CalPolyPomona

California State Polytechnic University, Pomona
Department of Mechanical Engineering

ME 2331L-01: INTRODUCTION TO DESIGN LABORATORY
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COVER SHEET FOR LAB REPORT

PROJECT #1

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Abstract:
We analyzed a mechanical pencil. The static analysis problem we addressed was how much gripping force per unit of contact area was necessary to hold the graphite in place. This was important as a mechanical pencil's ability to hold graphite in place is arguably its most important function. Understanding the necessary force is imperative to designing a functioning mechanical pencil, as it determines the length and grip strength of the Chuck.

Our methodology consisted of research into design specifications and other relevant information (e.g. force necessary to write) through online sources, mechanical dissection, and static analysis. Having made a few necessary assumptions, we concluded that a force of 14 N was necessary to hold the graphite in place when writing and a force of 4.96x10^-3 N was necessary to hold the lead when not. Considering the relative strength of the material composing a common, plastic mechanical pencil and the general ease of writing, these results were well within expectations.

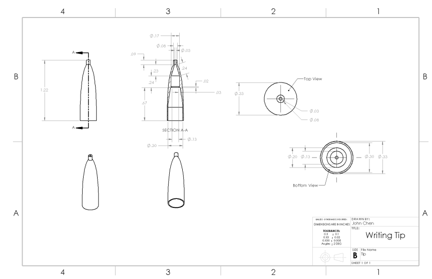
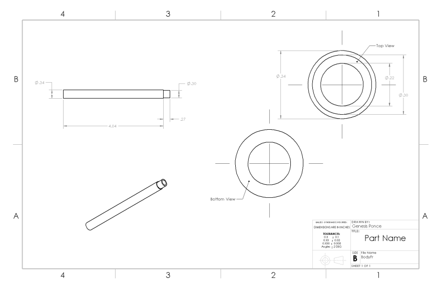
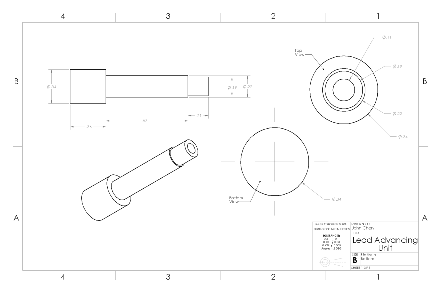
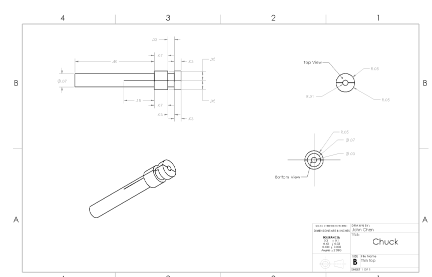
Introduction:

Mechanical pencils are common machines used for writing. The machine itself consists of an exterior frame and a variety of interior components. Graphite is fed into the frame of the mechanical pencil. Through interior mechanisms, the graphite is then exposed through the opposite end and held in place. Thus, the machine achieves its purpose as a writing implement, as the graphite is shaved off when pressing it against an adequate surface, leaving a trace. Given this, our problem statement will be finding the amount of force that is needed to hold the graphite in place when writing. With the limitations of data for the coefficient of graphite against other materials, and writing force we will have to assume these values in our analysis. All being said, this lab seeks to dive deeper into the interior mechanisms that allow for the mechanical pencil's use.

Fig. 1 Standard Mechanical Pencil Isometric View

How Does it Work?

Components

Part #	Part Name	# Req’d.	Location and Explanation	Image (Mechanical Drawings)
1	Writing Tip	1	The topmost outer part of a mechanical pencil. Used to both stabilize and push back the **Chuck Ring** when dispensing lead.	
2	Body	1	The outer body/shell of a mechanical pencil. Serves to keep the entire system together while also allowing for smooth gliding when the **Lead Advancing Unit** is used.	
3	Lead Advancing Unit	1	The bottom outer part of the mechanical pencil. Used to advance the **Lead** through the **Chuck** and **Chuck Ring** by pushing the **Lead Reservoir Tube**.	
4	Chuck	1	The top inner part of a mechanical pencil. Drives the **Lead** outward toward the **Writing Tip** with the support of the **Chuck Ring**.	

