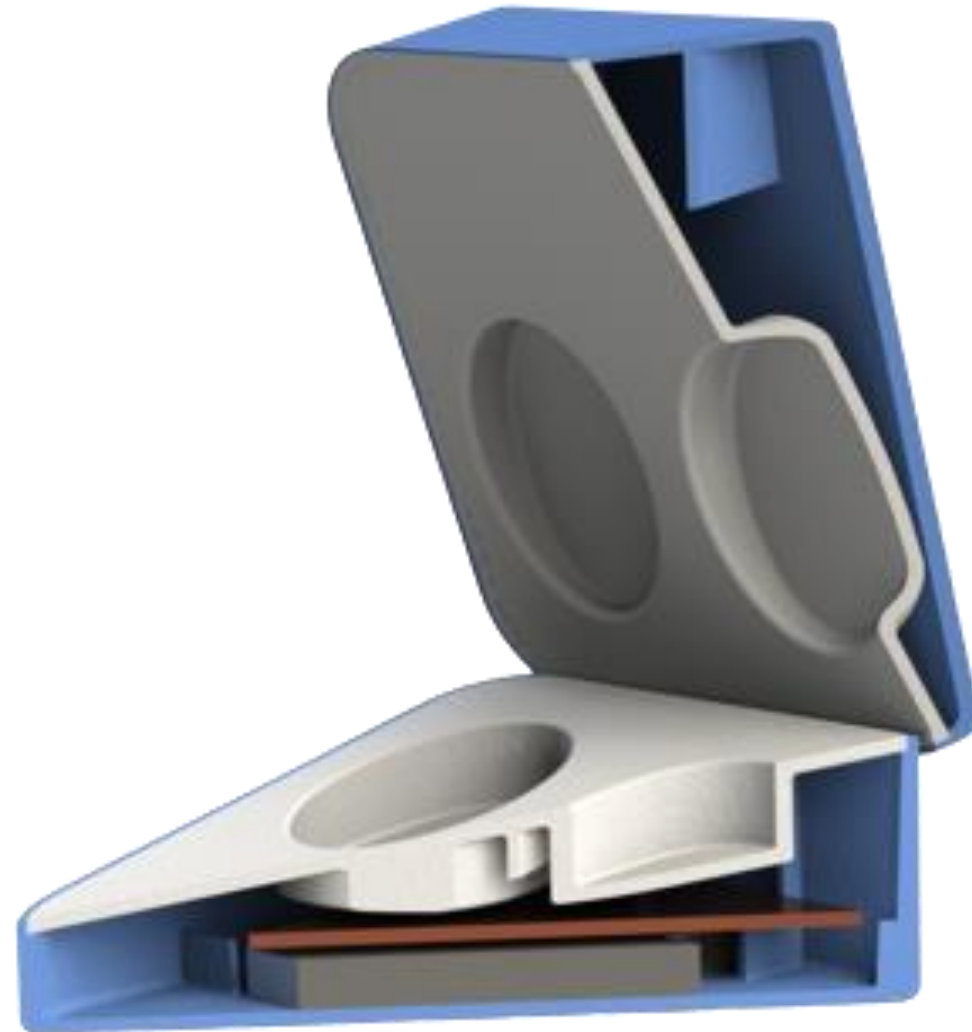


PD4044 – DESIGN FOR DFM

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Week 7 – Research, Breakdown & User Needs

What is injection moulding?

Injection moulding is a manufacturing process that allows for parts to be produced in large volumes. It works by injecting molten materials into a mould (or 'mold' in the United States). It is typically used as a mass production process to manufacture thousands of identical items.

The initial cost of production for the mold is the most expensive cost in the injection-moulding process. This is due to the high level of expertise required to design and manufacture a high-quality mold that can accurately produce parts.

It's main advantages over other processes are;

- It's allowance for complex geometries with very tight tolerances
- High repeatability and efficiency – takes only a few seconds for a part to be fully manufactured compared to 3D printers/CNC machines that can take hours.
- Reuses and reduces material waste much more than any other processes.
- Compatibility with loads of different materials and colours like thermoplastics, thermosets, resins and silicones.

What should I know?

Injection moulded parts must be designed with the proper draft, wall thickness, radii and other complications.

The typical part usually have two distinct sides: The 'Front' has better visual appearance along with the faces being smooth or having a texture according to your design specifications. The other side contains the hidden structural elements of the part (the bosses, ribs, snap-fits and so on). This side will often have a rougher finish and visible marks from the ejector pins.

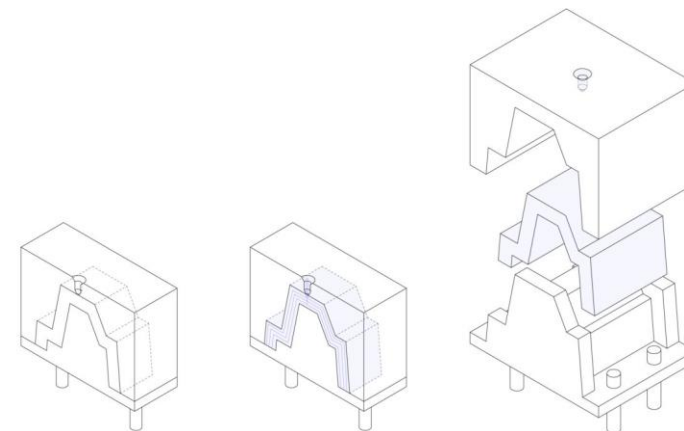
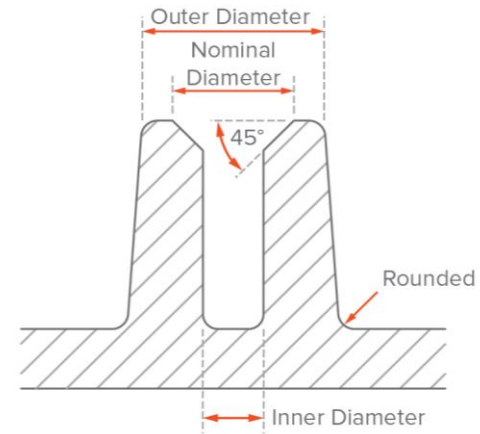


Diagram demonstrating how an injection mould operates.

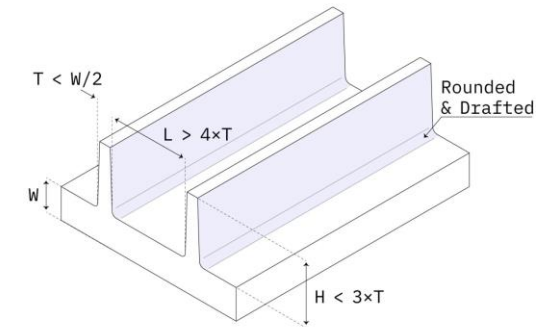
Common design features?

Design features can help add functionality to your design while still complying with standards.

- Threaded Fasteners – ways to add fasteners to my design so the product is secure and functioning can be done through bosses which function as point for attachment. It is vital that I support these with ribs or connect them to the main wall.
- Ribs can improve the stiffness of my part if even the recommended wall thickness is not enough to meet functional requirements of my object.



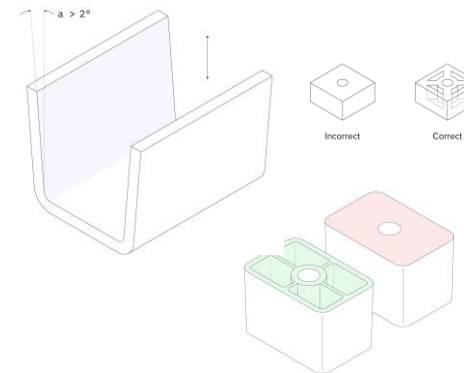
Recommended design for a boss.



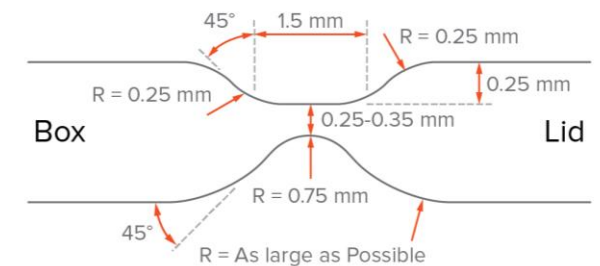
Recommended design for ribs..

Design rules?

- Using a uniform wall thickness is vital along with avoiding thicker sections as non-uniform walls can lead to warping as only a part of the material cools down.
- Getting rid of thick sections by hollowing that part out so that no defects occur like sinking, using ribs instead will design structures of equal stiffness and strength.
- Round all edges and add smooth transitions as the uniform wall thickness limitation applies to this as well.
- Adding draft angles so the mould does not leave marks on the surface due to high friction occurring during the process.



Design rules of an injection moulded part.



Recommended design for a living hinge.

Brand selection?



Apple.



Samsung.



Sony.



Beats..



Google Pixel.



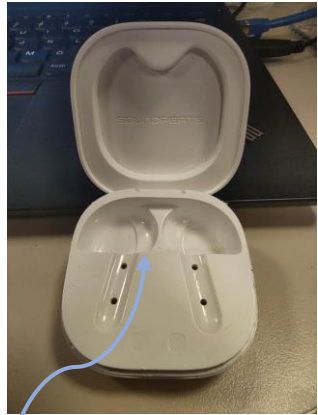
Sennheiser.

In order to not limit myself to a specific brand image, I researched and found that I will go with Samsung for my aesthetic as they have many different and distinguishable designs. This means I will use one of their earphone models to model my case for.

Material selection?

Material	Recommended wall thickness [mm]	Recommended wall thickness [inches]
Polypropylene (PP)	0.8 - 3.8 mm	0.03" - 0.15"
ABS	1.2 - 3.5 mm	0.045" - 0.14"
Polyethylene (PE)	0.8 - 3.0 mm	0.03" - 0.12"
Polystyrene (PS)	1.0 - 4.0 mm	0.04" - 0.155"
Polyurethane (PUR)	2.0 - 20.0 mm	0.08" - 0.785"
Nylon (PA 6)	0.8 - 3.0 mm	0.03" - 0.12"
Polycarbonate (PC)	1.0 - 4.0 mm	0.04" - 0.16"
PC/ABS	1.2 - 3.5 mm	0.045" - 0.14"
POM (Delrin)	0.8 - 3.0 mm	0.03" - 0.12"
PEEK	1.0 - 3.0 mm	0.04" - 0.12"
Silicone	1.0 - 10.0 mm	0.04" - 0.40"

Evaluation of Different Earphone Cases



PART DESIGN

The upfront side of the mould that houses the earbuds is simple and minimal.

PART DESIGN

This casing consists of three parts and has a bubbly exterior I really like.



AUDIO

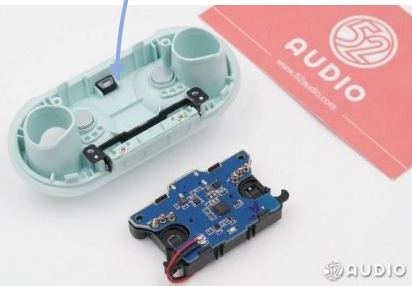


MOULD

Underside of the mould with wiring and the functional side of the mould where the features are showing.

PART DESIGN

This specific case consists of three components (without the electrical devices) which are the; Lid, main case and earbud housing. In my opinion this is a clean and simple design.



AUDIO

MOULD
Uniform thickness presented throughout the mould, Along with visible ribs and bosses.

PART DESIGN

This design has four sections as one has a casing that houses most of the electrical components.



MOULD

Housing slots into the casing using ridges.

PART DESIGN

Indentations for the battery in the main case.



AUDIO



oicua

MOULD

Small ridges holding motherboard in place and the housing for buds clicks into the design.

PART DESIGN

Simple three part assembly that is fully functional.

MOULD

Steel ring that holds the frame together instead of ridges



PART DESIGN

Lots of additional parts that give it its quality over competitors.

MOULD

Underside of the injection mould shows imperfections.

Evaluation of Different Earphone Cases



PART DESIGN

Magnets are put onto this specific case to assist with its closing mechanism.

PART DESIGN

Other magnets are used for the positioning of the earbuds themselves into the mould.



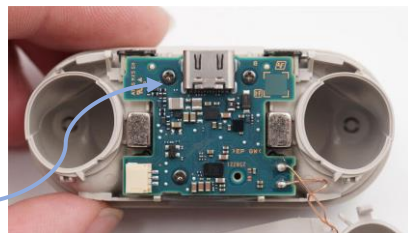
MOULD

The lid and housing for earbuds is one piece as the piece has a living hinge between them.



PART DESIGN

Battery is connected through a connector like this one.

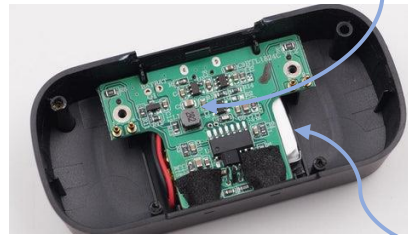


MOULD

This motherboard is fixed in place with multiple screws to the mould.

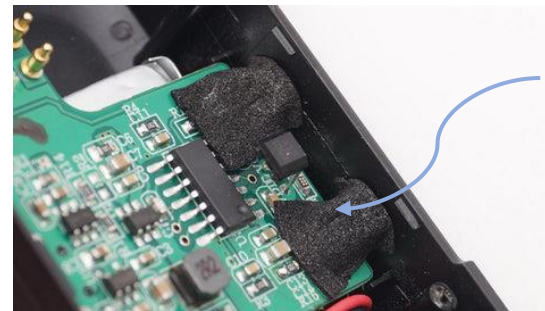
MOULD

Motherboard and battery housed right under each other using clips from the mould.



MOULD

Battery has a sponge on the other side and is attached to the mould.

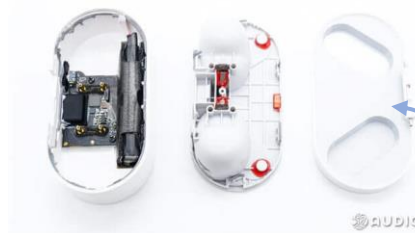


PART DESIGN

Two LED lights that are shaded with a sponge.

MOULD

Very basic mould with text on the inside showing manufacturer created during the moulding process.

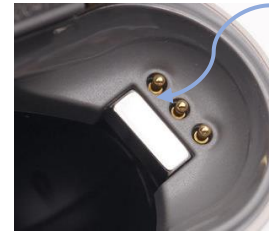


MOULD

Three component disassembly with the hinge form on the top face. Can also see all the moulding details on the middle face.

PART DESIGN

Three POP thimbles that charge the earbuds extrude into the housing.



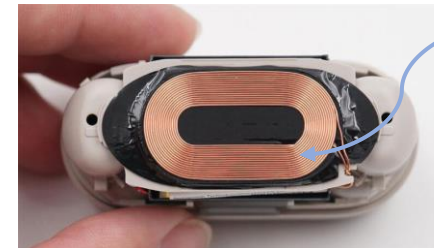
MOULD

Plastic rib that covers the motherboard, the lithium battery is also at the bottom.



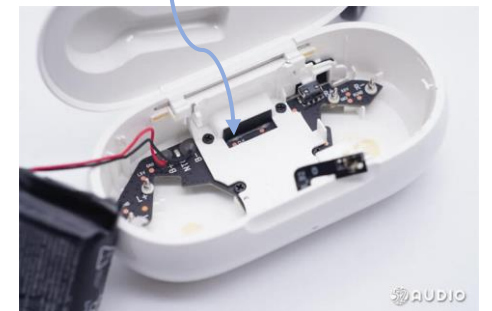
PART DESIGN

This is a wireless charger receiving coil on the bottom of a case.



PART DESIGN

Motherboard is fixed under the bracket in this case, battery is on the top.



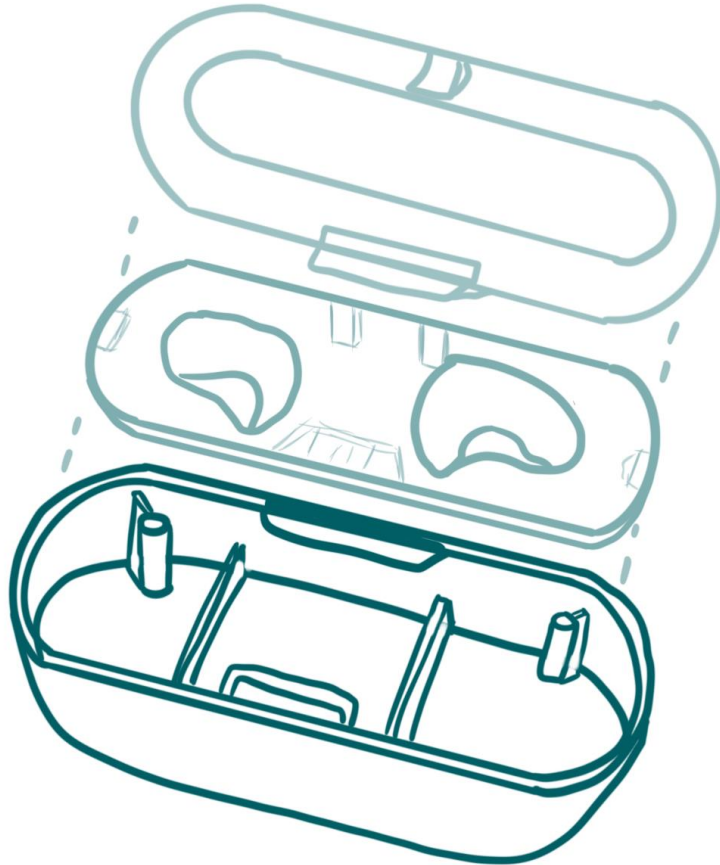
What Do I Need To Take Into Account?

- Choosing the right material - a material for the earbud case should have good dimensional stability along with tensile strength, surface rigidity and abrasion resistance. Most of all –be used for injection moulding.
- Part Tolerance - Tight tolerances increase the cost of production, but they may be required for your part to fit or function properly, especially if it is used in an assembly.
- Wall Thickness - Thinner walls reduce cycle time and reduce the cost of your part. A wall thickness of 1.5-2.5 mm is enough for many applications, but you can also refer to recommended wall thicknesses for different materials. Injection moulded parts should have consistent wall thickness. A sink mark will appear if a part is thicker in one section than another. This can also cause warping because the different thicknesses cool and shrink at different rates.
- DFM Features: Draft Angles, Ribs, fillets that I discussed earlier in my research.
- Gating: To properly design and manufacture your part using injection molding, the manufacturer must first understand what your requirements are in terms of its appearance. The gate location is an important consideration for the tool maker. Gates are entry sections that allow molten material to enter the mold.



Injection mold for an earbud case.

