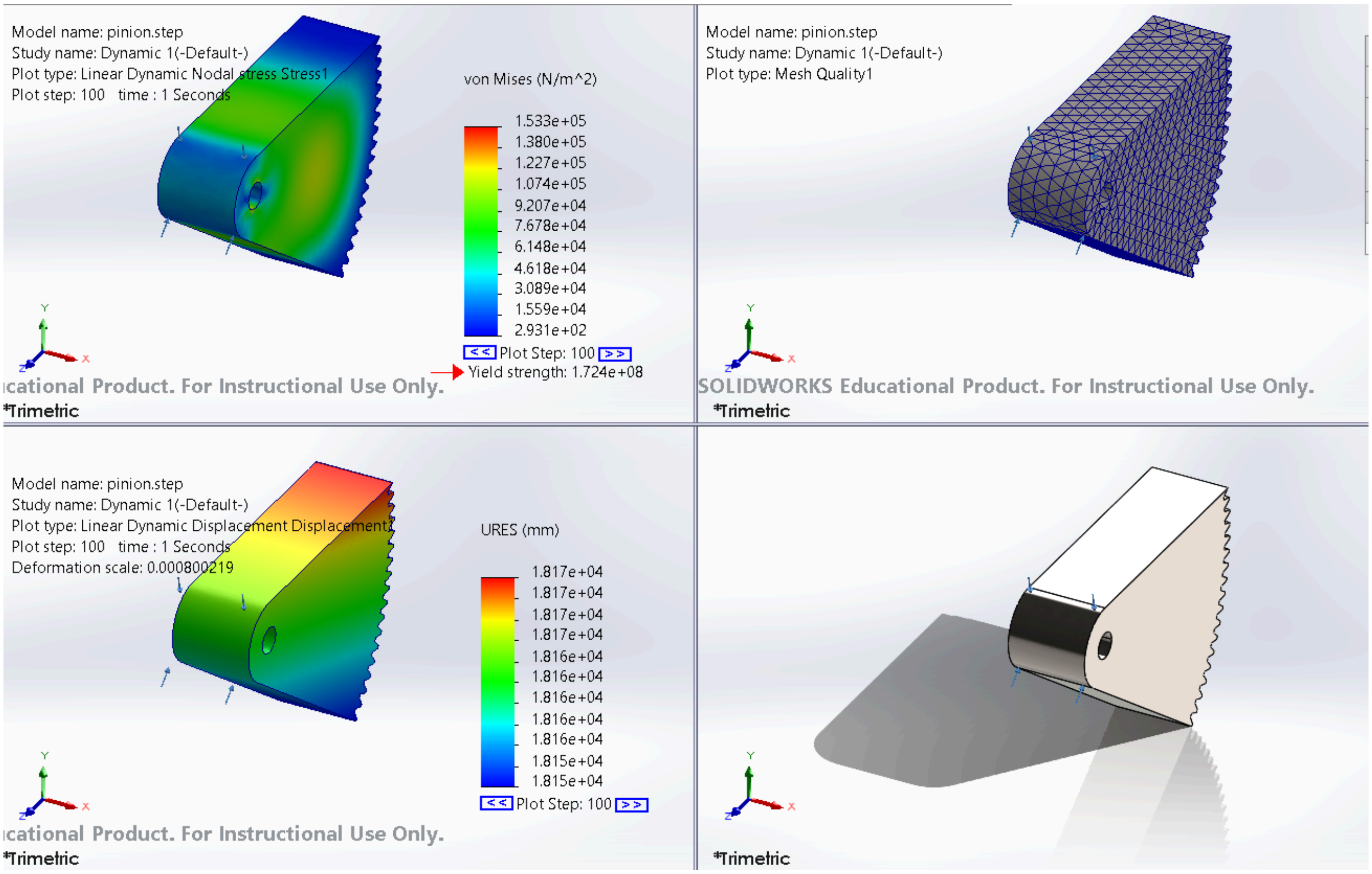


Appendix C. Solidworks CAD file of linear dynamic analysis

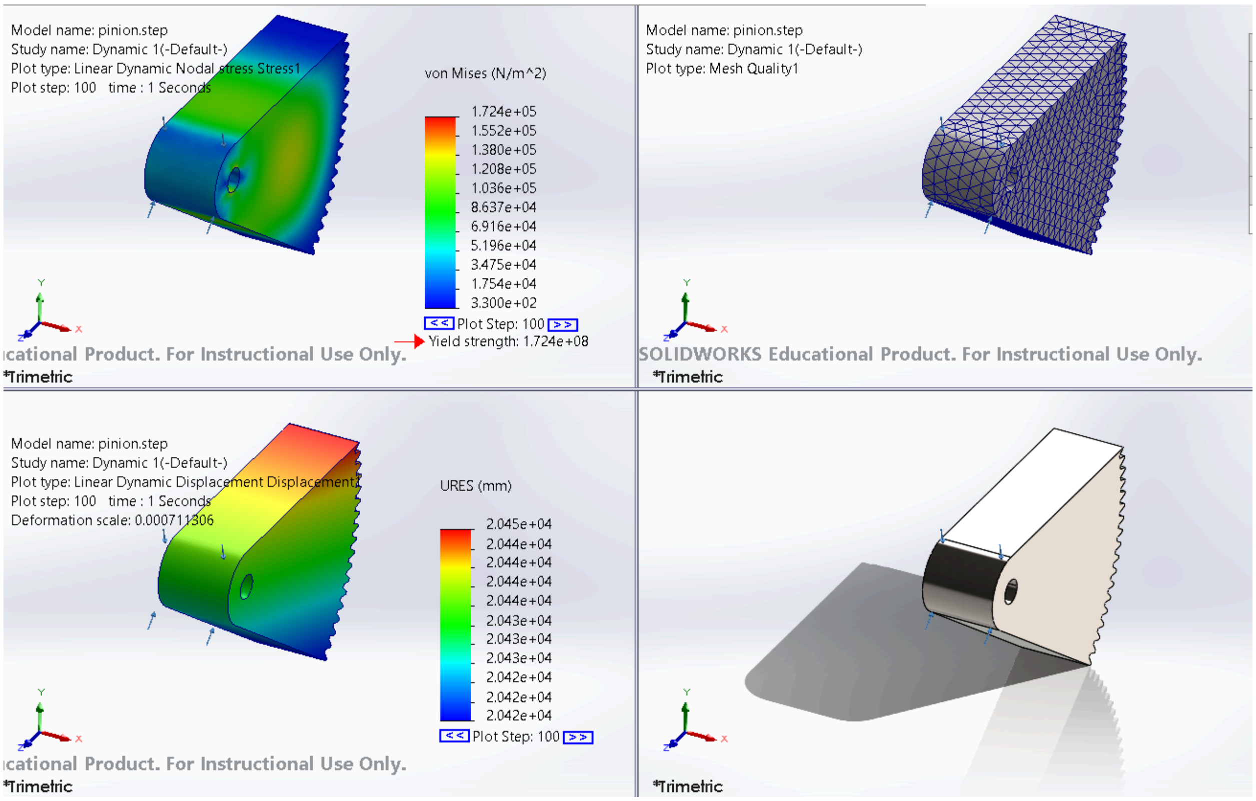
Appendix C.1: Solidworks CAD file of