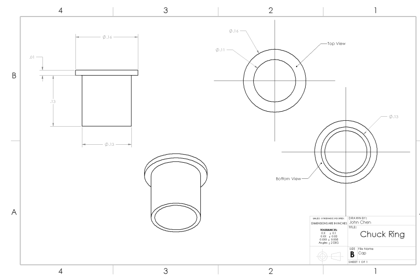
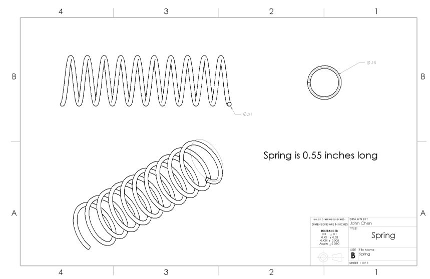
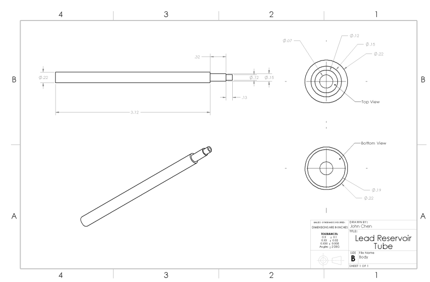
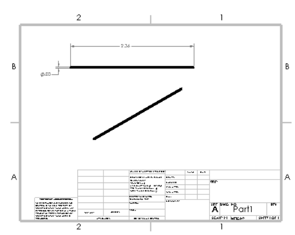
5	Chuck Ring	1	The topmost inner part of a mechanical pencil. Used to grip the **Chuck** to ensure the **Lead** stays in place.	
6	Spring	1	Located right under the **Chuck Ring**, the spring is used to return the system to its original state so the process is repeatable.	
7	Lead Reservoir Tube	1	Located in between the **Lead Advancing Unit** and the **Chuck**, the tube is used to store **Lead** and is driven by the **Lead Advancing Unit** to help dispense **Lead**.	
8	Lead	1	Located in either the **Reservoir Tube** or the **Writing Tip**, the Lead is the material that is used to write and translate through shearing on various mediums.	

Table 1 Components of a Mechanical Pencil

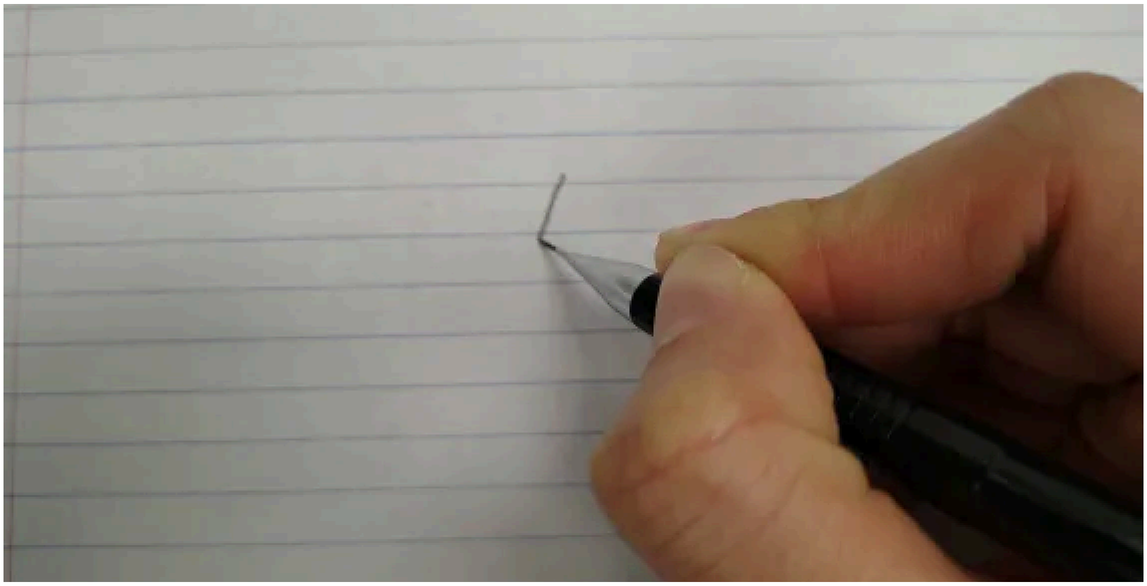


Fig. 2 Mechanical Pencil Lead Writing on a Surface

As seen in Figure 2, mechanical pencils are devices that are used to write and, more specifically, apply graphite (Lead) to a surface. The major functions of mechanical pencils is to hold sticks of graphite in place (stagnation), and to dispense said graphite (dispensation). In doing this, mechanical pencils resist the forces applied to their graphite while providing more graphite as iit shears away.