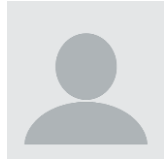
Earphone Case – My Main Takeaways



- Electrical components are located and secured in the bottom part of the case, which also houses the frame for the earbuds – an interference fit/snap fit is used to secure them in the case and make a seamless transition. The pin for the hinge and battery etc. will be the only thing not injection moulded. The shape can be anything as long as everything else is secure. The motherboard, battery, LED's and charging port are the components.
- The frame houses the earbuds, magnets are often used to put the earbuds in the correct place and the charging stilts that connect the earbuds to the battery.
- The cover for the casing operates on either a hinge or by sliding and is often closed securely by smaller magnets.

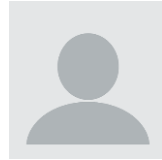
Key Highlights from Interviews

**Users identities remained anonymous besides the approx. age.*



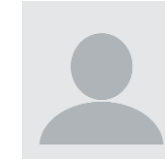
Anonymous
~ 22

- Enjoys the convenience of their portability and there being no wires.
- Headphones have been tangled in their hair before, so they prefer earphones.
- Prioritizes sound quality even at an expense.



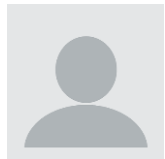
Anonymous
~ 19

- Prefers the least possible amount of touch controls on the product.
- Likes a case that doesn't have friction to slide in and out of pocket easily.
- Strong magnets are a must.



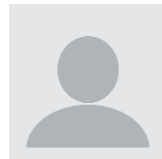
Anonymous
~ 20

- Finds that the case is sometimes too hard to get a grip on it to open.
- Case isn't entirely smooth and they sometimes confuse then opening for the hinge.
- Good battery capacity is necessary for them.



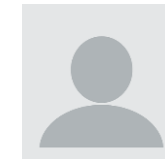
Anonymous
~ 43

- They value protection of the actual earphones and like a durable case.
- Prefer a hygienic case where wax won't build up.
- A durable product is a must for them.



Anonymous
~ 44

- Like something that's cute and aesthetic.
- Don't mind having cheaper items as long as there is some quality.
- Prefer something that they can't accidentally knock over.



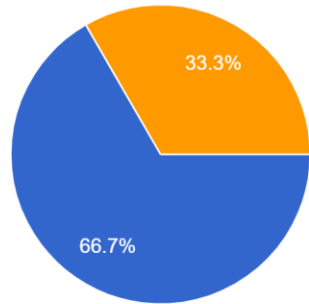
Anonymous
~ 19

- Enjoys a durable product with an extra protective cover around it.
- Likes something that doesn't get scratched easily and ruins the aesthetic.
- Sleek and minimalistic is their style.

Questionnaire

I made a Google Form and sent it around to group chats and people I knew to see if they could identify some user needs/experiences I should account for.

Do you use wireless earbuds?

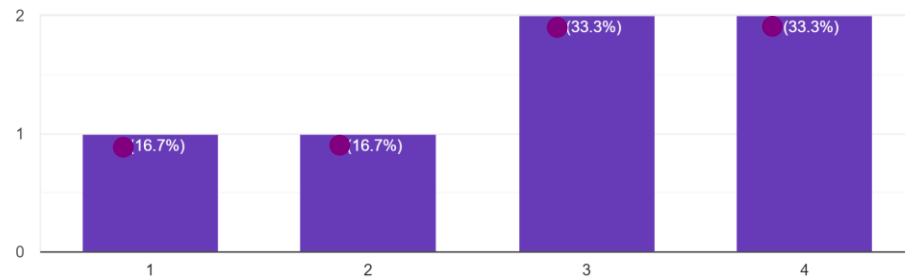


- Yes
- No
- I used to have some/planning on buying them.

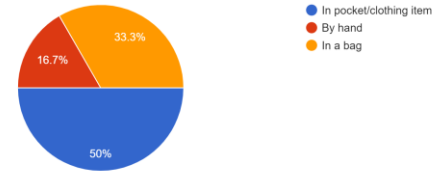
What features would you like to see in an earbud case specifically designed for sports use?

- it being durable and easy to hold
- it not falling out of my pocket
- i would like to see it not breaking or chipping
- being easy to open
- it not falling out of what I'm wearing
- being easily stored

How important is the portability of the earbud case to you?



What is your preferred method of carrying your wireless earbud case?

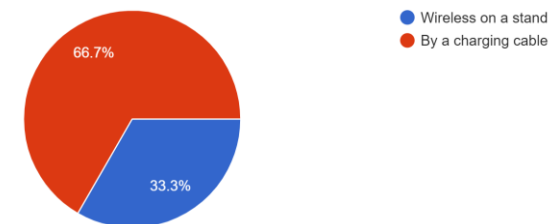


- In pocket/clothing item
- By hand
- In a bag

Have you experienced any issues with your current earbud case? If so, what were they?

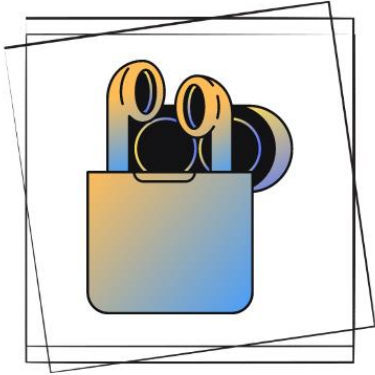
- They slip out of my hand sometimes
- they go out of battery really quickly
- It had trouble staying in my pocket
- it getting lost :(
- it getting dusty and dirty
- being hard to find in the dark i guess?

What is your preferred method of charging your wireless earbud case?

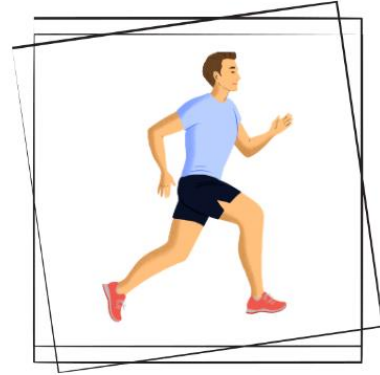


- Wireless on a stand
- By a charging cable

Design Story?



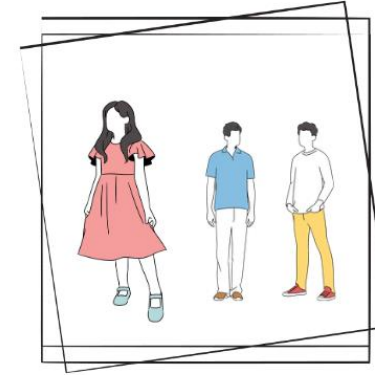
- User buys new earphones, they do a lot of exercise and go to the gym often.



- User runs a lot, they don't want the case to slip out of their pocket or be uncomfortable when they're trying to move with the object digging into them.



- User goes to the gym a lot, they want a durable case because they often throw things down on the floor.



- User prefers quick access to the earphones and noise cancellation in public places.

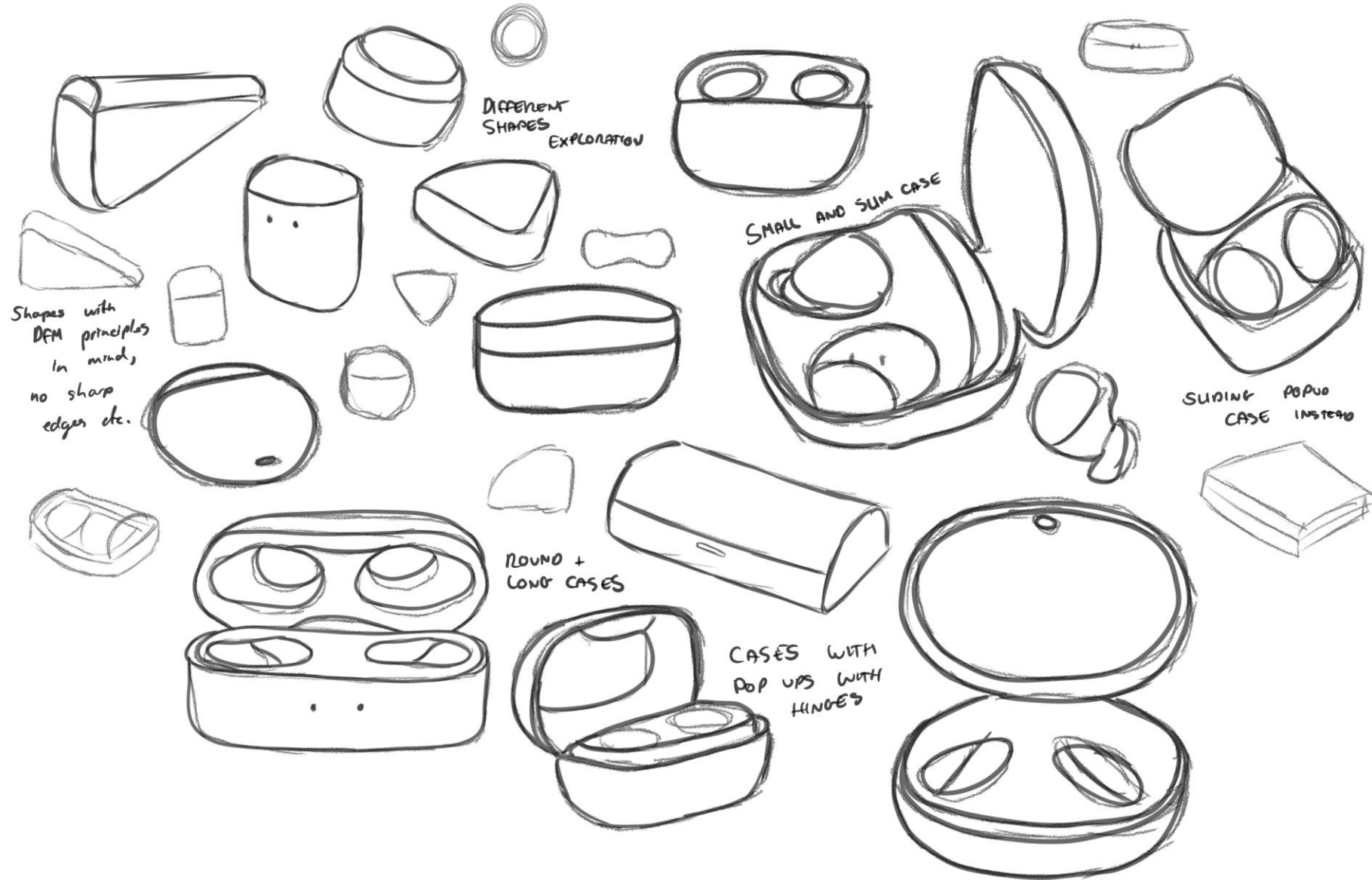
User Needs

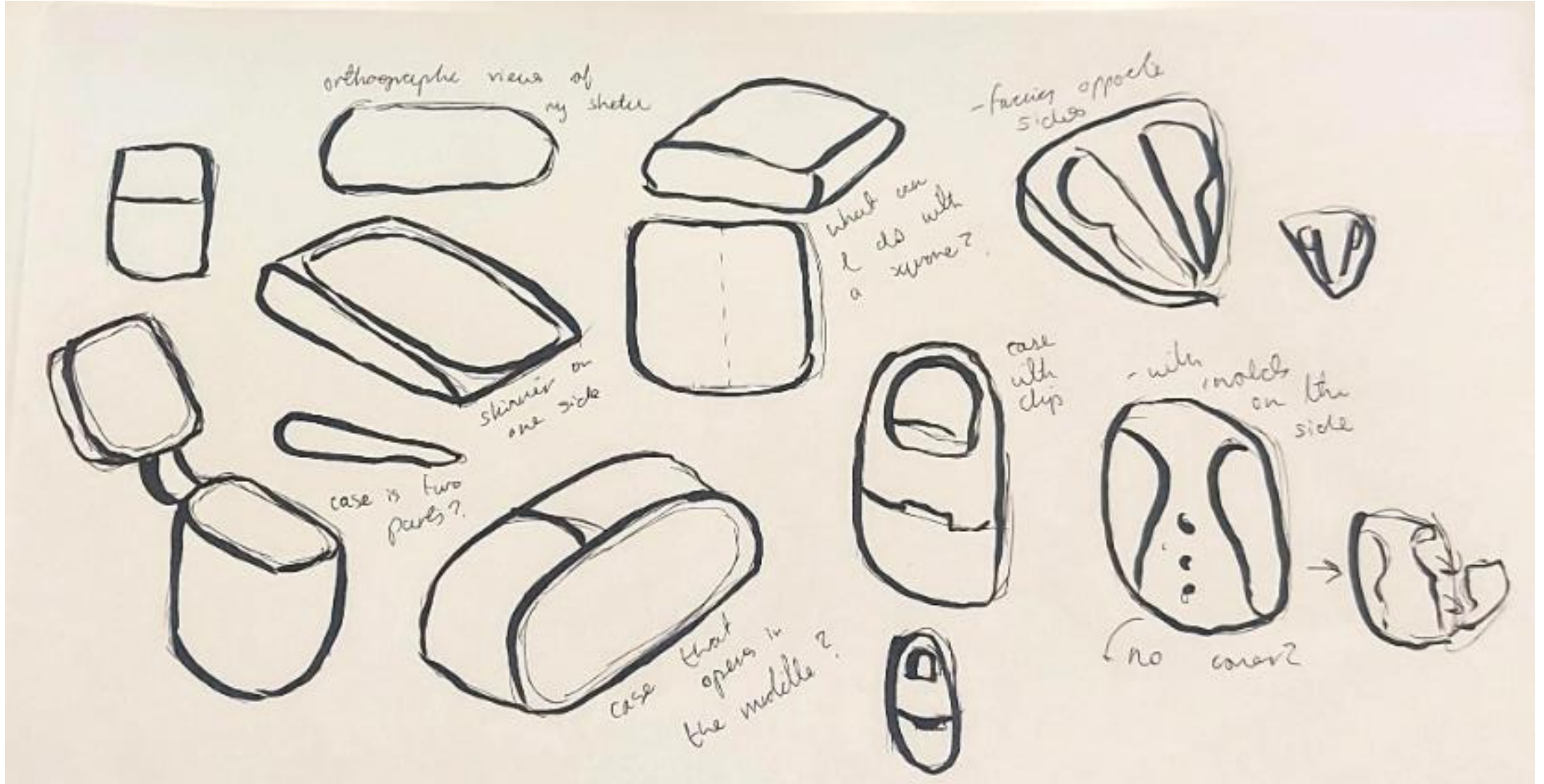
- A durable case that won't break and get worn out quickly.
- A hinge design that can be used countless without failure.
- A case that has enough friction so that it doesn't slide or be hard to grip.
- A feature where someone can pull the case open easily.
- An indication of which earbud goes into which ear.
- An indication for the battery percentage somewhere on the case.

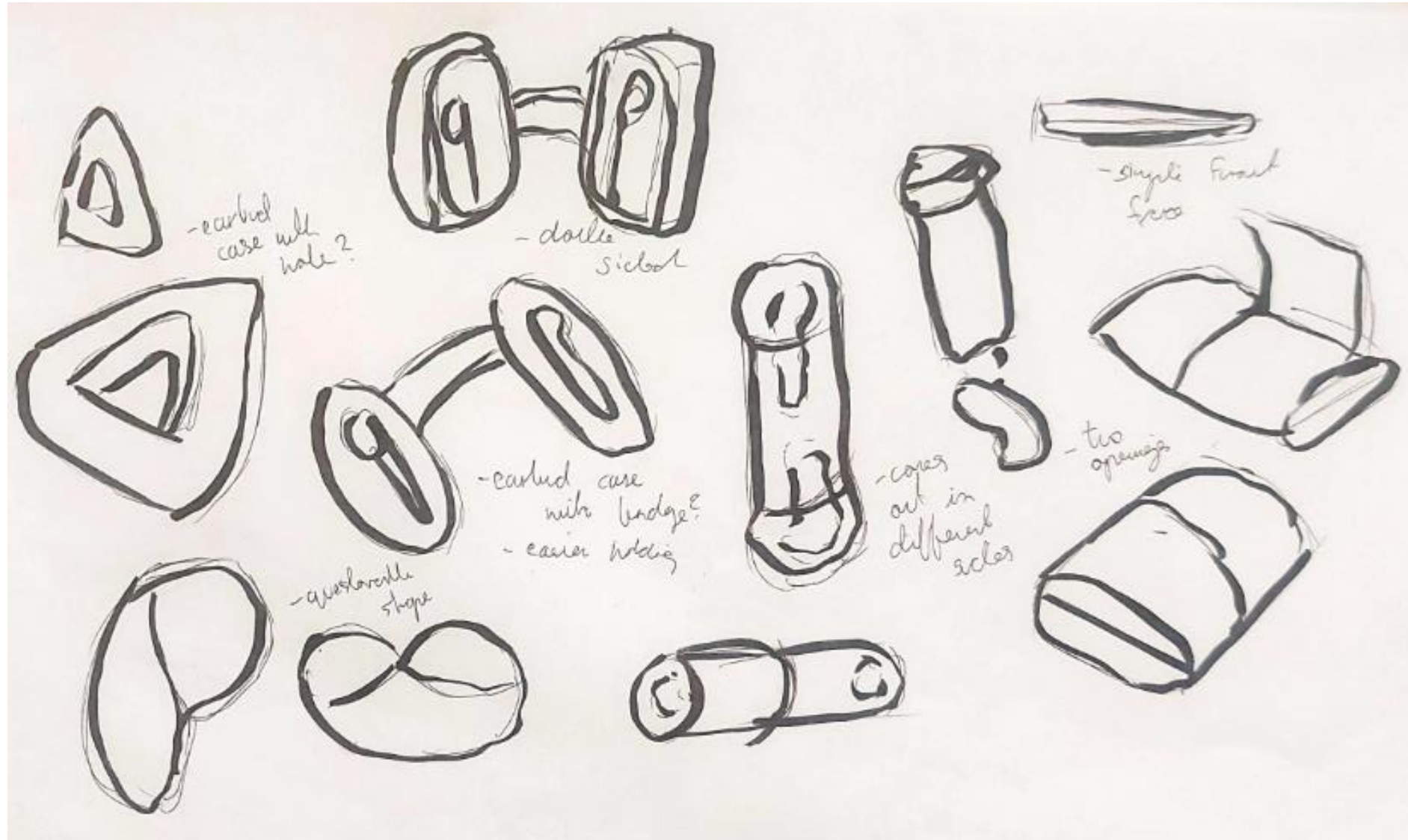
Design Guide:

