UNIVERSITY of the AEGEAN | SCHOOL OF ENGINEERING
DEPARTMENT OF PRODUCT AND SYSTEMS DESIGN ENGINEERING

MSc Thesis Title:

Design of a Lighting Product

Major： Integrated Product Design and Innovation, MSc

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Abstract

Brief

The aim of this thesis is to design an interior lighting product featuring ambient and task lighting. The context is a short-term rental accomodation and specifically a bedroom and the activity of the user leisure reading. The user has to be capable of alterning the state of the luminaire from ambient to task lighting and vice versa manually.

Methodology

In this thesis, the aim is to focus in the stages of concept and preliminary design, thus the detailed design phase is not conducted. A preliminary research is conducted mainly exploring the discipline of Lighting and its intersection with Industrial Design. Following the initial research, the targeted research leads to insightful input that along with the brief contribute in the definition of the Design Specifications. After the solid definition of the problem, an exploration of possible solutions is implemented through ideation, sketching and a morphological chat. Having produced useful material, in this phase of the design process three cocept designs are developed that comply with the design specifications.The concept lighting products are designed in a 3d conceptual form, thus initial dimensioning has been made. It is important to note that technical drawings and BoM are not produced in this thesis, since it has a conceptual direction. In the final chapter, the most suitable concept is chosen, with the help of the Opportunity Tournament decision-making tool. The conclusion is that in the case a protoype is produced,additionally to the final product (Concept 2) that is chosen for the initial brief, it would be interesting to test the lighting product of Concept 1, since it would be suitable if the brief is re-framed regarding the context and specifically if the space is altered from a short-term rental accomodation to a privately owned residence.

Chapter 1: Initial Research

Lighting and Architecture

Lighting is a core element of Architecture, as one of the core principles that define lighting is geometry. Would it be possible to perceive forms without light? One can state that with touch a form can be perceived, but this applies only in a smaller scale, in the one of the human metrics. Following the same logical path, would it be possible for someone to perceive textures with the abscense of light? In this case, some material properties such as roughness, temperature, toughness can be sensed by touch. When the parameter of lighting is included, the form and materiality of a space is revealed. Lighting confirms the “Gestalt principle of emergence : The whole is perceived as greater than the sum of its parts.”

The catalytic role of lighting in architecture, among other domains of our lives has been praised by the masters of Architecture.

"Light creates ambience and feel of a place, as well as the expression of a structure." Le Corbusier

"Light is the magical ingredient that makes or breaks a space." Renzo Piano

“Architecture appears for the first time when sunlight hits a wall” Louis Kahn

Daylight and Architecture

Light, from a physics point of view is either a wave or a particle. In both cases light is an eternal traveller. In daytime natural light is always present even when its source, the Sun, is not visible. Ambient / diffused light is sublime. The interaction of Light and Form reveal its prescense. The following images depict that daylight reaches us if the conditions allow it. The connection of Light with the soul and faith throughout the passage of time is analysed further on. The interplay of Light with form and materiality, is of great importance and depicts that Light is a dynamic medium, one can view it as a transcending, sculptural material.