Mechanical pencils achieve their major functions through all 8 components working together. See all components in Table 1 above.

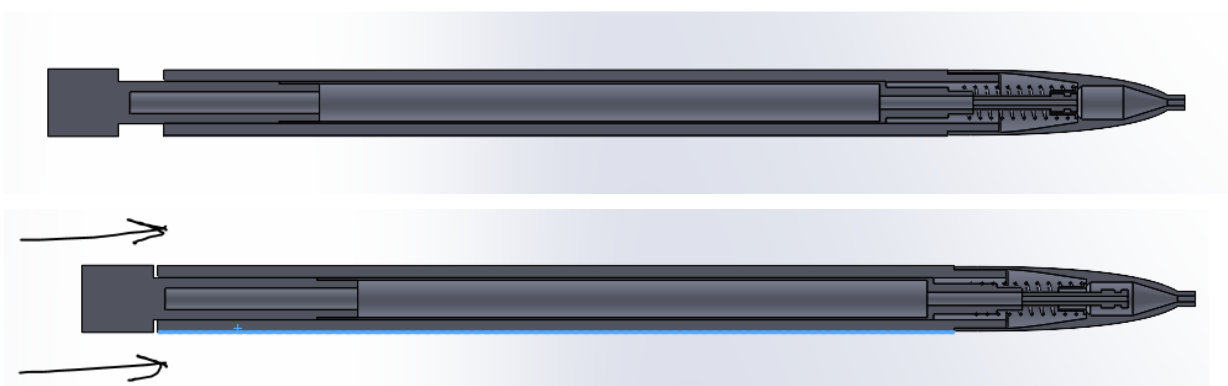


Fig. 3 Lead Advancing Unit CAD Model C-Section Visual

To begin, the release of Lead starts with a pushing input at the base of the pencil (Lead Advancing Unit). This pushing input advances the Lead Reservoir Tube which translates into the upper half components of the Mechanical Pencil.
See Figure 3 for visuals.

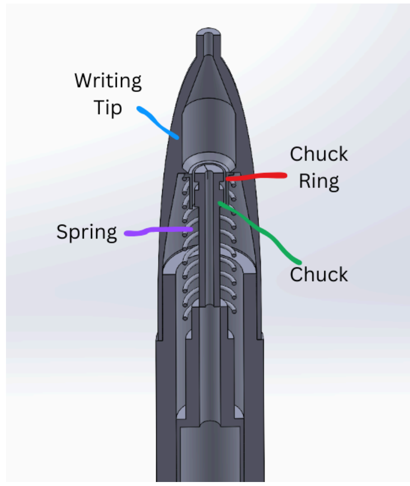


Fig. 4 CAD Sectioned View Top Half

The upper half of our components are the Writing Tip, Chuck Ring, Chuck, and Spring. These components are responsible for the mechanical pencil's functions of stagnation and dispensing. Focusing on the first function, stagnation, is completely achieved by the most important component, the Chuck. With the support of the Chuck Ring the Chuck applies a gripping force to keep the Lead in place; this function achieves stability for our mechanical pencil allowing a user to exert different levels of force while maintaining the same length of Lead.

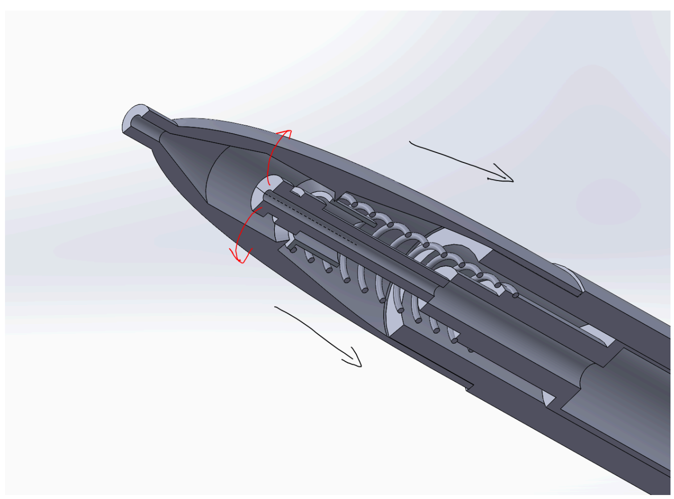


Fig. 5 CAD Model Chuck Function Visual

Moreover, Using Figure 5 as a reference, we can see the interaction between the Chuck, Chuck Ring, and Writing Tip for our second function, dispensing. As the Lead Advancing Unit is pushed the Writing Tip's reaction onto the Chuck Ring releases the Chuck from the grasp of the Chuck Ring; this allows the Chuck to loosen its grip and open which releases the Lead from the Lead Reservoir Unit toward the Writing Tip's exterior achieving our dispensing function.