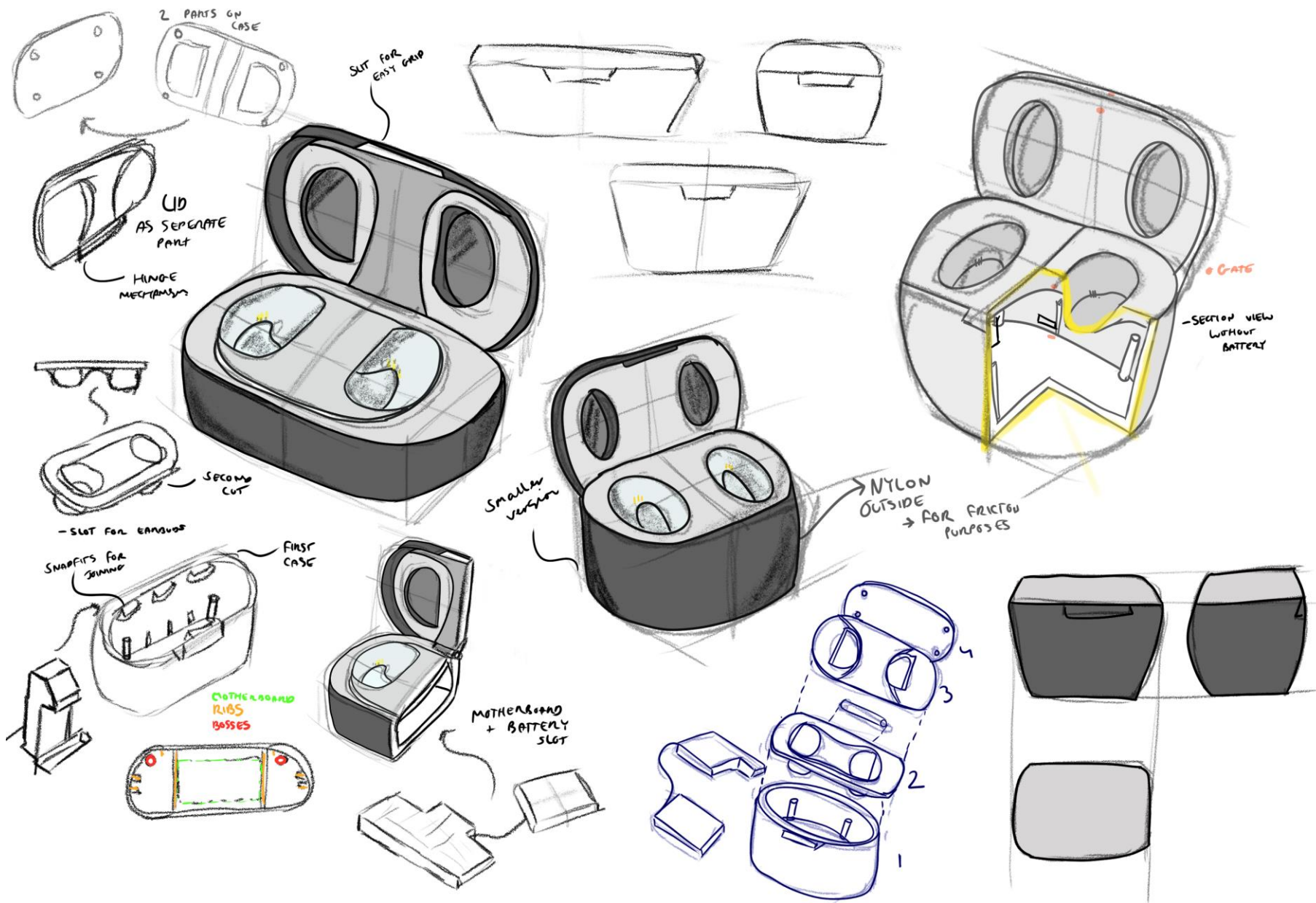
Designing the perfect gym earphone case, the case should be comfortable and snug fit in the pocket when carried around when someone is doing different activities. It should have enough friction to not slip out of any pockets but not too much as they can get caught on clothing and other things. Durability and protection of the earbuds is non-negotiable and has to be included.

Week 8 - Ideation & Concept Generation



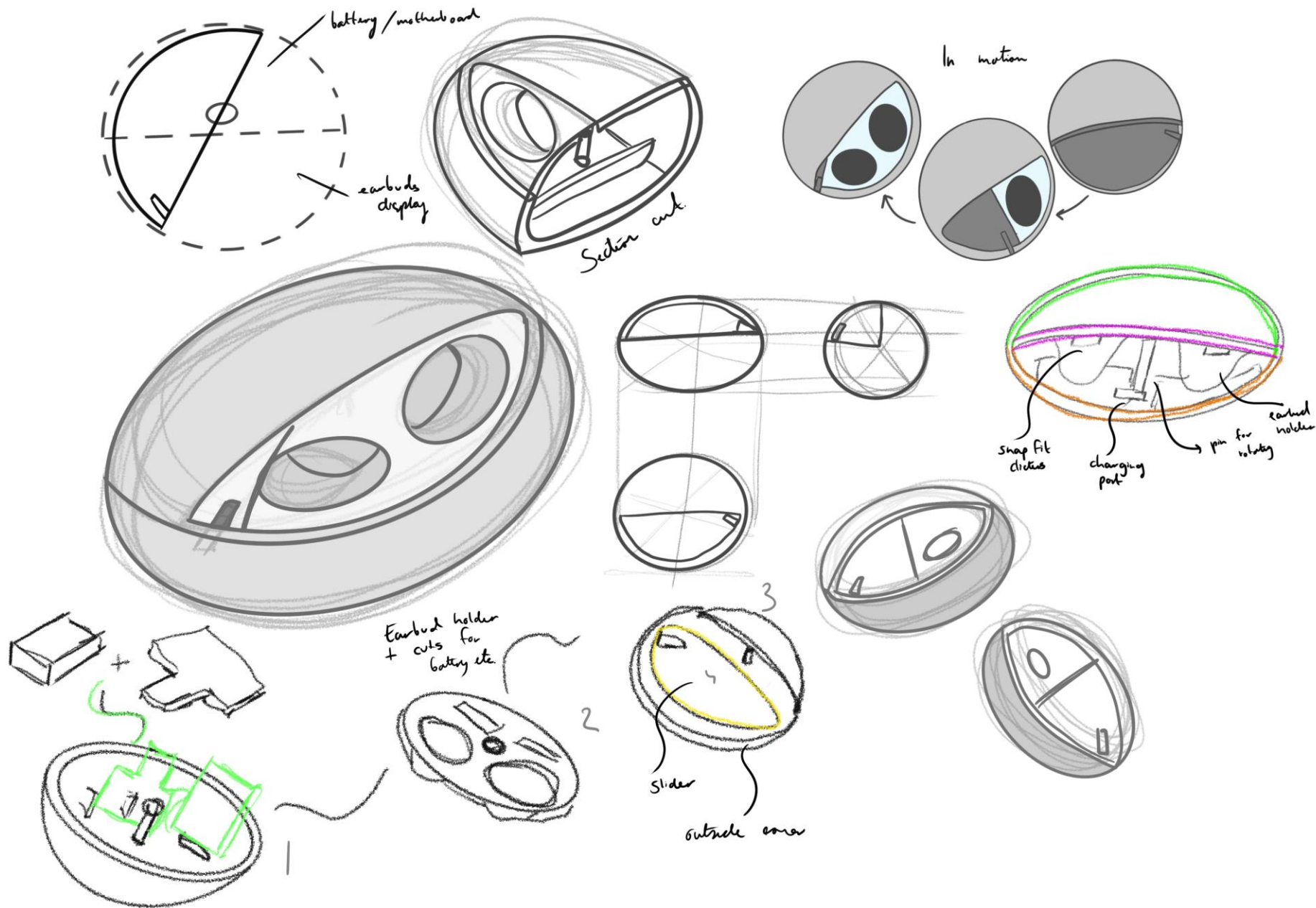






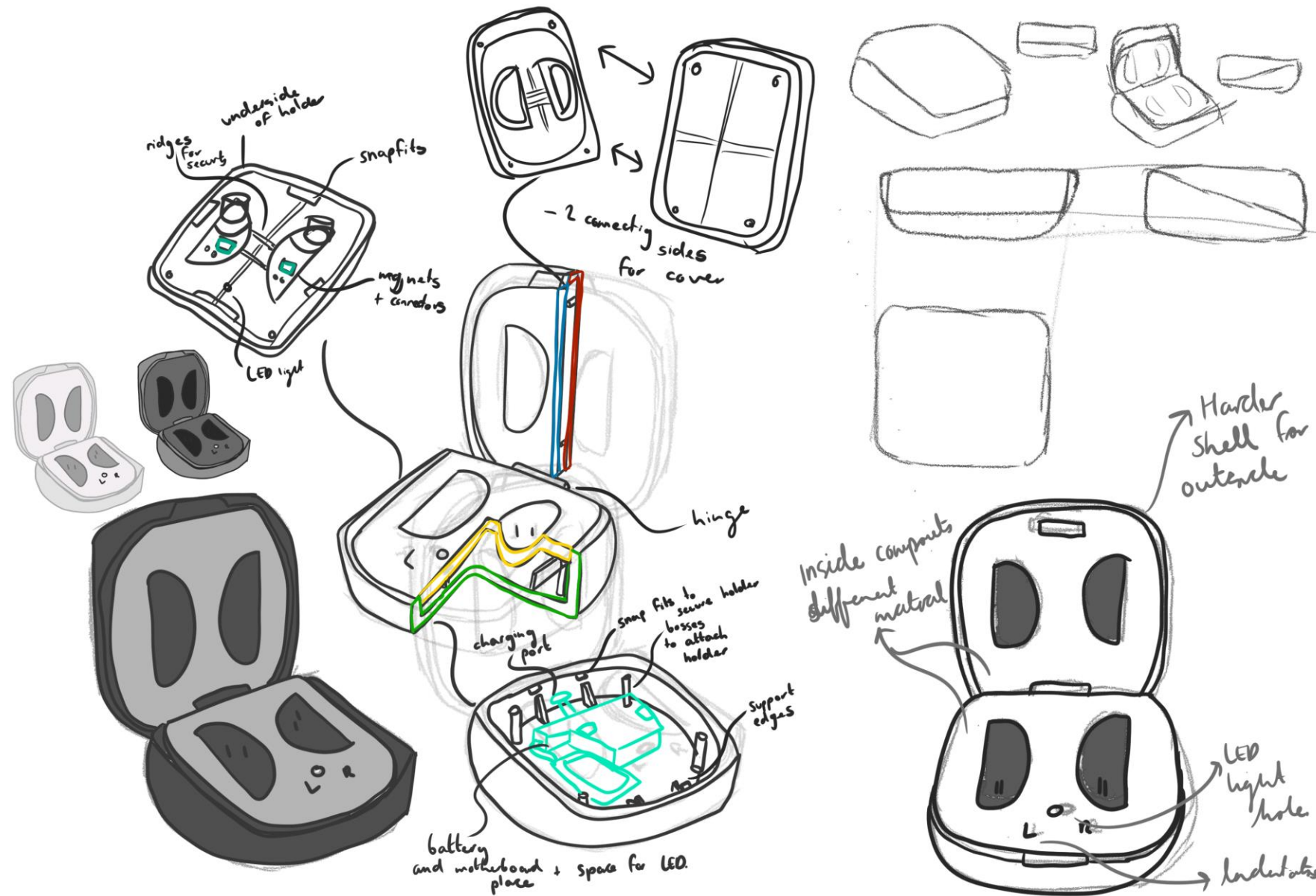
Concept 1

- Compact design
- Easy to open (magnets)
- More than three components
- A bit chunky
- Really plain



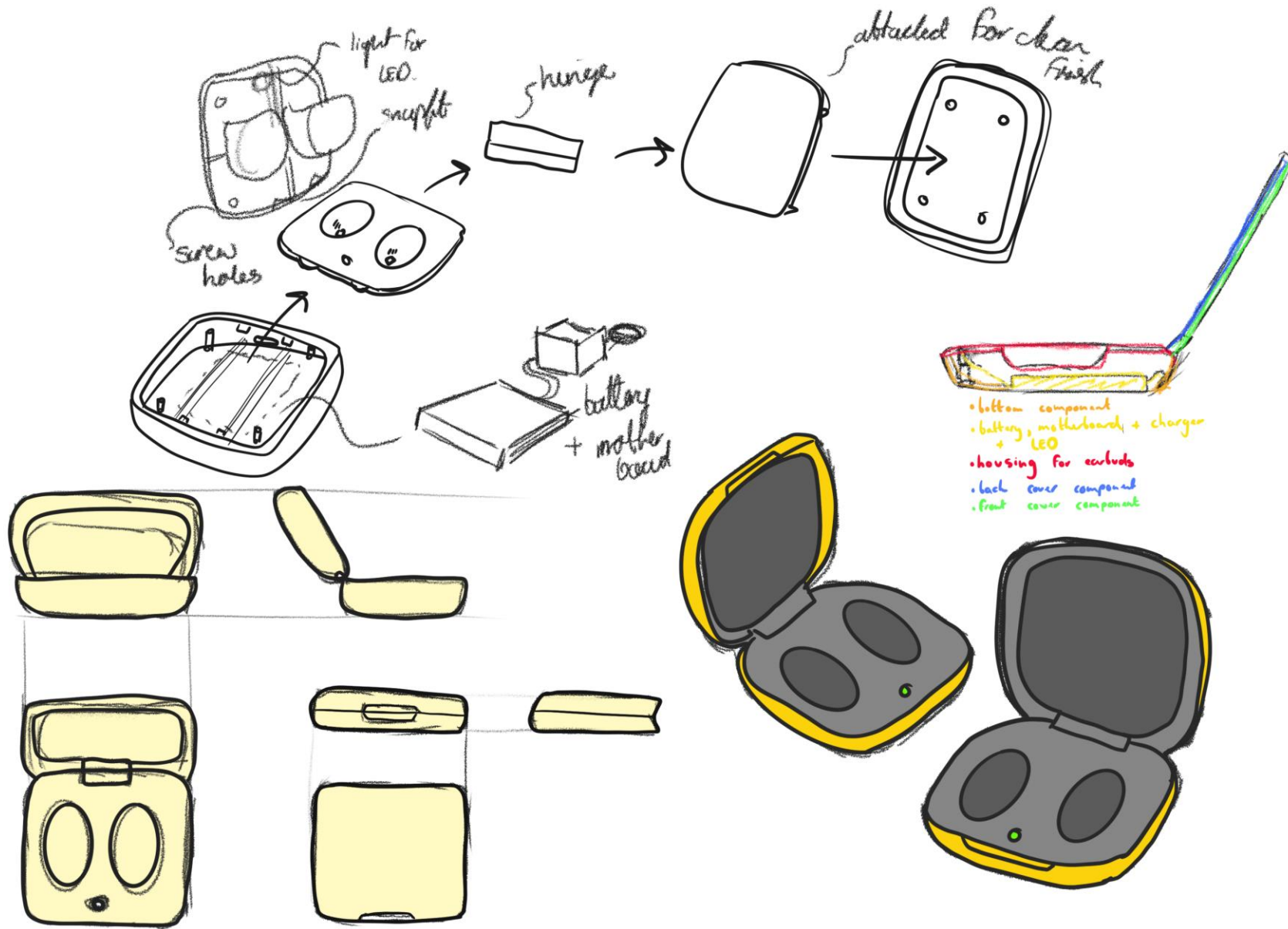
Concept 2

- Unique round design
- Slides instead of the typical hinge
- Hard to manufacture
- Space issue regarding electrical components
- Might have issue with friction



Concept 3

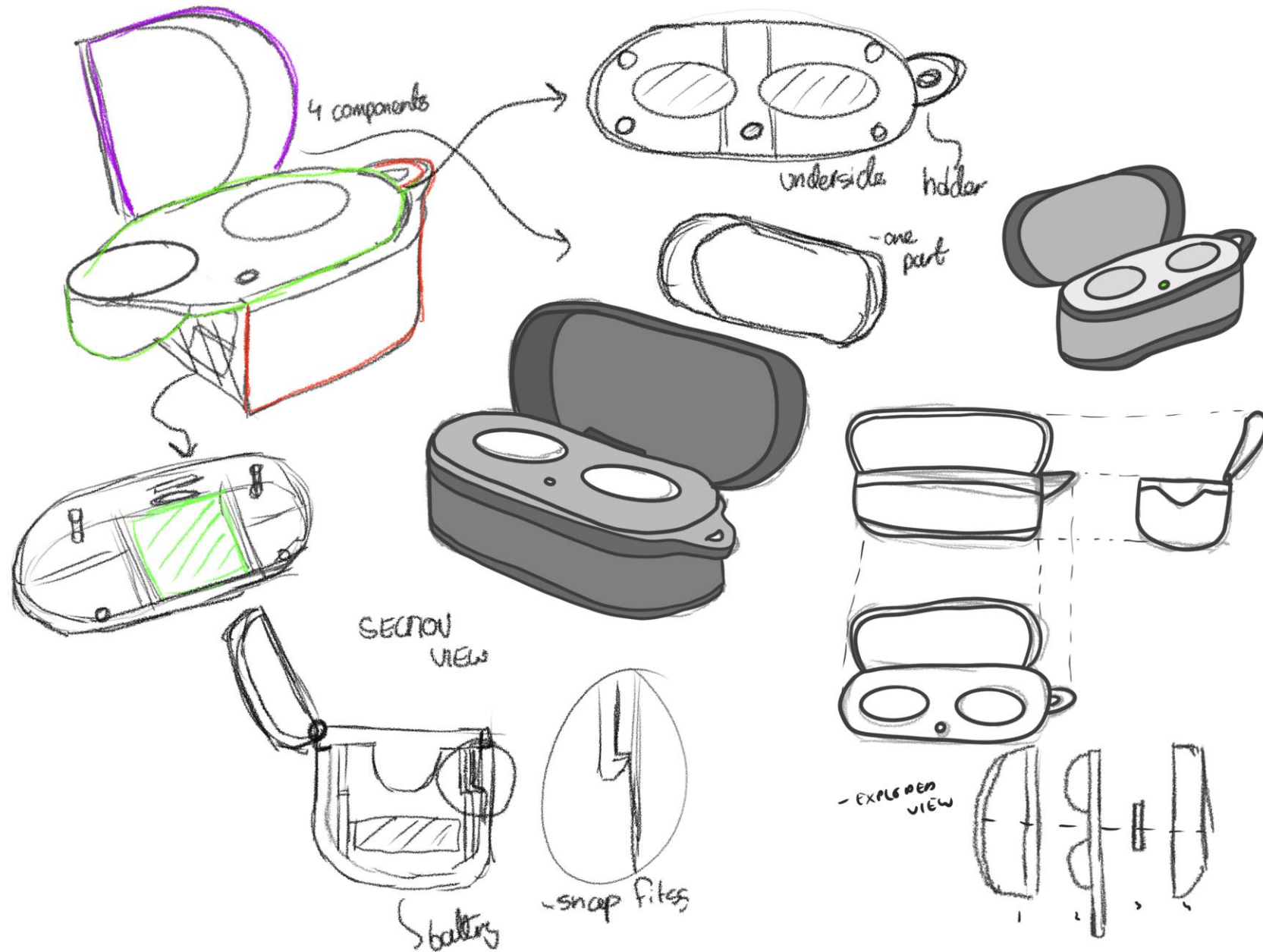
- Simple design yet has an appealing angled look
- LED light and left and right symbols are a nice addition
- Weight distribution could be wrong



Concept 4

- Very slim and appealing
- Easy to model

- Problem fitting components/not as powerful.
- Could have friction problems.