linear dynamic analysis for 350 N of force applied.



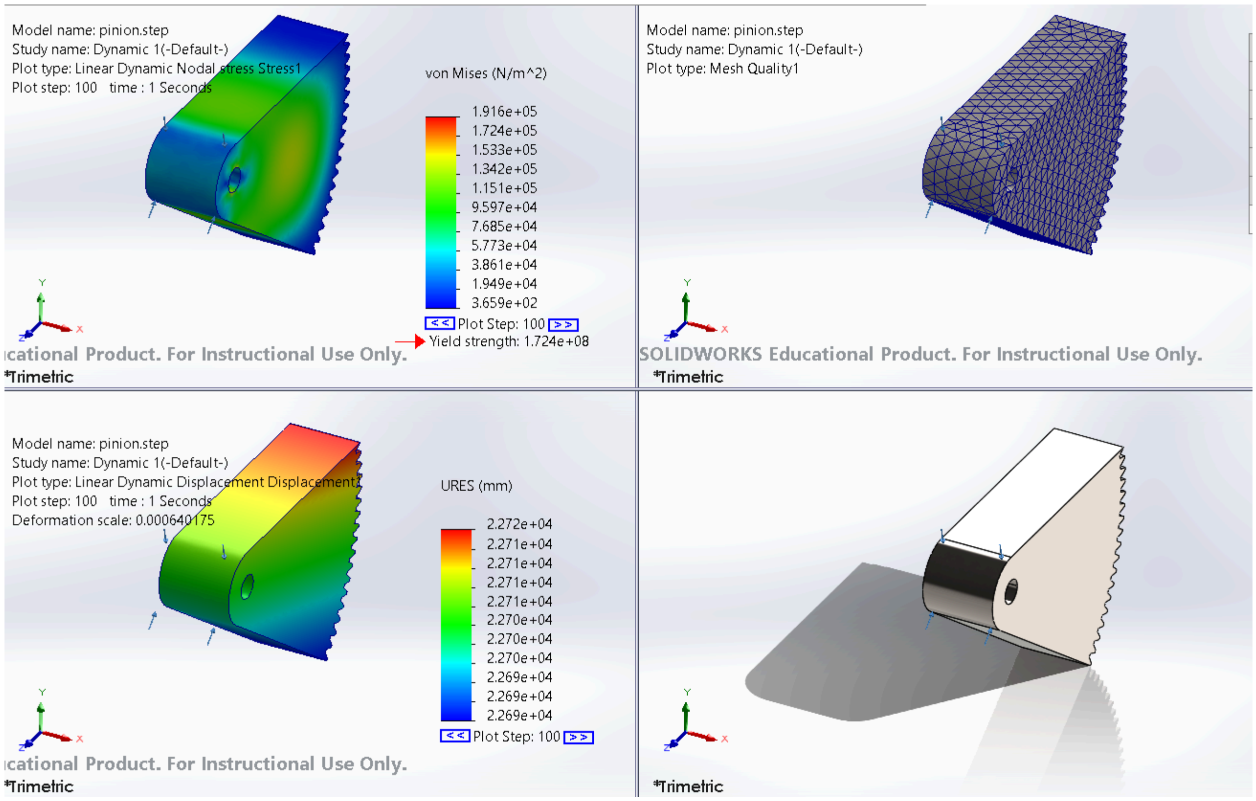
Appendix C.2: Solidworks CAD file of linear dynamic analysis for 400 N of force applied.