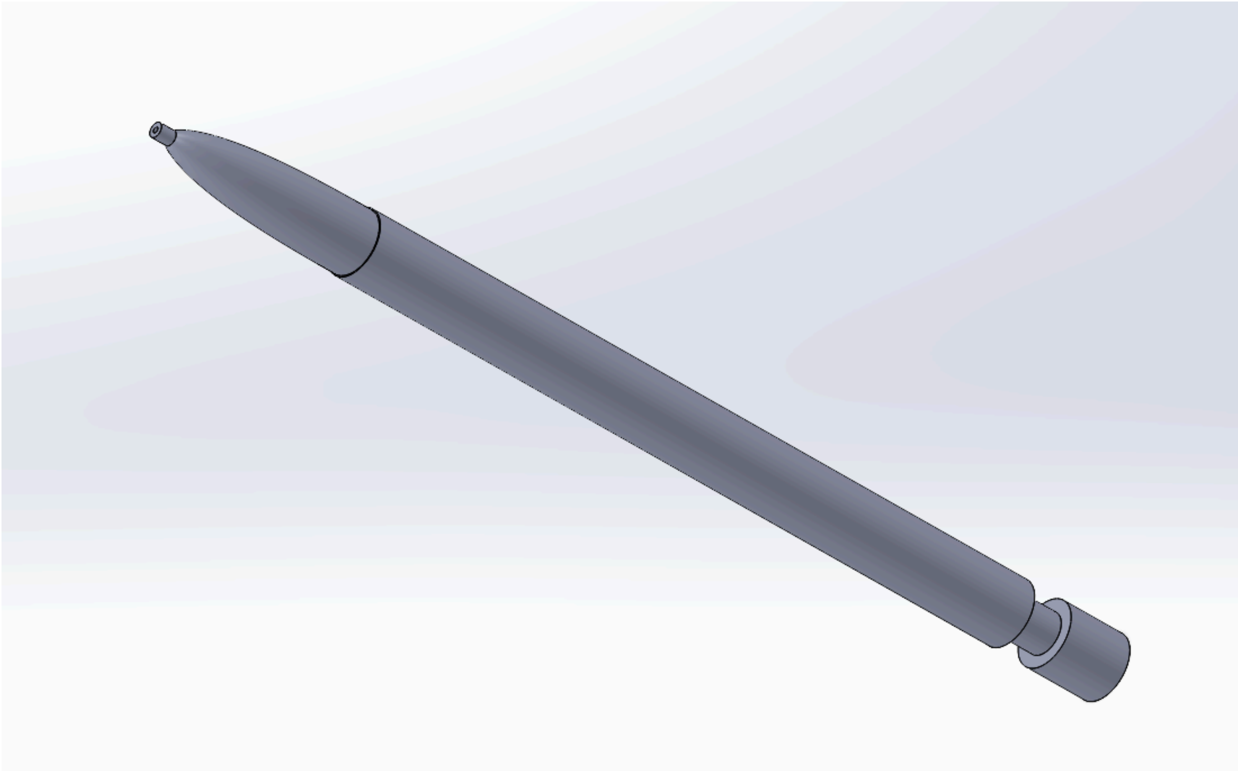


Fig. 6 CAD Assembly

After the end of the dispensing process the Mechanical Pencil returns to its original form through its spring acting as a recovering force (see Figure 6 for original state visual). In short, a mechanical pencil works through the use of all its individual components, and can not achieve its major functions without them.

Static Analysis:

As previously stated, the Chuck is the component responsible for holding the graphite in place. For that reason, it was necessary to investigate the gripping force of the Chuck on the graphite in order to further understand the lead holding mechanism of the pencil. Specifically, our static analysis problem was finding the force applied to the graphite by the Chuck per unit of surface area.

Since the gripping force on the graphite results in an equal and opposite normal force, it was possible to find the gripping force through the friction necessary to hold it in place. This is because friction is related to normal force. Since the Chuck must obviously hold the graphite whether the pencil is in use or not, we decided to investigate the gripping force in each state. In order to do so, however, we had to make a few assumptions. Particularly, since researching the coefficient of friction of graphite and the plastic material gave varied results, as did the necessary force applied to the graphite for writing, we assumed these values to be 0.1 and 1.4N, respectively. For simplicity's sake, we also looked at the graphite assuming the pencil was in a perfectly vertical position. Furthermore, the graphite was viewed in a cross section, since the gripping force is realistically applied at all points of contact between the graphite and the Chuck. This way, we were able to first find the total gripping force necessary to hold the graphite, which we then used to find the necessary force per unit of contact area.