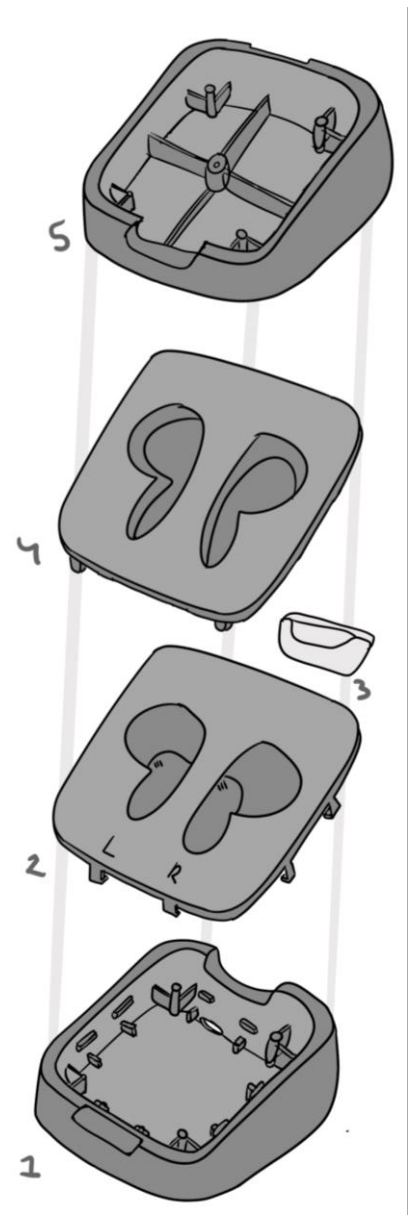
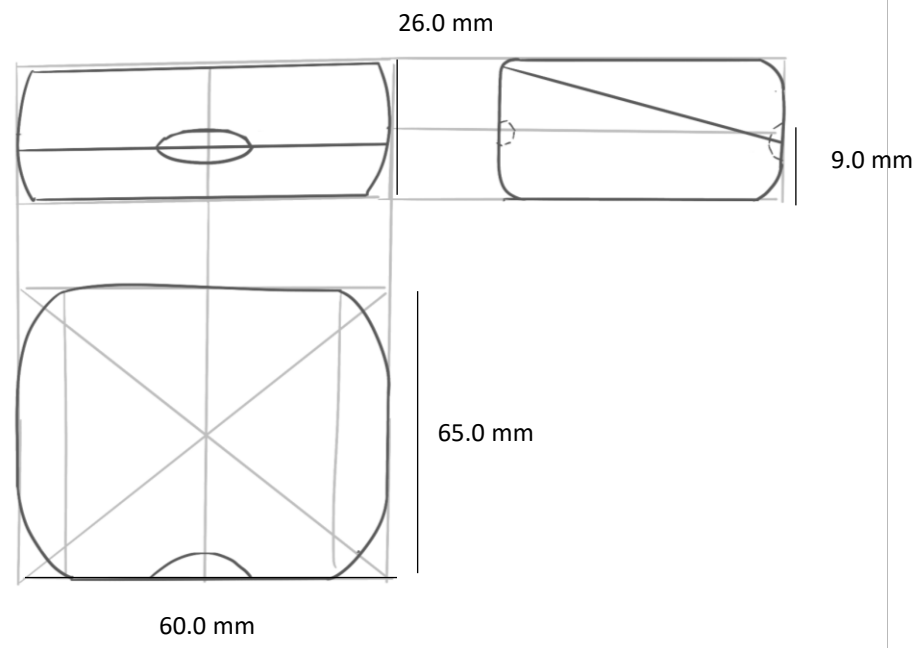
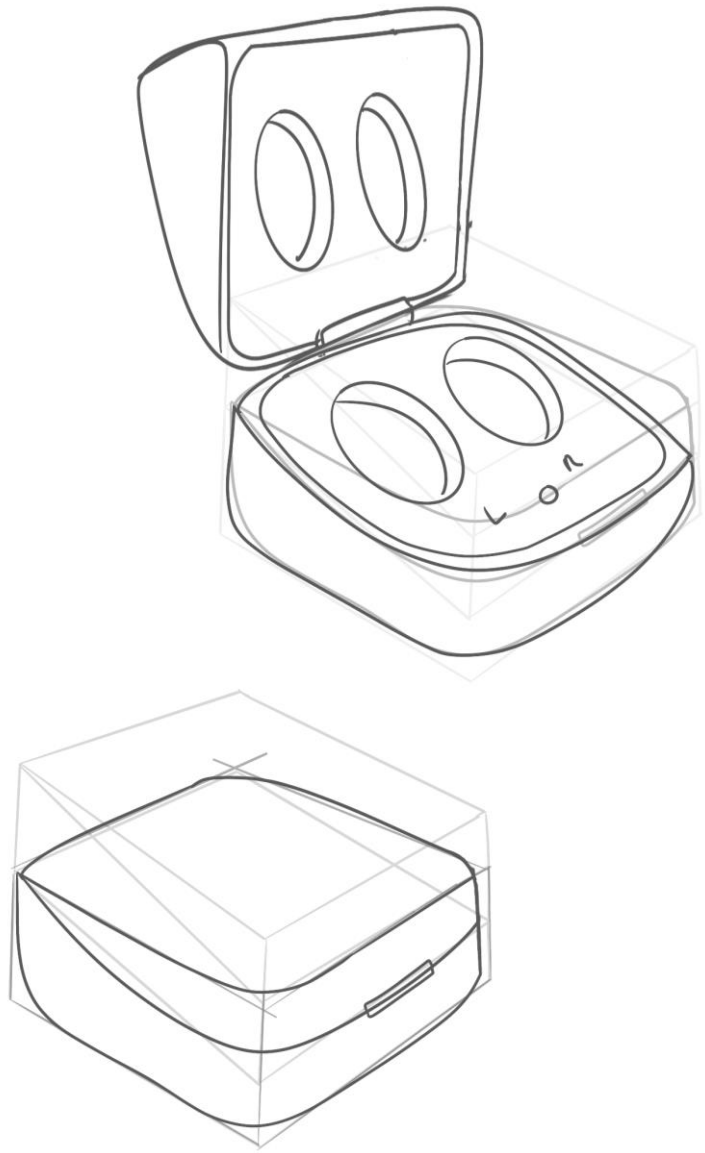


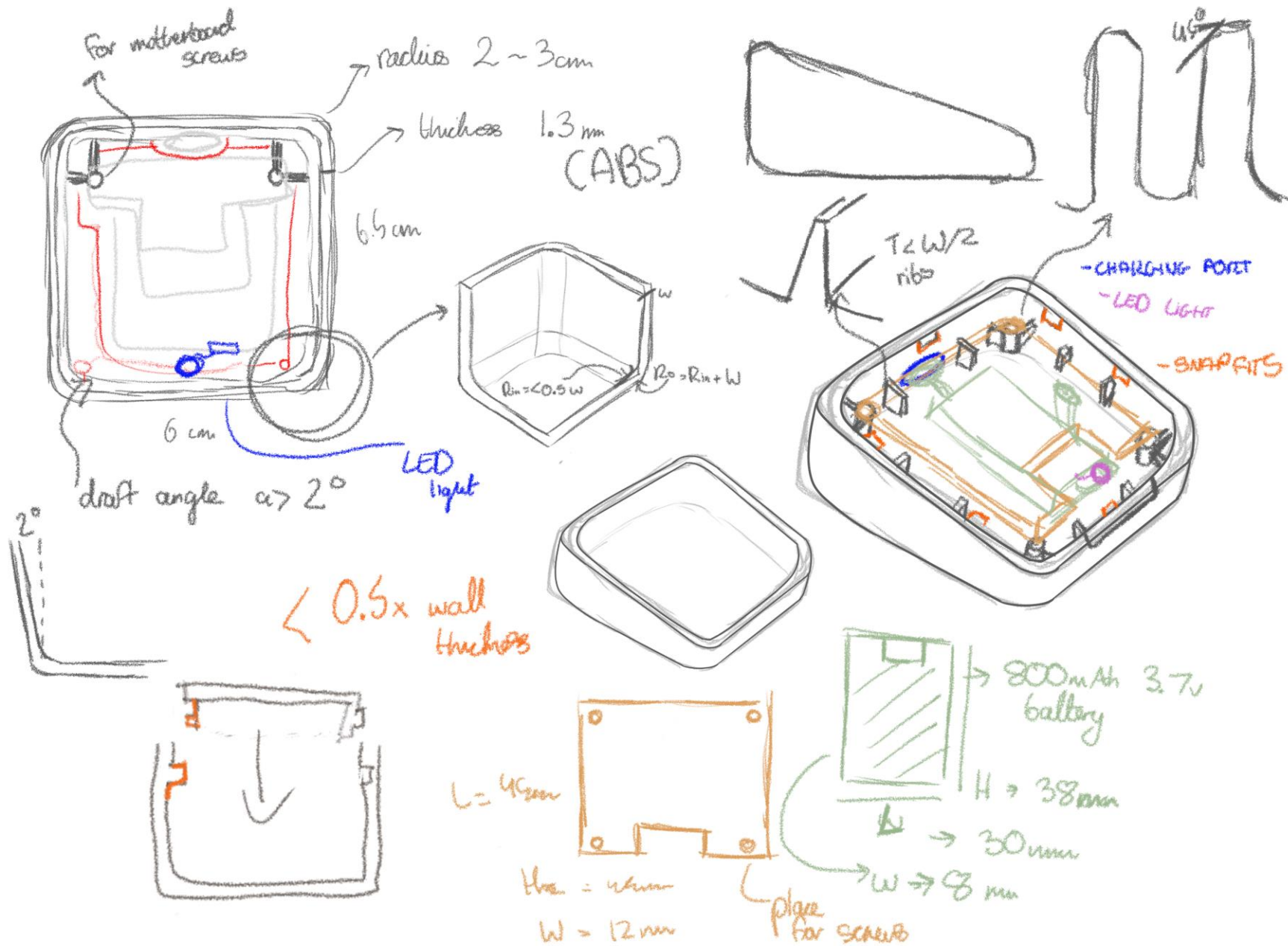
Concept 5

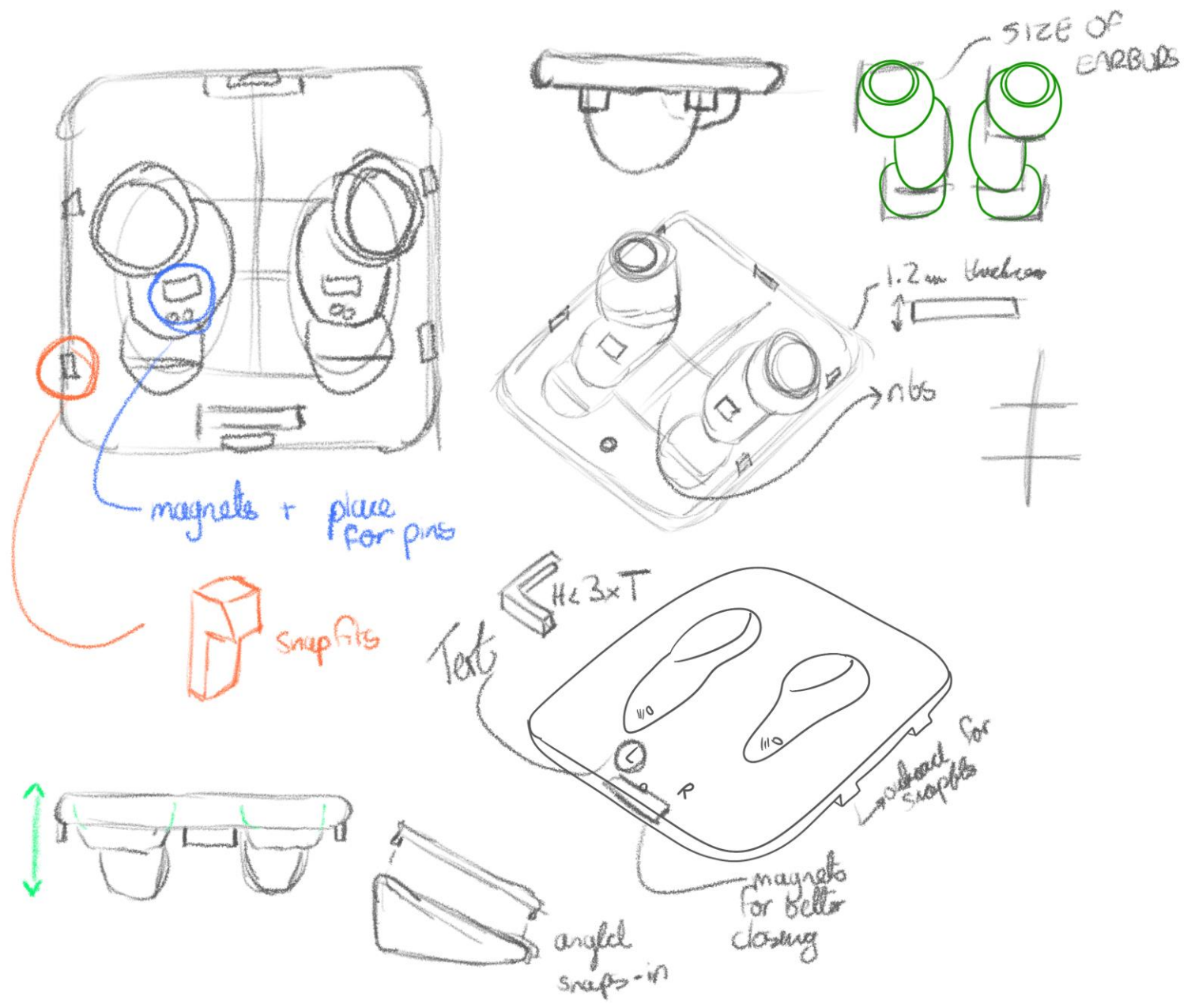
- Unique hook and clip for attaching earphones
- Seems chunky
- Basic form

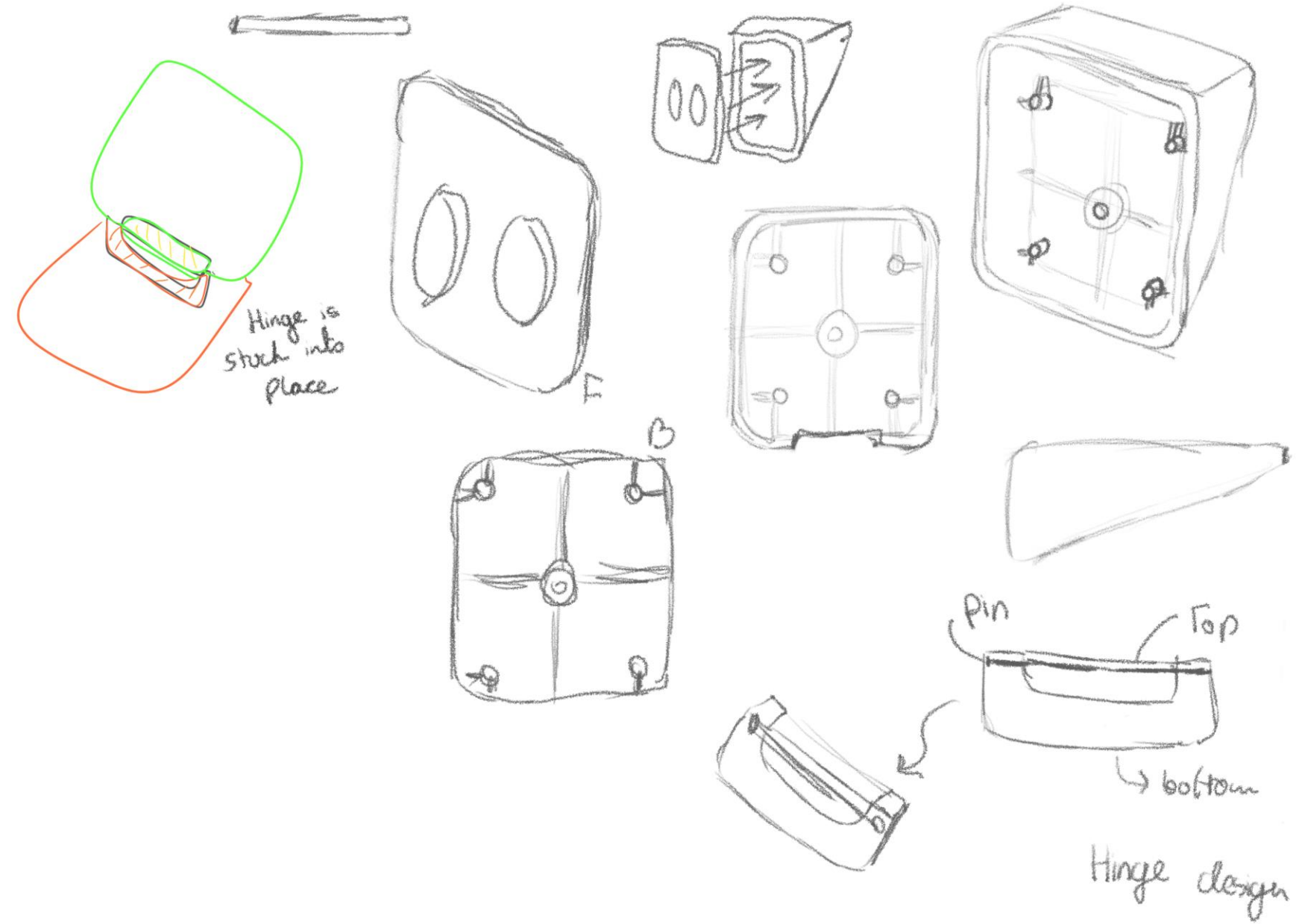
Week 9 – Finalisation of Concept

Chosen Concept









Bill Of Materials:

BASE – ABS
 BASE INSERT – ABS
 COVER INSERT – ABS
 COVER – ABS

ADDITIONAL:

-HINGE PIN – PLAIN CARBON
 STEEL
 -BATTERY
 -PCU
 -SCREWS

Process Cycle (Reiteration):

1. Clamping – Two halves of the mould to be securely closed by the clamping unit – exerting sufficient force when the material is being injected.
2. Feed pellets into the machine and inject from the bottom side of the parts at the gate.
3. Plastic cools – shrinking may occur if not enough additional material is injected, wait for the elapsed cooling time.
4. The cooled part is ejected from the mould.

End Of Life?

The thermoplastic ABS that I have chosen for my parts is a suitable option for recycling since it can be repeatedly melted and moulded without losing its characteristics.

In order to recycle ABS injection-moulded parts, the parts are normally broken down into tiny bits, melted, and then extruded into pellets. The creation of new items can then be done using these pellets.

Manufacturing Process Review:

Design the case on CAD software – taking into my consideration the DFM principles so that the product meets the desired functionality and aesthetic.