Appendix C.3: Solidworks CAD file of linear dynamic analysis for 450 N of force applied.



Appendix C.4: Solidworks CAD file of linear dynamic analysis for 500 N of force applied.



Appendix D. IEEE Abstract Submission

Design of an Automated Wine Opener

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I. Abstract

This project encompasses a design and analysis of an automated wine bottle opener. The opener is intended to open wine bottles of various sizes and shapes. The design is a counter top item that is safe and easy to use for any disabled person. The wine bottle opener features a simple lever action mechanism to bring the corkscrew down to the cork and remove it promptly as the lever is returned to its upward position. The corkscrew is screwed into the cork with the force applied through the downward force with the rack and pinion. Once the lever is raised, the corkscrew is locked from rotating so the cork is pulled out. This standstill machine will sit solidly on top of a smooth surface with the use of suction cups. Wine drinking is a large tradition in many cultures and these ideals were considered when designing the bottle opener. The drawings and design were initially drawn on paper and then modeled using the Solidworks CAD program. A final design was chosen based on the ability of the most limited users, ensuring that anyone can open a bottle of wine even if they can only use one body part.

Index Terms - Automated, Wine, Opener

II. Introduction

Wine, an enduring cultural staple spanning centuries, has gained and kept its popularity throughout the years. Over time, advancements in wine production have paralleled innovations in bottle opening mechanisms. Handheld corkscrews and automated devices have proliferated, yet many require two-handed operation for either inserting or removing the cork.

In our modern, inclusive society, it's crucial to consider the diverse needs of individuals. For instance, an elderly person with arthritis may struggle to extract a cork, while a disabled veteran may find conventional corkscrews challenging to use. The aim of this project was to develop a stationary, automated wine bottle opener accessible to all, ensuring safety and efficacy. Designed with inclusivity in mind, our solution integrates assistive technology, featuring a lever action rack and pinion system adaptable to individual needs.

Presently, there is a gap in the market for a wine opener accessible to diverse disabled demographics, including those with motor skill disabilities, visual impairments, amputations, and more. Furthermore, existing automated wine openers lack the convenience, affordability,

ease of use, and maintenance desired by consumers. The proposed automated wine opener seeks to address these shortcomings by offering a more convenient and maintainable design tailored to a wide range of disabled individuals. It aims to be cost-effective while ensuring the integrity of the wine remains uncompromised.

III. Literature review

Assistive technology is any modified tool(s) and device that lets people with differences work around challenges. They make tasks and activities more accessible at school, work and home. Assistive technology is designed to help people with disabilities perform tasks that might otherwise be difficult or impossible for them. These technologies aim to enhance the quality of life, promote independence and facilitate inclusion for individuals with disabilities across various aspects of daily living, education, employment, and social interaction.