Through our investigation, we found that a gripping force of 4.96x10^-3 N was necessary to hold the graphite in place when the mechanical pencil was not in use and a force of 14 N was necessary when it was. Since the Chuck is usually shorter than the lead, and considering that a stick of graphite of length significantly shorter than the Chuck moves when in use, this length was used when considering the contact area between the Chuck and the graphite. Thus we found the contact area to be 0.29688 cm^2, such that the necessary force per unit of contact area is 10.105 N/cm^2 when in use and 0.0167 N/cm^2 when not.

Simplified Model

When Suspended (Not writing):

FBD of Graphite in the Pencil

$\rho = 2.2 g/cm^3$

$d = 0.07 cm$

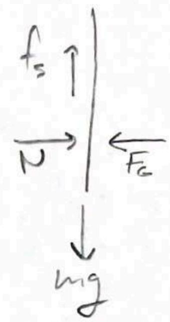
$h = 6 cm$

$m = \rho \cdot V$

$= \rho \cdot \pi r^2 h$

$= 2.2 \pi \left(\frac{0.07cm}{2}\right)^2 (6cm)$

$= 0.0506 g$



$\sum F_y = 0$

$f_s = mg$

$\mu_s = 0.1$

$f_s = N\mu_s$

$N\mu_s = mg$

$F_G = N = \frac{mg}{\mu_s} = \frac{(0.0506 \times 10^{-3})(9.81)}{0.1}$

$= \boxed{4.96 \times 10^{-3} N}$

$\sum F_x = 0$

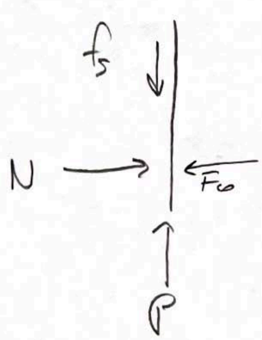
$N - F_G = 0$

$F_G = N$

When writing:

FBD of Graphite in the Pencil

$P = 1.4 N$



$\sum F_y = 0$

$P - f_s = 0$

$f_s = P$

$N\mu_s = P$

$F_G = N = \frac{P}{\mu_s} = \frac{1.4}{0.1} = \boxed{14 N}$

$\sum F_x = \emptyset$

$N - F_G = 0$

$F_G = N$

Gripping Force of Chuck per Unit of Contact Area

Chuck length:

$l_c = 1.35\text{cm}$

Graphite radius:

$r_G = 0.035\text{cm}$

Contact Area:

$$A = 2\pi r_G l_c$$
$$= 2\pi(0.035)(1.35)$$
$$= 0.29688\text{cm}^2$$

When Graphite is Suspended:

$$F/A = \frac{(4.96 \times 10^{-3})}{0.29688} = \boxed{0.0167\ \text{N/cm}^2}$$

When Mechanical Pencil is in Use:

$$F/A = \frac{14}{0.29688} = \boxed{47.157\ \text{N/cm}^2}$$

Conclusion:

Through our study of the Mechanical Pencil, we uncovered the distinct efficiency of this machine; every component has its purpose. As an example, the Chuck needs support from everything to the Chuck Ring to achieve stagnation, to the Lead Advancing Unit to achieve dispensation. Moreover, our study led us to not only discover the functions of Mechanical Pencils but the importance of components like the Chuck, its interactions with the graphite being the focus of our static analysis.

Through which we found that 0.0167 N/cm^2 are necessary to hold the graphite in place when the pencil is not in use and 10.105 N/cm^2 when it is. However, we recognize the limitations of our findings as, expectedly, our assumptions are blatant potential sources of inaccuracy. Namely, we could not precisely determine the writing force and the coefficient of friction between the graphite and the chuck, which may have resulted in some margin of error.

Resources:

- https://www.youtube.com/watch?v=bGe2CV2_QLE
- https://pmc.ncbi.nlm.nih.gov/articles/PMC6110209/#:~:text=Previous%20studies%20have%20reported%20that,1.7%20N1%2C%202).
- https://hypertextbook.com/facts/2004/NinaChen.shtml#:~:text=There%20are%20generally%20two%20types,the%20tire%20of%20the%20car.
- https://www.emachineshop.com/coefficient-of-friction/