I should include:

Draft Angles

Bosses

Ribs

Core sides

gates

And I should specify:

Ejection Points

Material choice

Material finish

Undercuts

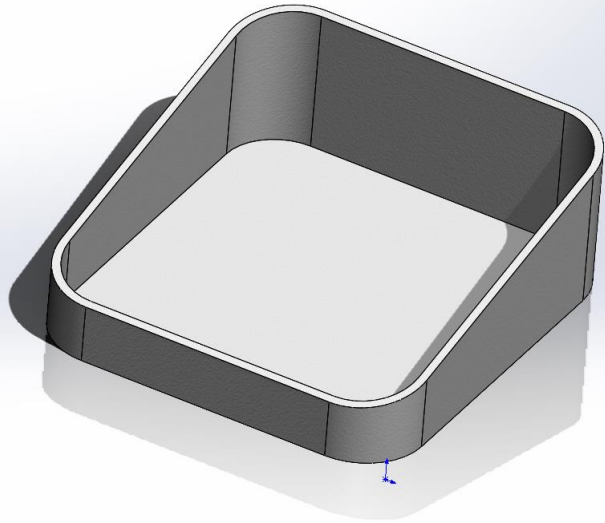
The elements of the earphone case should be to the right size and proportion that I specified along with allowing sufficient internal space for the configuration of elements.

Week 10 – DFM Workshop



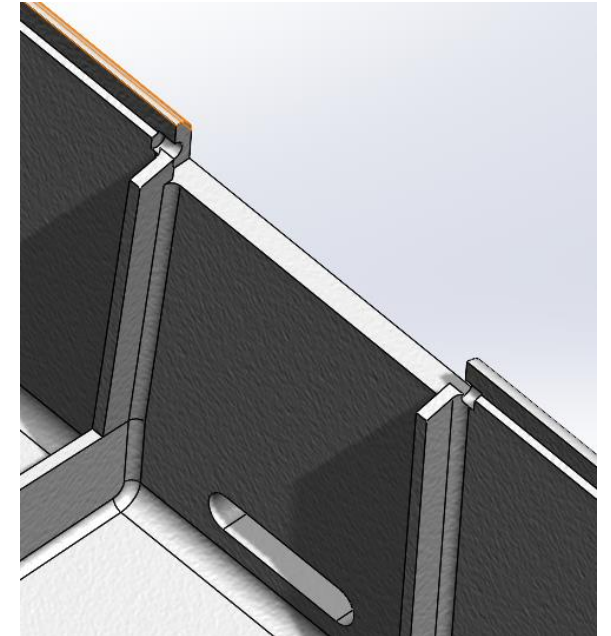
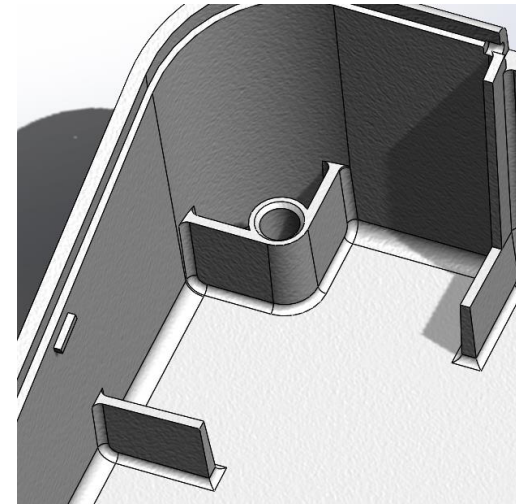
I made my model in 3D using foam provided in the workshops during Week 10. I feel that this helped my progress in my design and reinforce the design decisions that I made. The product was a bit bigger than I expected but I didn't think the proportions were out of place. I put it in my hand, pocket, bag etc. To see if the dimensions of it were realistic and after my experimentation I decided to go with the sizing that it was.

Week 11 – Develop CAD Database

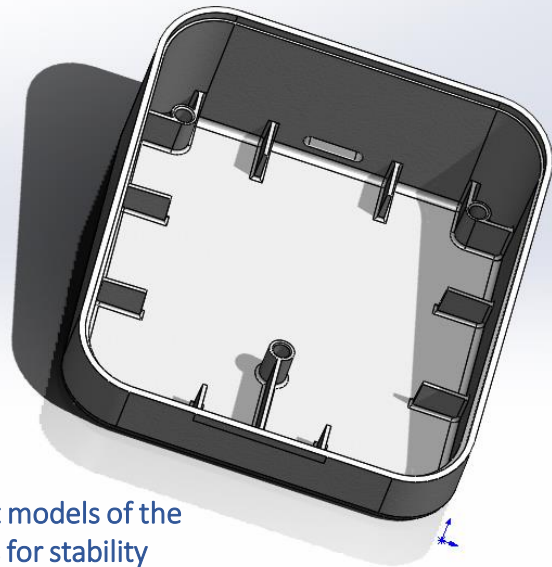


I began my CAD model with a simple cube that I extruded and cut at an angle following the shell feature.

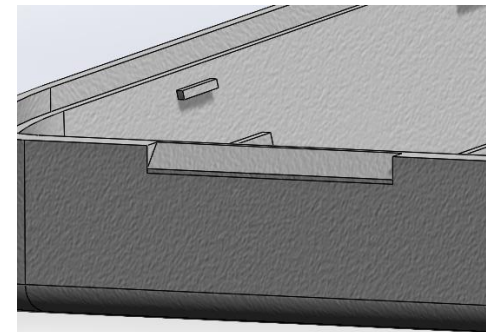
I made sure to detail all my DFM features with fillets and chamfers that I got the thickness from with the equations in my research. This was to make sure that my model is up to functional standard by having a uniform thickness.



I then began making my DFM features which I planned out in the previous stage. I didn't want to overload it with too many ribs but had enough to still fit the battery and have the motherboard comfortable fit.

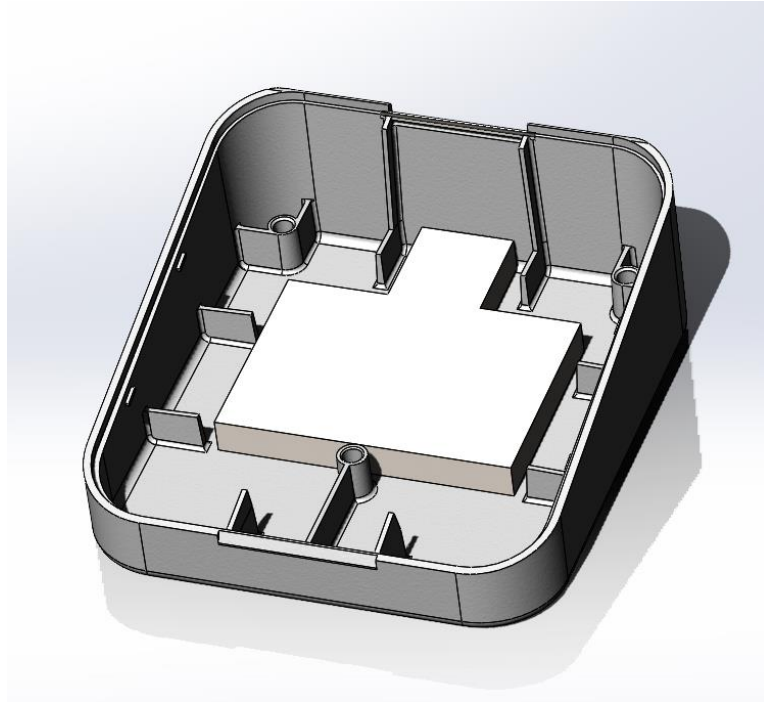


Going back to my research most models of the base had smaller ribs on all walls for stability which I implemented here.

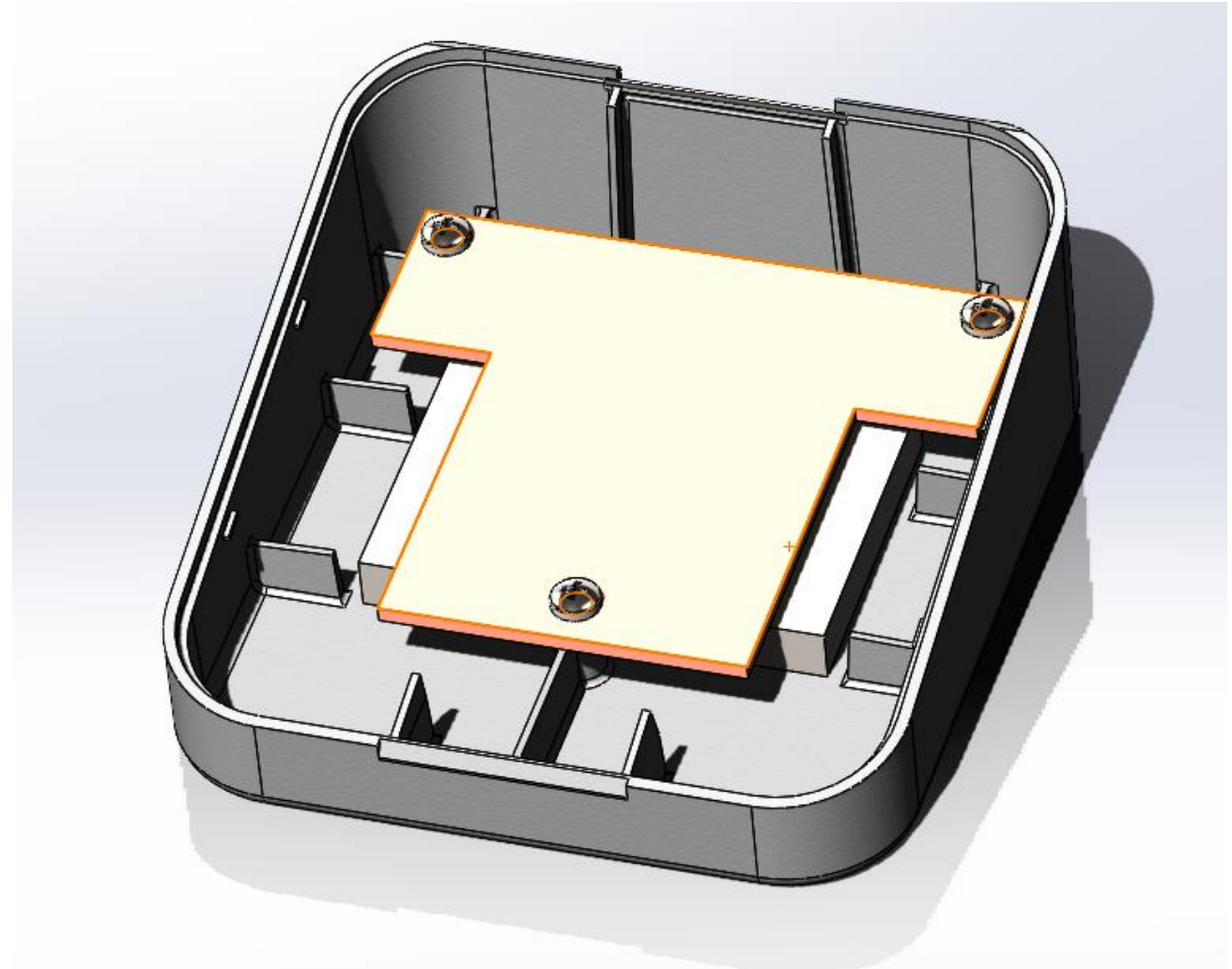


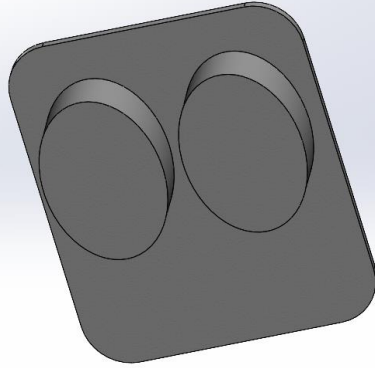
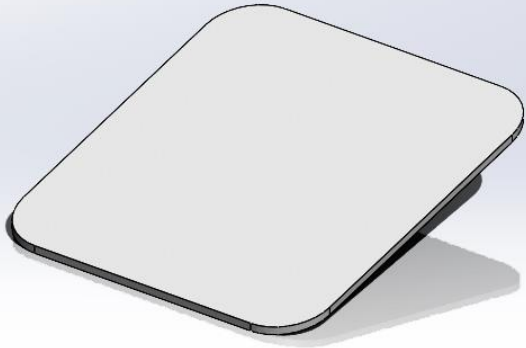
I had to tweak a few things especially working with draft angles and fillets, I implemented four snap fits (two on each side) and added taller ribs to support the base insert by letting it rest on the plastic when being pressed in.

I made room for the pin on my hinge and made a lot of small alterations for everything to work properly.

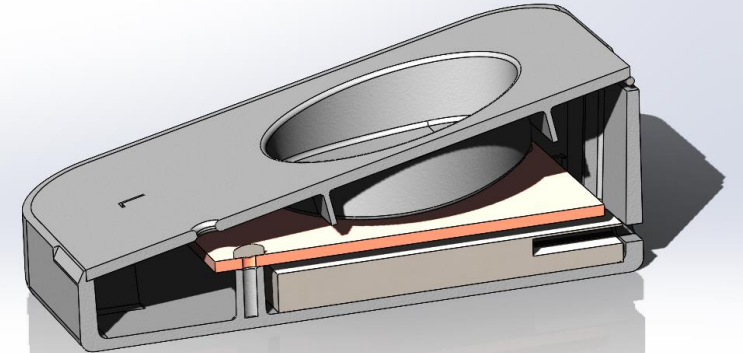


My next stage was adding in the battery and motherboard into my base model. Since most batteries that I explored in my features were placed on the bottom using tape this was the reasoning for me doing the same. I used the smallest screws I could find that fit into my bosses – the pan head screw. My motherboard was also made in the shape that fit the placement of my features. This was the bottom half of my model complete.



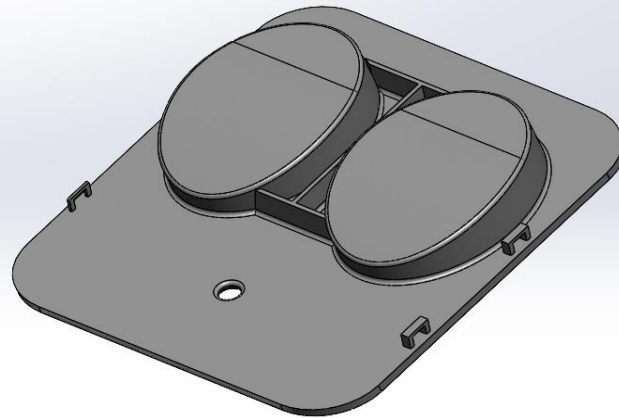


Here is a section view of the bottom half of my earbud case, I made sure that nothing was interfering with each other while still being functional.



I then put my piece into the assembly and had to do some tweaking to make the snap fits fit correctly.

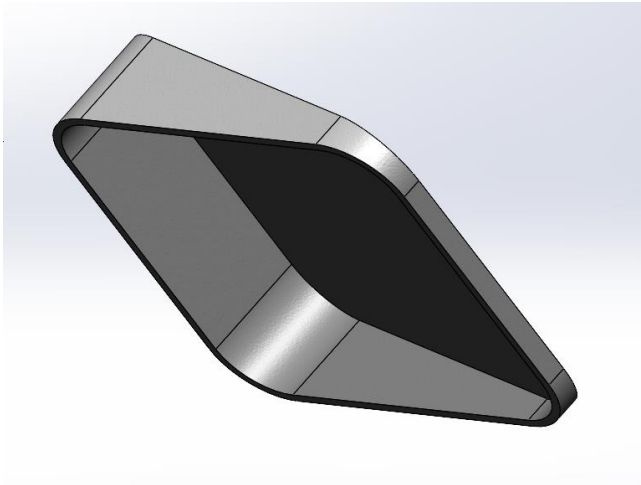
I started off my insert for the base with two extruded cuts and moved onto extruding the indents for the earpieces.



I didn't put a lot of DFM components into this part because I felt like it wasn't necessary and it would overload the component.

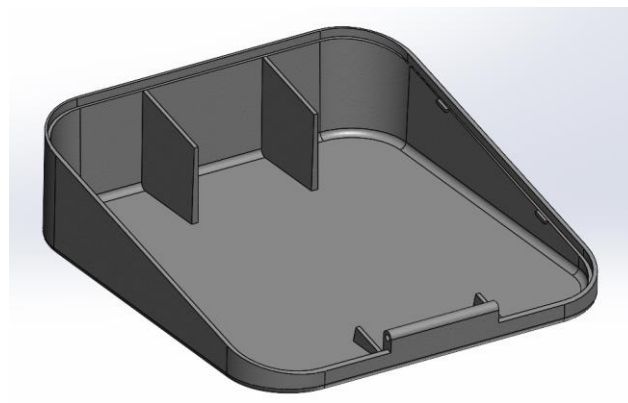
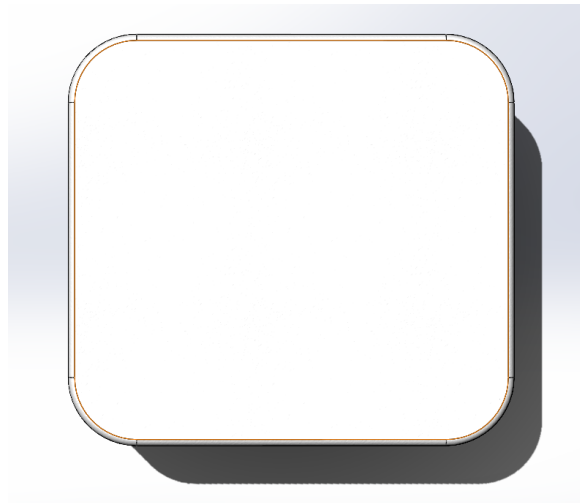


I added in extra ribs for support of this feature along with the other side of the snap fits. I also indented the letters along with including a hole for the LED light to come through to the bottom.