Disabilities affect a significant portion of the population in the United States, impacting individuals of all ages, race, and socioeconomic backgrounds. According to data from the U.S. Census Bureau, approximately 61 million adults in the United States live with a disability, around 26% of the entire population. [1] This includes individuals with physical, sensory, cognitive and mental health impairments. Disabilities vary in nature and severity. The most common types of disabilities include mobility impairments, such as difficulty walking or climbing stairs, sensory impairments, including vision and hearing loss, cognitive disabilities such as developmental or intellectual disabilities, and mental health conditions, such as depression, anxiety and post-traumatic stress disorder. Disabilities affect individuals throughout their life. While children may experience developmental disabilities or chronic health conditions impacting their development and functioning. Elderly people may face age-related disabilities, such as mobility limitations, cognitive decline and sensory impairments. There is also an impact on daily life as well with disabilities. Including education, employment, healthcare access, transportation and social participation. Individuals with disabilities can encounter many barriers to accessing services, accommodations, and opportunities to access full inclusion and participation in society.

Table 1. Assistive Technology use by age of person and type of device. (Numbers are in thousands)

Assistive Technologies	All Ages	44 Years and younger	45-64 years	65 years and older
Anatomical Device	4565	2491	1325	748
Mobility Device	7394	1151	1699	4544
Vision Device	527	123	135	268

Information above was provided by the Centers for Disease and Control and Prevention [2]. This table outlines the primary focus of our project: three key categories of assistive technologies. Firstly, anatomical devices, also known as orthotic devices, play a pivotal role in supporting, safeguarding or enhancing the function of various body parts. Often prescribed by healthcare professionals, these devices address a spectrum of musculoskeletal and anatomical challenges.

Secondly, mobility devices serve as indispensable aids for promoting independence and enriching the quality of life for individuals with mobility limitations. They empower users to maneuver their environment with greater autonomy and participate in diverse activities.

Lastly, visual devices constitute a diverse array of tools and technologies aimed at strengthening accessibility and autonomy for individuals with visual impairments or blindness. As depicted in Table 1 above, there exists a pressing need for the development of a solution that addresses these challenges efficiently.

IV. Design

Through the use of Solidworks CAD software a final design was created as shown in Figure 1. This design was created with intentions of being inclusive for persons with an ambulatory or visual disability. The combination of automatic clamps, a lever, and a rack and pinion mechanism minimizes the effort required to open a bottle (Table 2). The automatic clamps hold the wine bottle while cutting the seal as the bottle is placed within the clamp. The lever provides a mechanical advantage when removing a cork. Finally the rack and pinion provides a smooth motion in the y-axis, preventing injury or contamination to the wine. This makes it ideal for users with limited hand strength, dexterity, or upper body mobility.

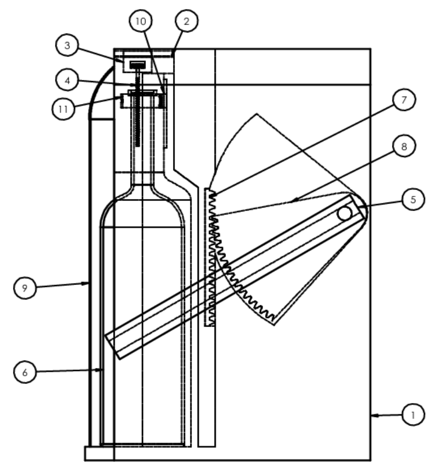

Fig. 1 CAD drawing of the final design

Table 2. Parts list and description of the Design

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Wine Opener Body	Housing for all parts	1
2	Rack Arm	Connects Rack and Pinion to the Corkscrew Head	1
3	Corkscrew Head	Adustable and contains the Corkscrew	1
4	Corkscrew	Free to move up and down but only spin when pushed up	1
5	Handle	Handle is fixed to the pinion	1
6	Wine Bottle	Standard Wine Bottle	1
7	Rack	Custom Rack to move the Rack Arm up and down	1
8	Pinion	Custom pinion to move the rack with limited movement	1
9	Bottle Cover	Prevents injury and contamination	1
10	Clamp Cutter	Clamp for Bottle	1
11	Clamp Cutter Arms	Clamp arms for Bottle with cutting blades for the seal	2

V. Conclusions

The design of this automated wine opener was created to be inclusive of those with ambulatory or visual disabilities. The simple lever action rack and pinion mechanism is an assistive technology that allows any disabled person(s) to operate the device.

This device has many alleys in which advancements could be made. Potential future developments include increasing and expanding the client base. This could be done by designing new handles or attachments to target any type of disability or handicap that a person may be dealing with.

Additionally, efforts can be made to facilitate an easy cleaning method free of chlorine products. This will help prevent any contamination of the wine when opening.

References

[1]*WIPO Technology trends 2021- assistive technology*. (2021). . World Intellectual Property Organization (WIPO).

[2]Centers for Disease Control and Prevention. (2015, November 6). *NHIS - National Health Interview Survey on disability - table - assistive technologies*. Centers for Disease Control and Prevention.