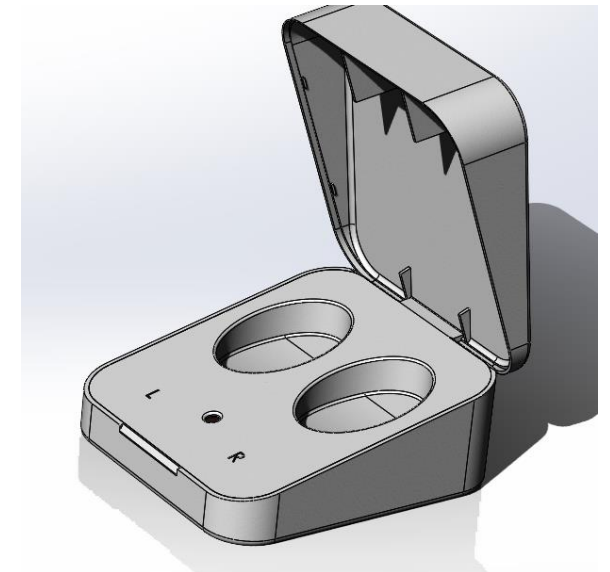
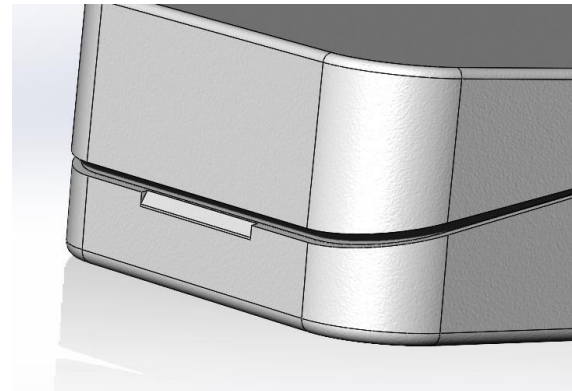
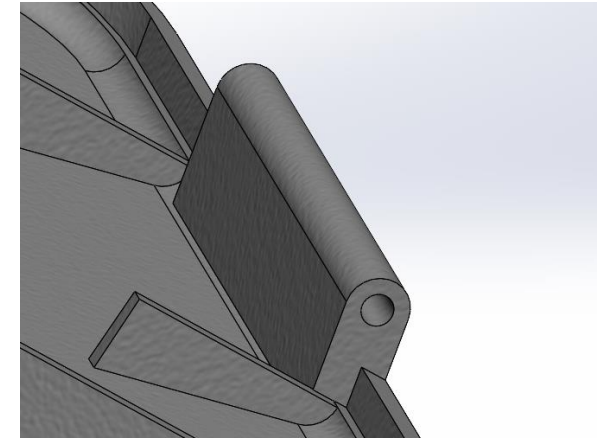
I made my top cover just like what I did with the base by shelling out the inside.

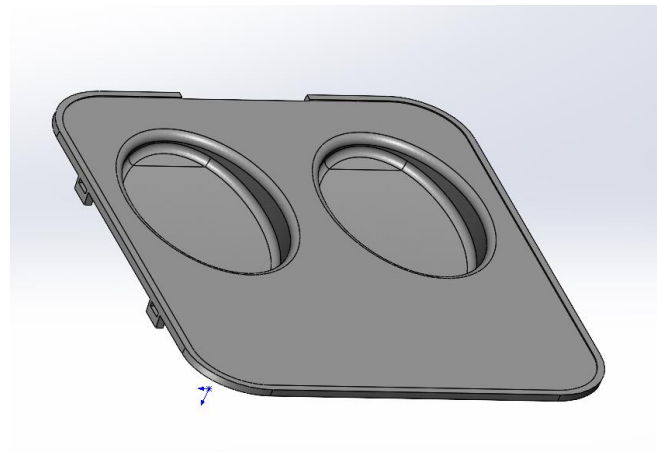
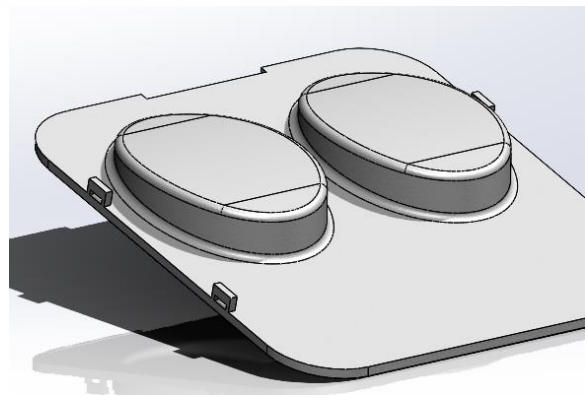
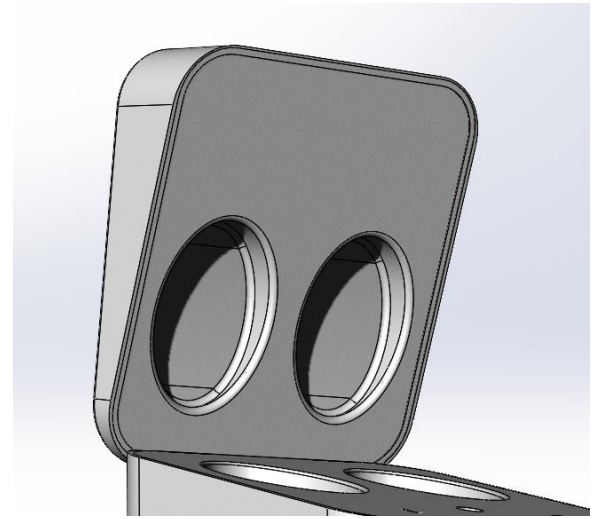
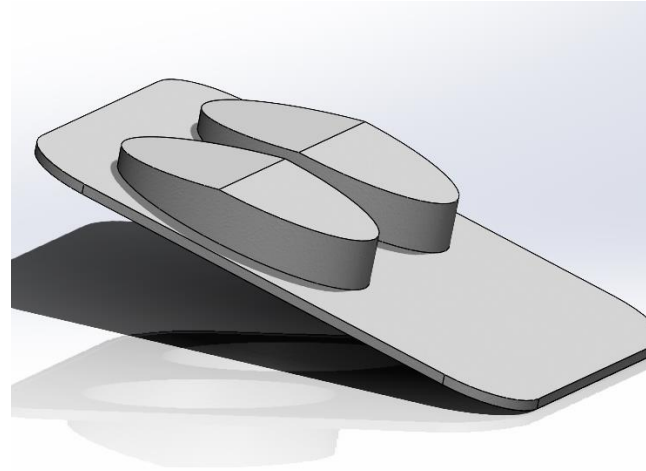
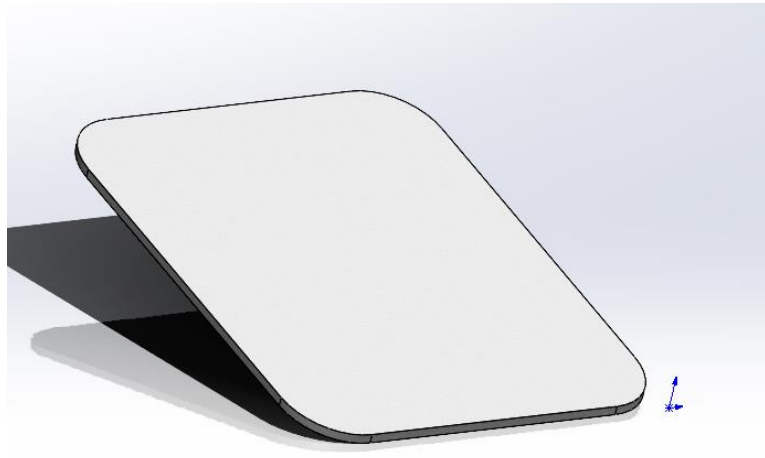
I made sure that the top and bottom aligned perfectly with each other. - which didn't prove to be the case when I originally made the part for some reason but I got there in the end.



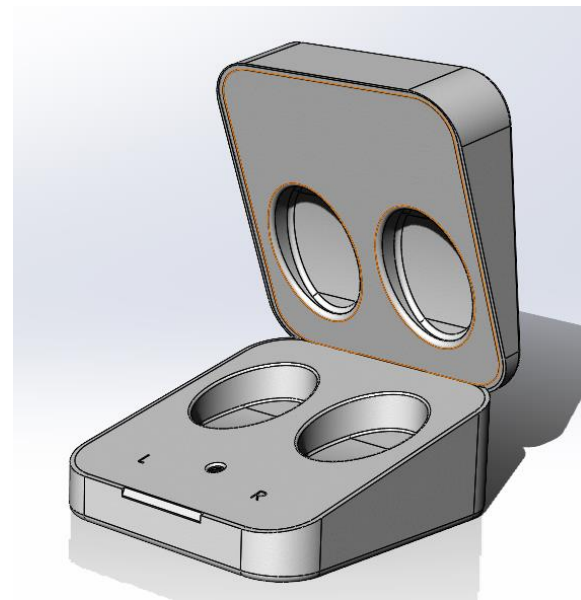
I added the same snap fits onto this part of the model and made the ribs up to the top again so that it would support the insert. I didn't add any ribs to the side this time however because the cover wasn't supporting as much weight as the base.

I modelled the hinge onto the cover part even if I originally set out to make a separate hinge which proved to be pretty complicated and this was a much more simple alternative.





I didn't add connecting ribs across the two holes as the bottom has more features like magnets, charging ports that needed more of that support while the top only keeps them covered.



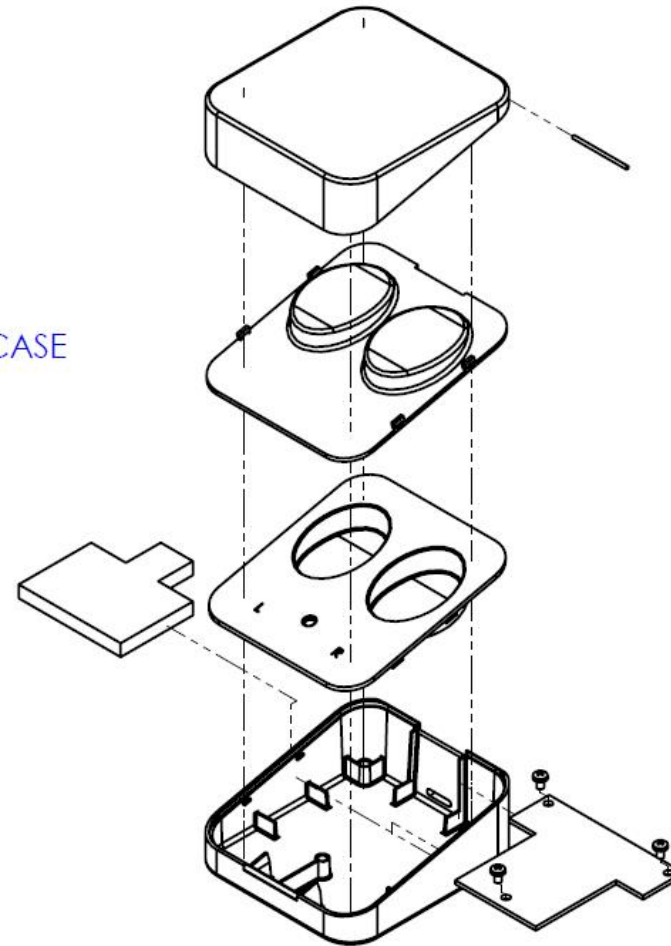
For my top insert I worked on the same premise as my bottom, making a few readjustments for the top half so that it fits into the base.

I added a few finer details like the snap fits and inserted everything into my assembly until everything was finally complete.



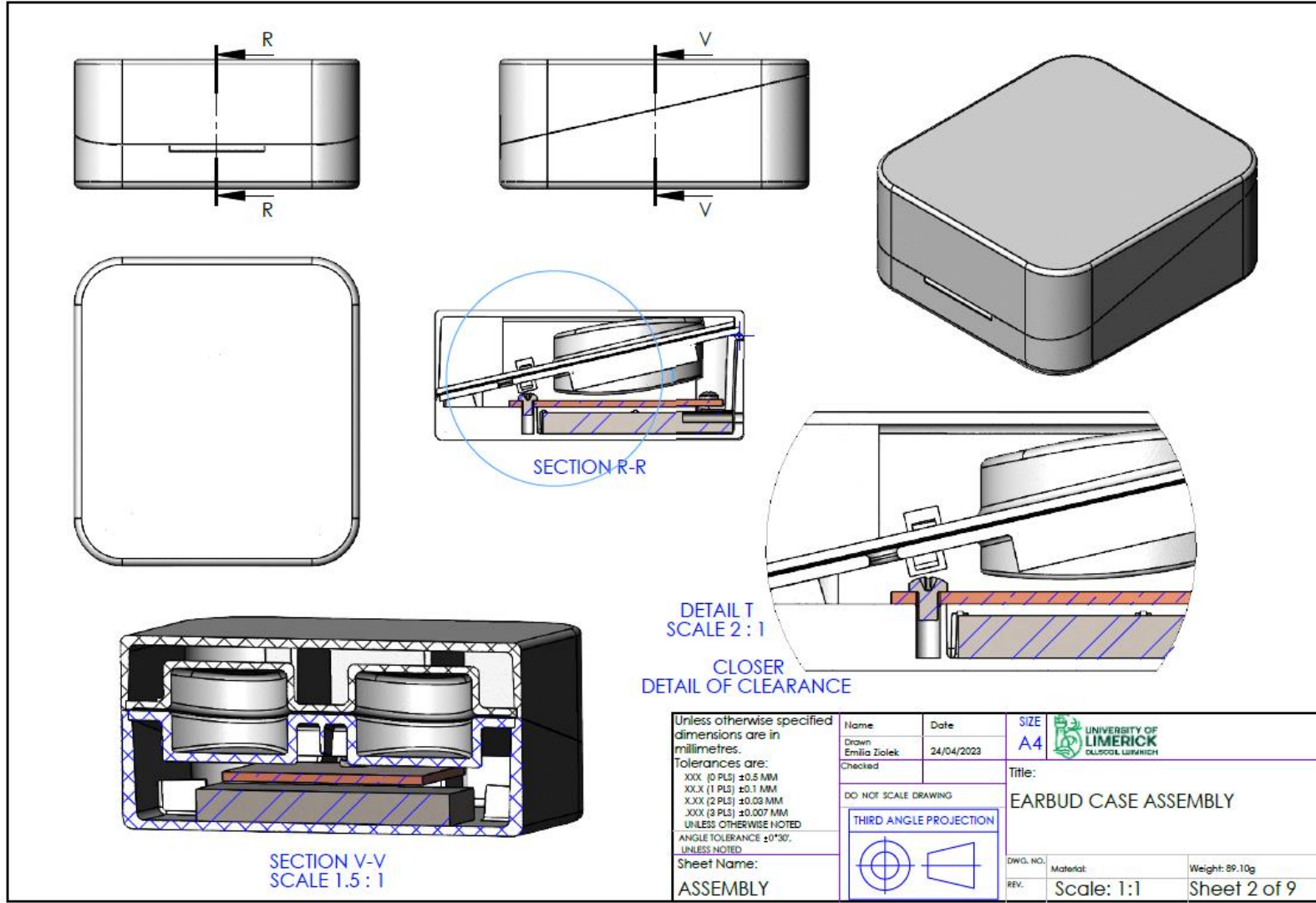
CAD DATABASE MODEL FOR EARBUD CASE

EMILIA ZIOLEK - 21307067
PD4044



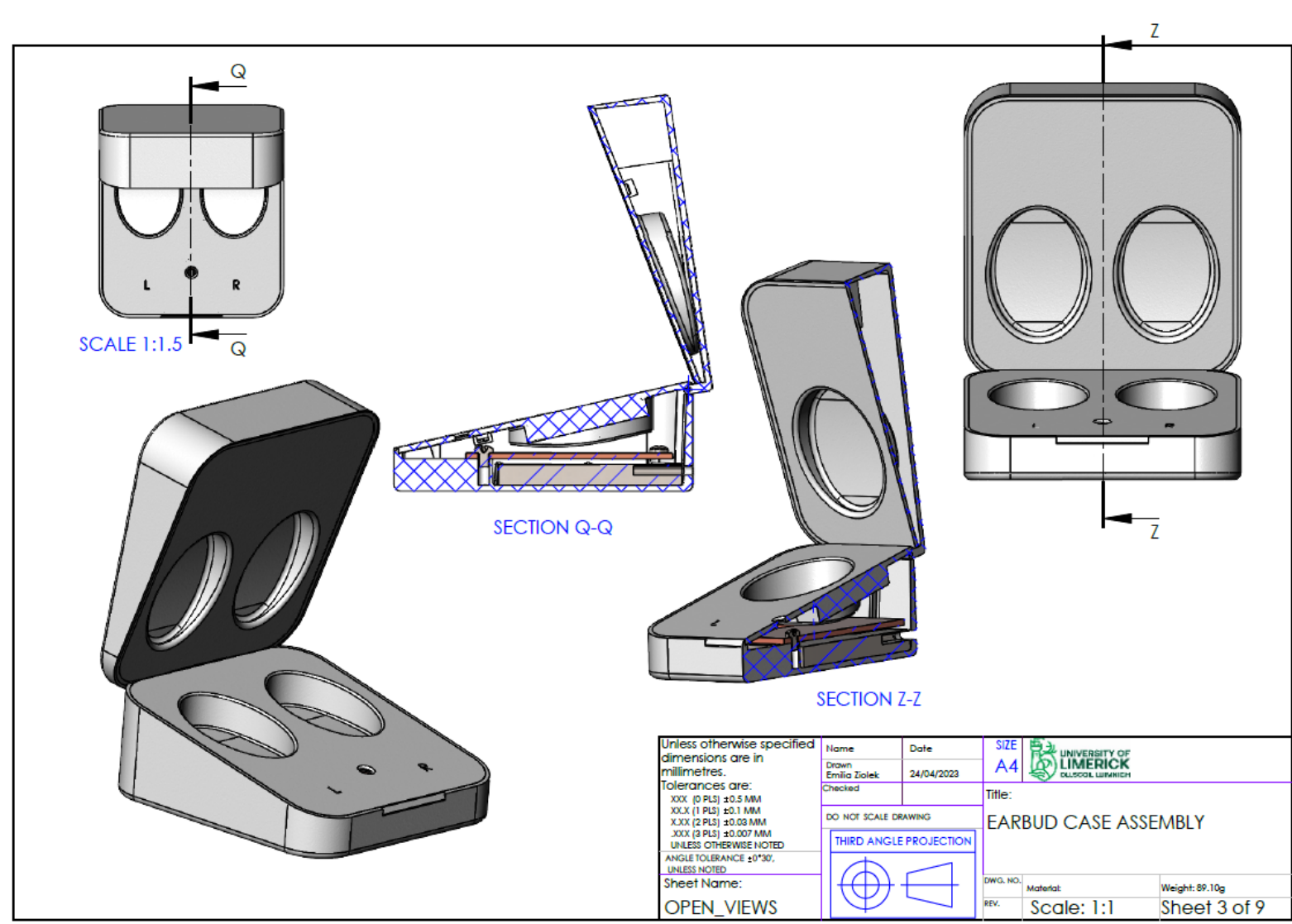
These are my drawings for the model that I included in the process book to keep in as a reference.

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Unless otherwise specified dimensions are in millimetres. Tolerances are: .XXX (0 PLS) ±0.5 MM .XX.X (1 PLS) ±0.1 MM .XXX (2 PLS) ±0.03 MM .XXX (3 PLS) ±0.007 MM UNLESS OTHERWISE NOTED ANGLE TOLERANCE ±0°30', UNLESS NOTED	Name	Date	SIZE	UNIVERSITY OF LIMERICK COLLEGE LIMERICK
	Drawn Emilia Ziolk	24/04/2023	A4	
Sheet Name: ASSEMBLY	Checked		Title: EARBUD CASE ASSEMBLY	
	DO NOT SCALE DRAWING		DWG. NO.:	
	THIRD ANGLE PROJECTION		REV.:	
			Material:	Weight: 89.10g
			Scale: 1:1	Sheet 2 of 9

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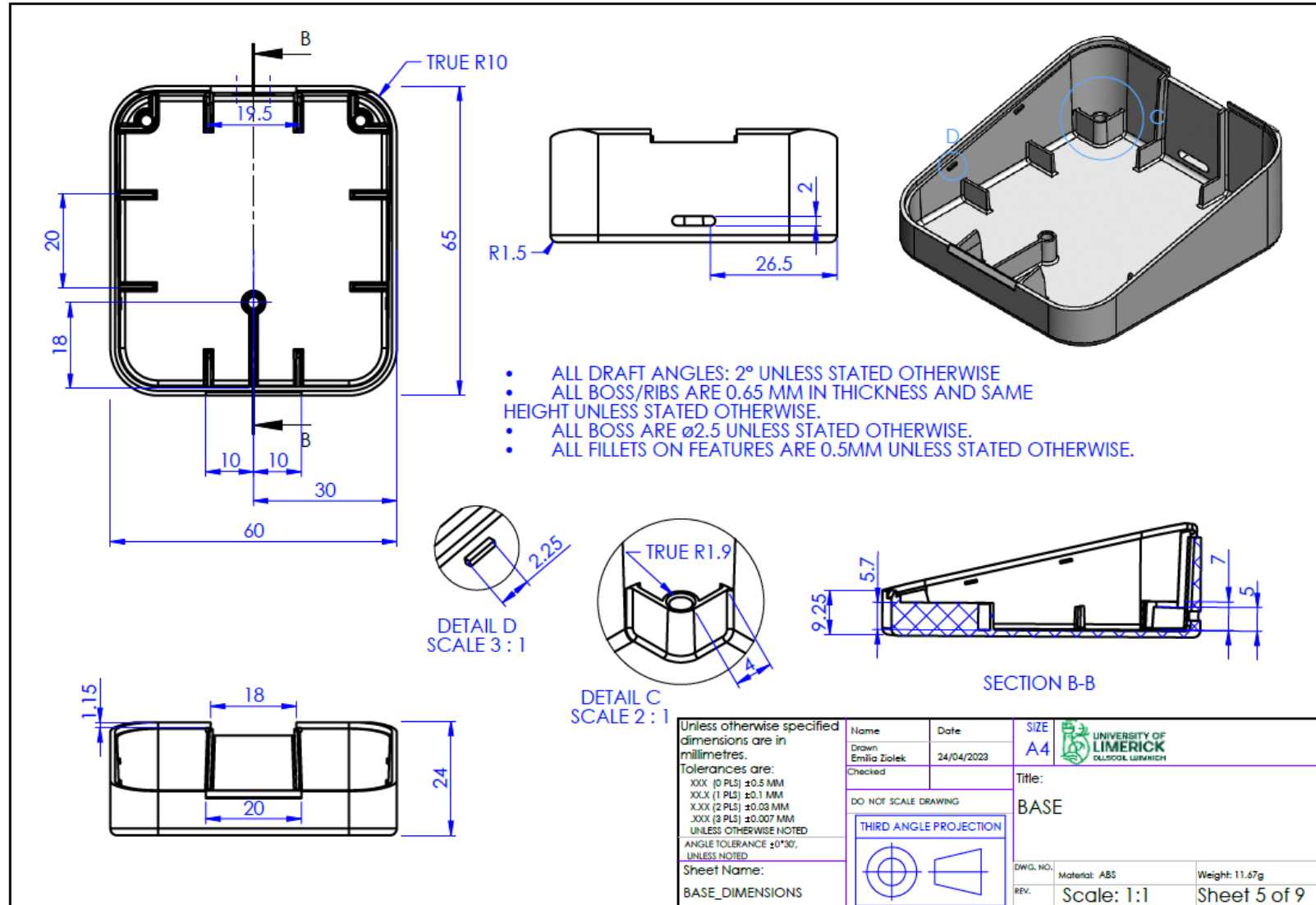
Unless otherwise specified dimensions are in millimetres. Tolerances are: XXX (0 PLS) ±0.5 MM XXX (1 PLS) ±0.1 MM XXX (2 PLS) ±0.08 MM XXX (3 PLS) ±0.007 MM UNLESS OTHERWISE NOTED ANGLE TOLERANCE ±0°30', UNLESS NOTED	Name	Date	SIZE	UNIVERSITY OF LIMERICK DLSCHOOL, LIMERICK
	Drawn Emilia Ziolek	24/04/2023	A4	
	Checked			Title:
Sheet Name:	DO NOT SCALE DRAWING THIRD ANGLE PROJECTION 		DWG. NO.:	Weight: 89.10g
OPEN_VIEWS	REV.	Material:	Scale: 1:1	Sheet 3 of 9

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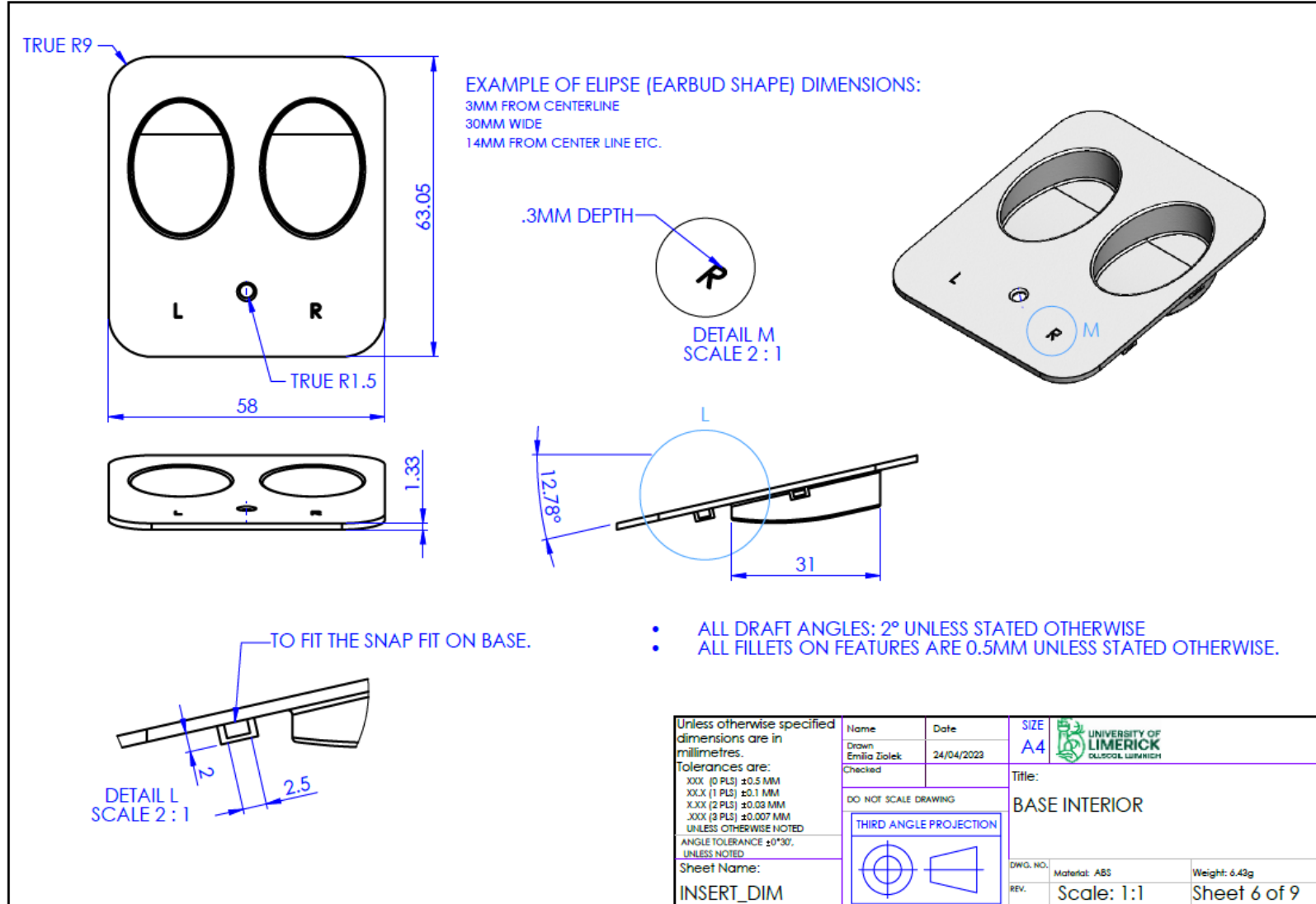
ITEM NO.	PART NUMBER	Material	QTY.
1	BASE	ABS	1
2	BATTERY	Alloy Steel	1
3	MOTHERBOARD SCREW		3
4	COVER	ABS	1
5	BASE INTERIOR	ABS	1
6	MOTHERBOARD	Copper	1
7	COVER INTERIOR	ABS	1
8	PIN	Plain Carbon Steel	1

Unless otherwise specified dimensions are in millimetres. Tolerances are: XXX (0 PLS) ±0.5 MM XXX (1 PLS) ±0.1 MM XXX (2 PLS) ±0.09 MM XXX (3 PLS) ±0.007 MM UNLESS OTHERWISE NOTED ANGLE TOLERANCE ±0°30' UNLESS NOTED Sheet Name:	Name Drawn Emilia Ziolk Checked	Date 24/04/2023	SIZE A4	UNIVERSITY OF LIMERICK COLLEGE LIMERICK
	DO NOT SCALE DRAWING THIRD ANGLE PROJECTION		Title: EARBUD CASE ASSEMBLY	
EXPLODED_VIEW	DWG. NO. REV.		Material: Scale: 1:1	Weight: 89.10g Sheet 4 of 9

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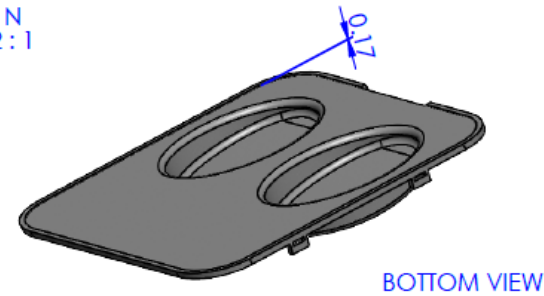
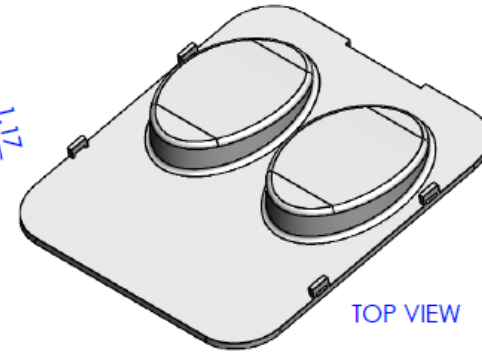
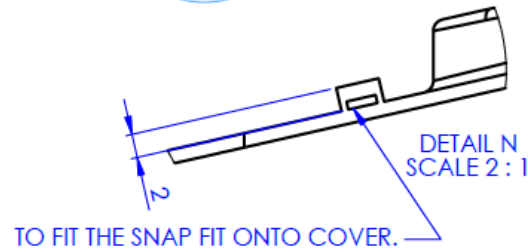
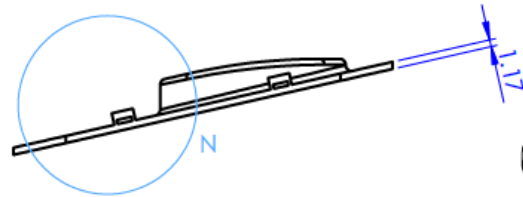
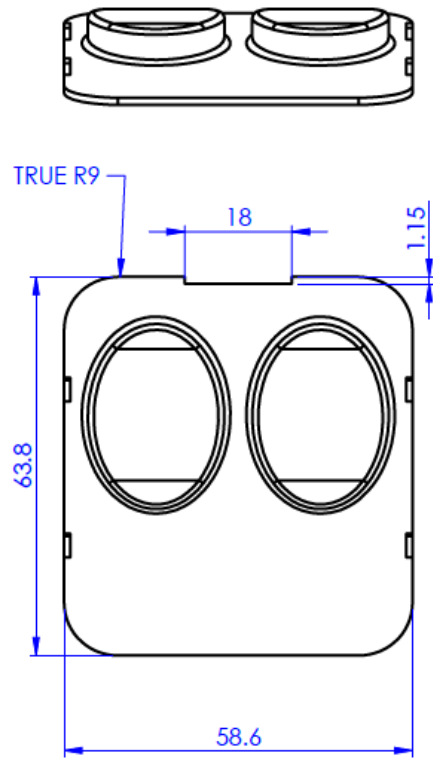
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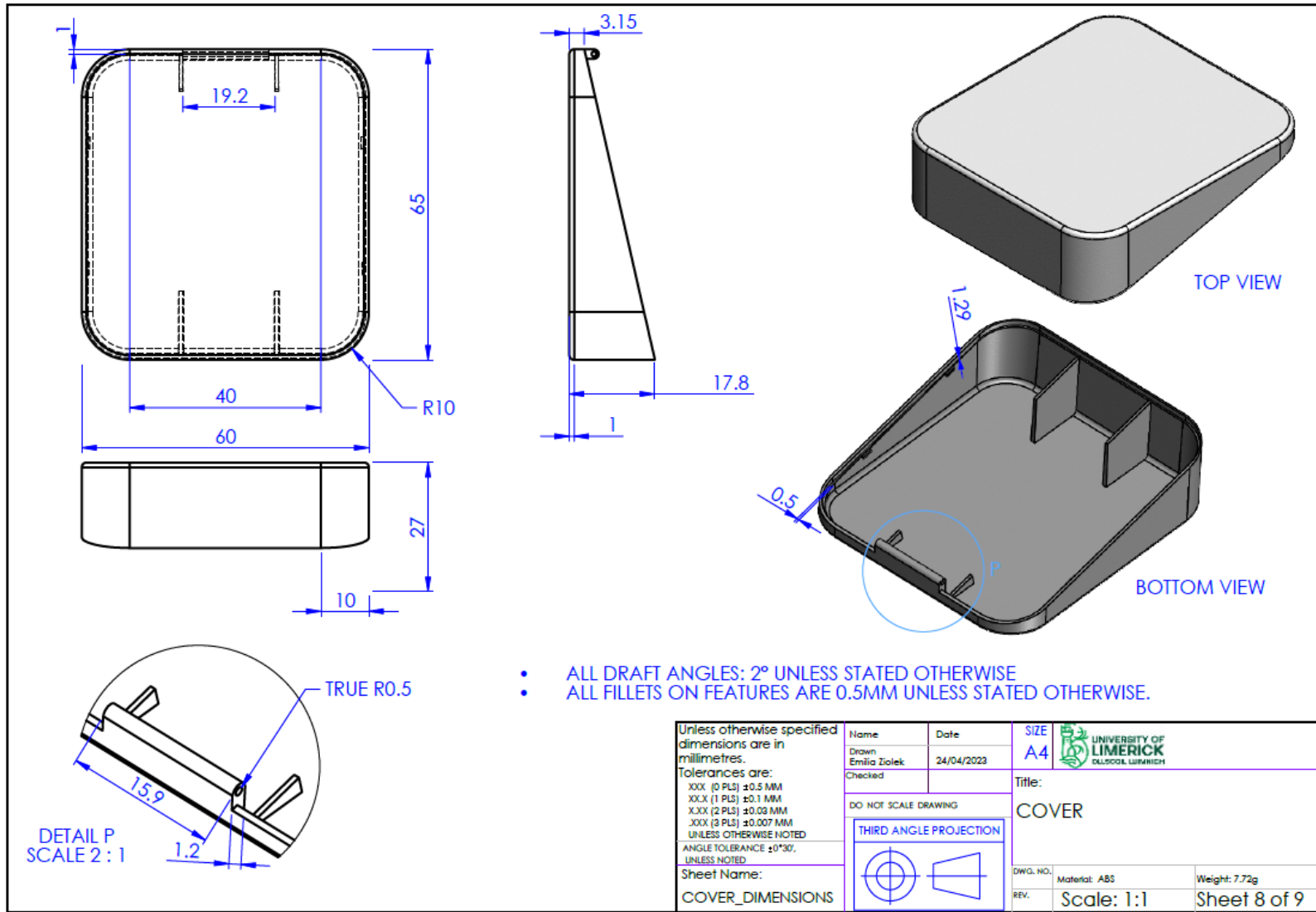
EXAMPLE OF ELIPSE (EARBUD SHAPE) DIMENSIONS FOR COVER:

3MM FROM CENTERLINE
 30MM WIDE
 14MM FROM CENTER LINE ETC.

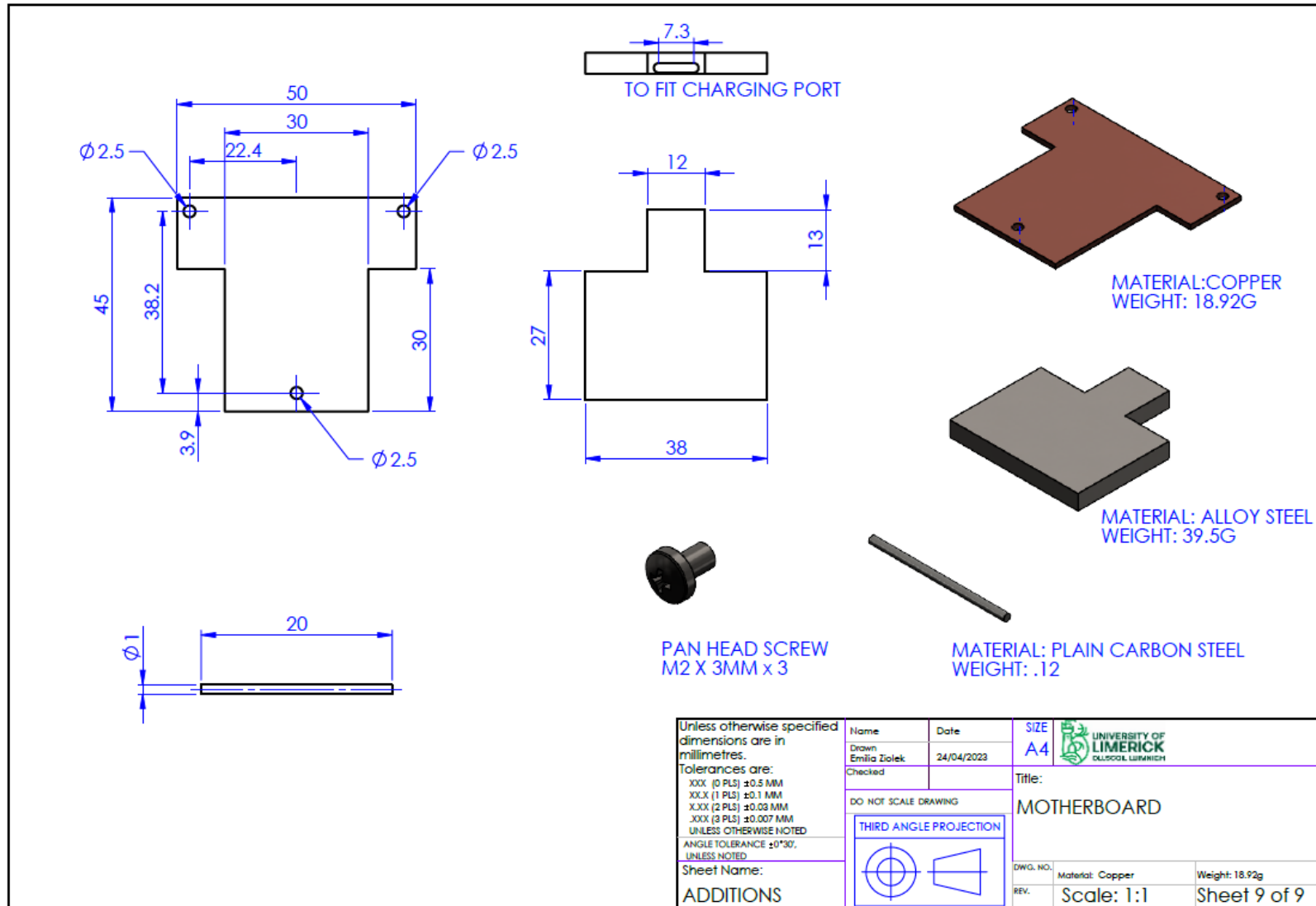


- ALL DRAFT ANGLES: 2° UNLESS STATED OTHERWISE
- ALL FILLETS ON FEATURES ARE 0.5MM UNLESS STATED OTHERWISE.

Unless otherwise specified dimensions are in millimetres. Tolerances are: .XXX (0 PLS) ±0.5 MM .XXX (1 PLS) ±0.1 MM .XXX (2 PLS) ±0.03 MM .XXX (3 PLS) ±0.007 MM UNLESS OTHERWISE NOTED ANGLE TOLERANCE ±0°30', UNLESS NOTED Sheet Name: CINSERT_DIM	Name	Date	SIZE	UNIVERSITY OF LIMERICK COLLEGE LIMERICK
	Drawn Emilia Ziolek	24/04/2023	A4	
	Checked	DO NOT SCALE DRAWING		Title: COVER INTERIOR
	THIRD ANGLE PROJECTION		DWG. NO.	Material: ABS
		REV.	Scale: 1:1	Sheet 7 of 9



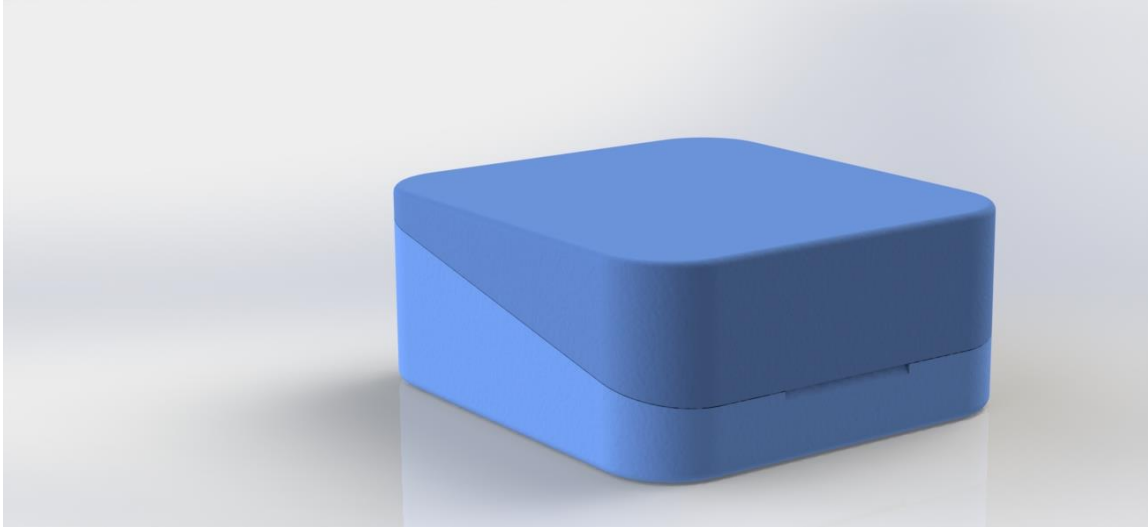
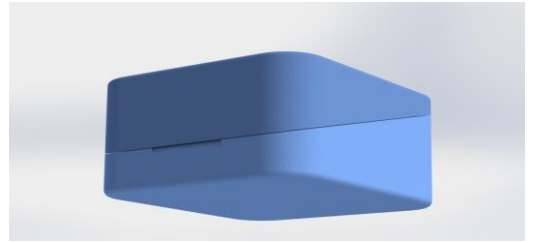
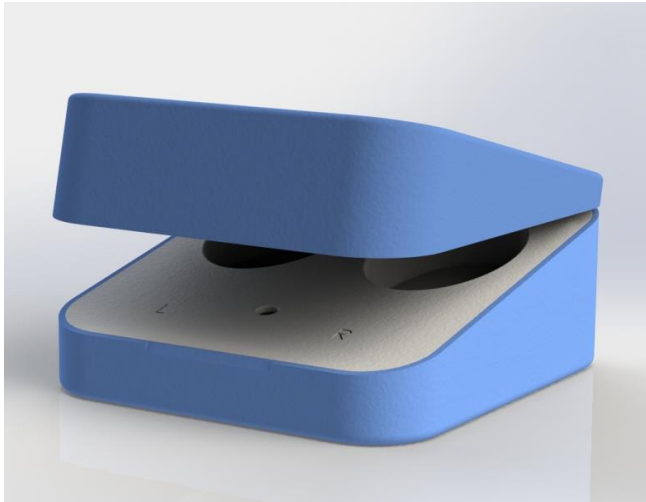
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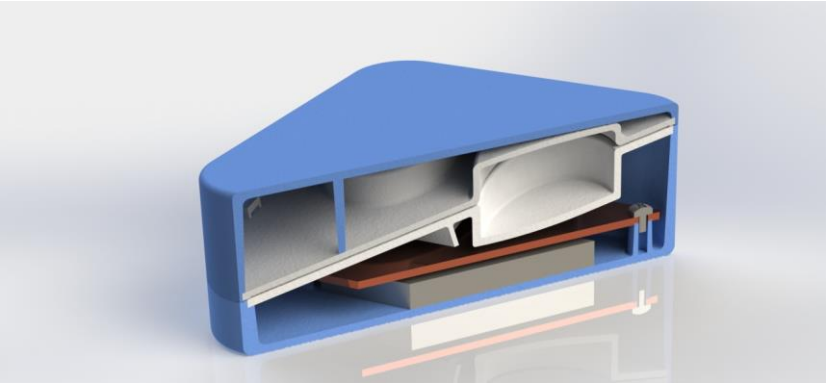
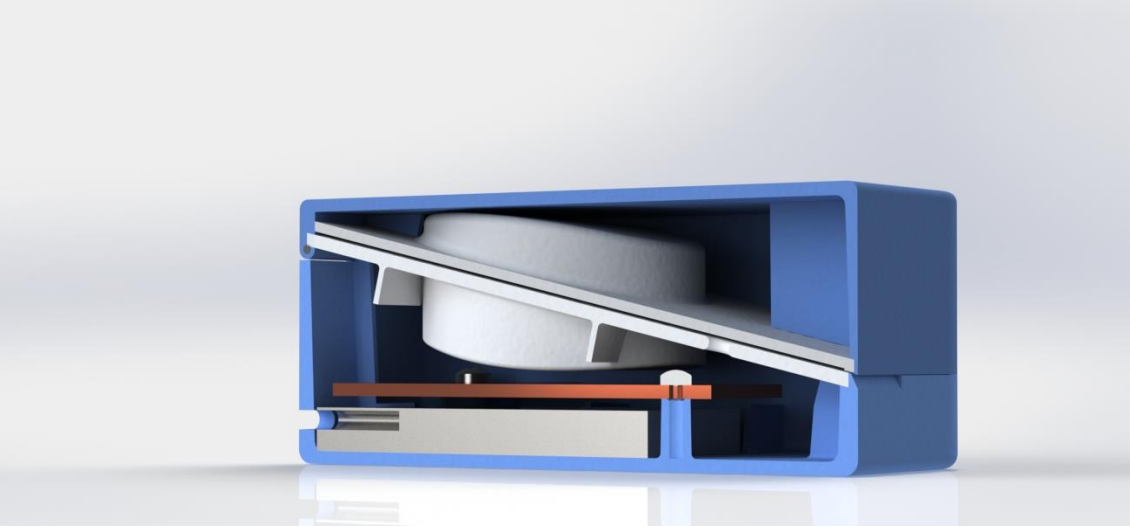
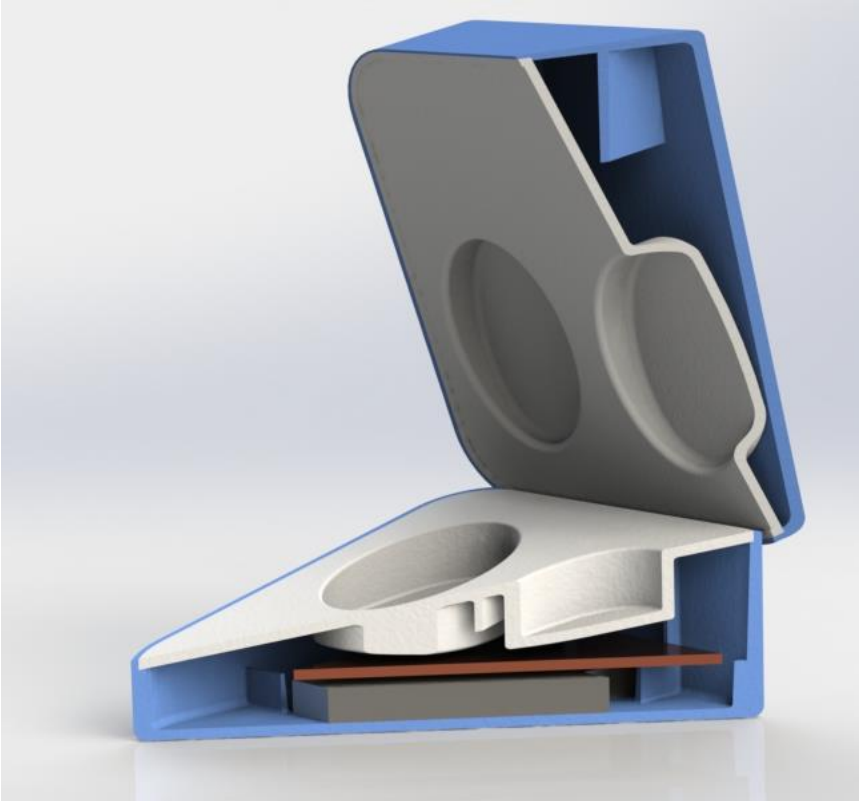
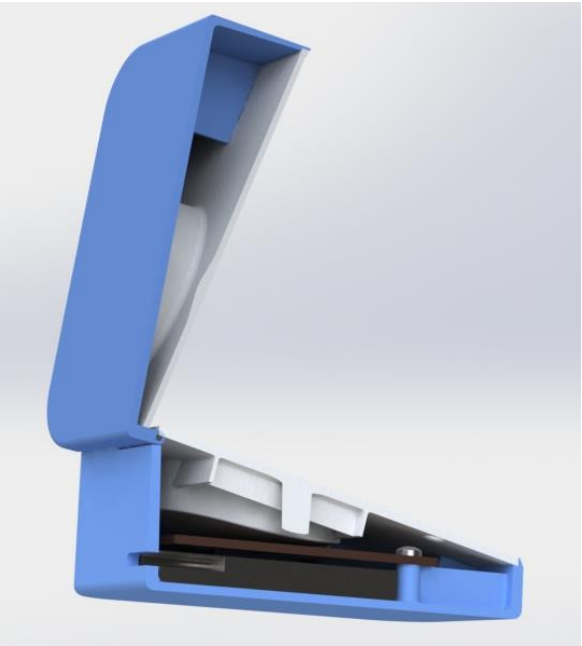
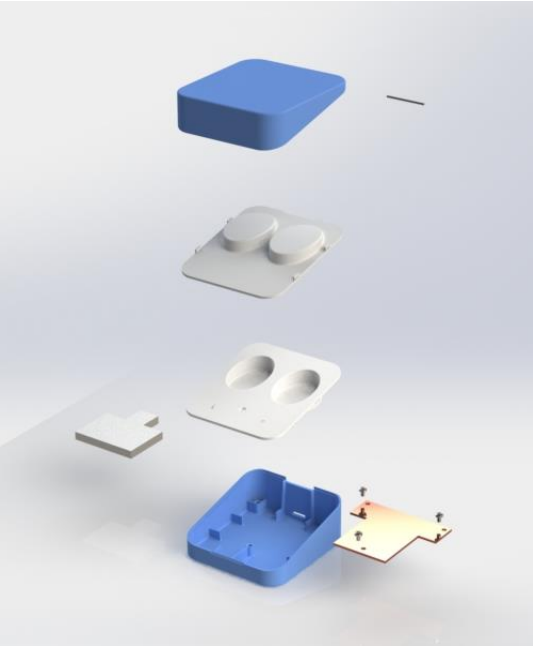
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Week 12 - Submission

Final Renders



Final Renders



Evaluation

Hinge that is part of the top cover and is connected to the case by a pin that is lodged in between them.

Port for LED light to run through from the battery and be displayed after the injection moulding process.
Green – 100%-70%
Orange – 69% - 40%
Red – Below 40%

Small ridge for the user to be able to pull off the case from its magnets – that are mounted on both side of both the base and the cover.

Place for earbuds, where the charging connectors and magnets are also placed – but weren't included for this demonstration.

Features:

Simple shape designed for easier storage, maximizing protection by placing earbuds towards the centre of the case and lifting them up to face the user. ABS material durable and able to withstand countless drops to the floor and has enough friction to sit comfortably in the pocket.

USB C type port – where the wiring itself must be must it and was not included. Located on the back of the charging case for aesthetic and usability.

My Main Goals To Fulfil At The Start Of This Project:

Designing the perfect gym earphone case, the case should be comfortable and snug fit in the pocket when carried around when someone is doing different activities. It should have enough friction to not slip out of any pockets but not too much as they can get caught on clothing and other things. Durability and protection of the earbuds is non-negotiable and has to be included.

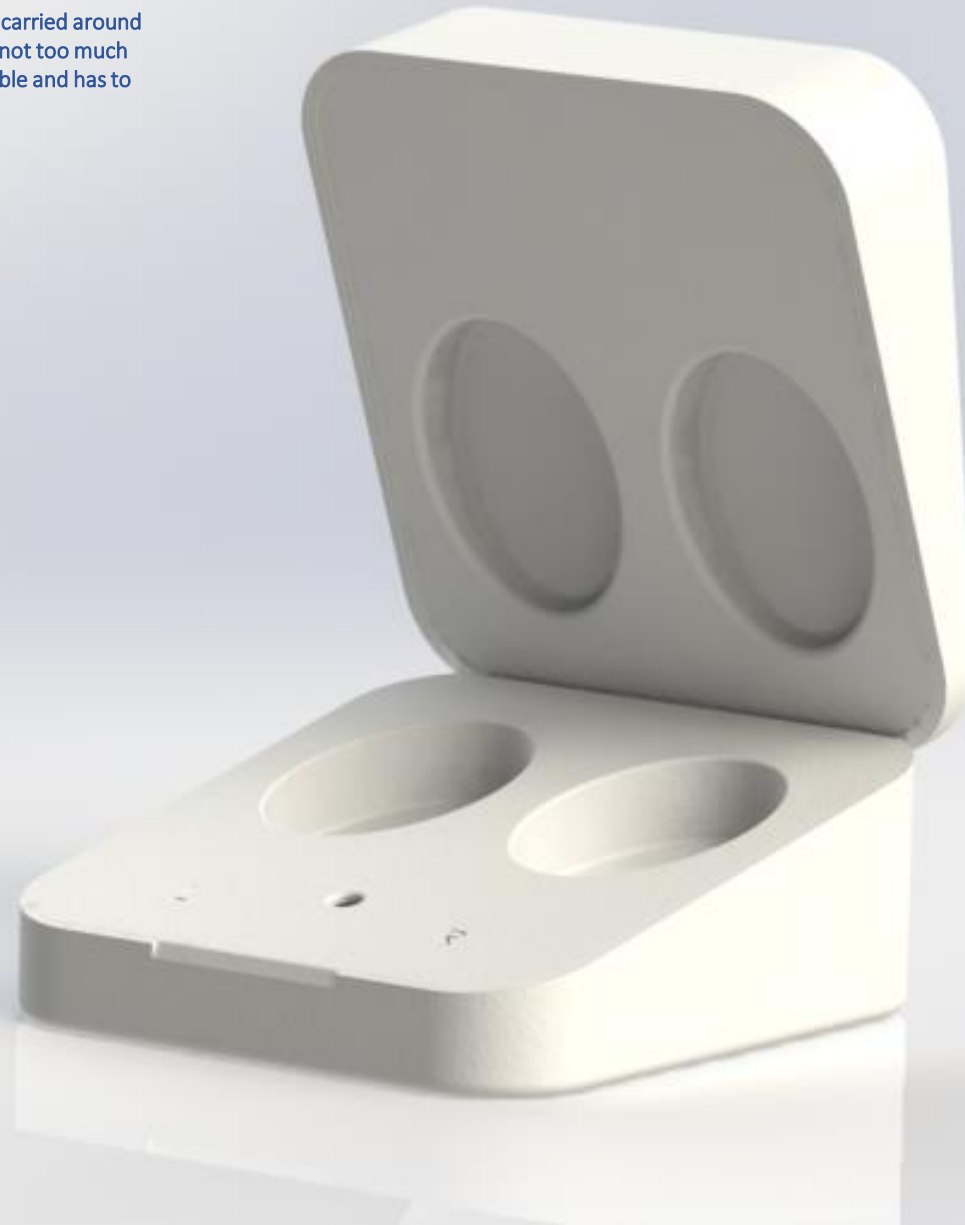


Did I Succeed?

I believe that my final product still fulfils the goal that I set for it while being completely manufacturable in real life. I focused on having a case that is a snug fit in the pocket, while not having edges that can get caught on things. I feel that the width and quite large structure can fit into the pocket and have the resistance of not moving around too much, yet the smooth edges prevent it from getting caught on anything.

I also included the earbuds to be at an angle as I believe it both centres the earbuds more towards the middle of the case where they can get less damaged from the outside as it's being thrown around and it makes them easier to take out as the surface faces the user parallelly.

My material choice of ABS also contributes to my objective as it is known for its hard and tough nature. Overall I believe I satisfied my user needs of having a durable and protective earphone case while also providing comfort and reliability for its intended user. The internal DFM features that I included like the snap fits and ribs hold the product securely together and are completely manufacturable. There is enough structural support provided from them to achieve a very durable case. Uniform wall thickness throughout the design along with draft angles for pulling the piece apart are all a part of this design. All gates are located on the centre of these parts on the side of structural elements.



Thank You.