Image 1: Church of the Light, Osaka Japan

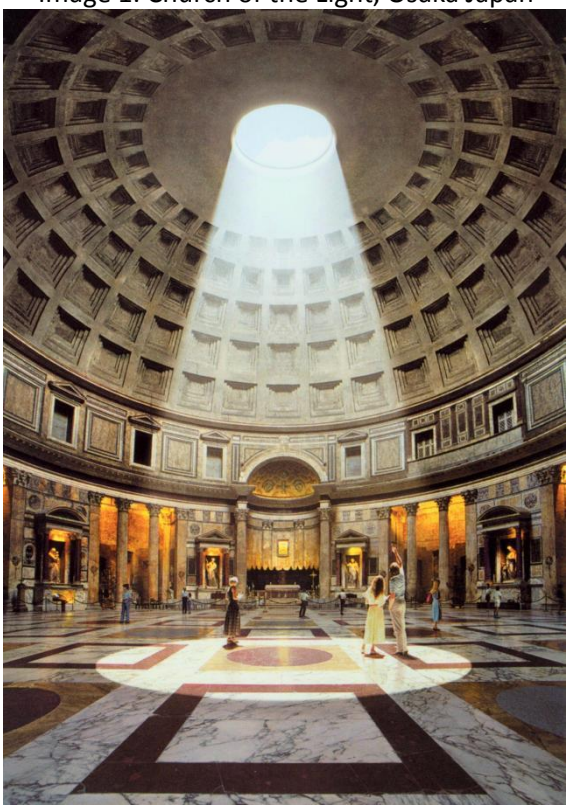


Image 2: Pantheon, Rome

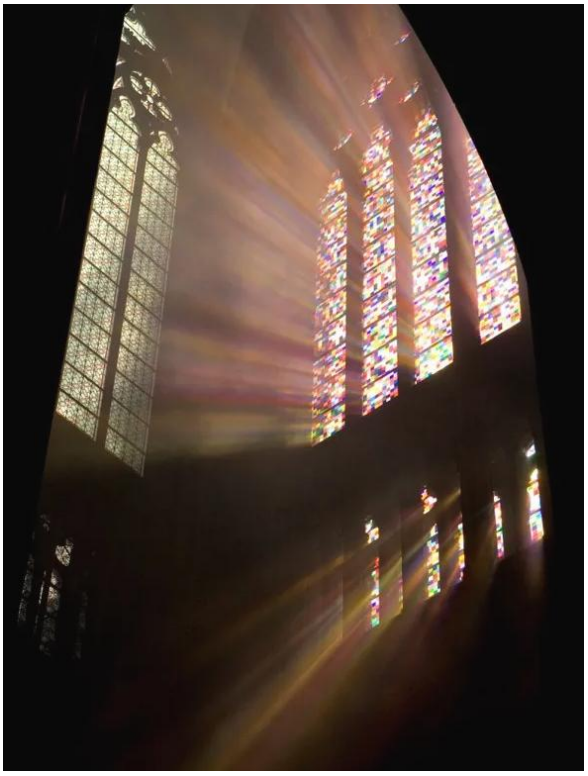


Image 3: The Cologne Cathedral

Light and Materiality

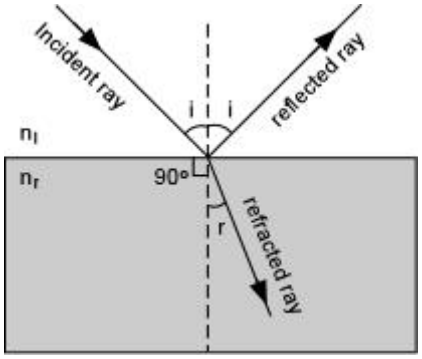
The field of lighting is present in many practices. Photorealism and rendering depend on the accuracy of the properties that will be assigned in a material and the accurate simulation of lighting behaviour. Also, specifically for this thesis where the aim is to design a lighting product, fundamental properties of materials that interfere with light need to be addressed and comprehended. Understanding these material properties of light is essential for various scientific, technological, and engineering applications, including optics, photography, telecommunications, and materials science.

These properties are presented bellow: (*Stephen A. Nelson, 2014*)[i]

Reflection and Refraction of Light

When light strikes an interface between two substances with different refractive indices, two things occur. An incident ray of light striking the interface at an angle, i, measured between a line perpendicular to the interface and the propagation direction of the incident ray, will be reflected off the interface at the same angle, i. In other words the angle of reflection is equal to the angle of incidence.

If the second substance is transparent to light, then a ray of light will enter the substance with different refractive index, and will be refracted, or bent, at an angle r, the angle of refraction. The angle of refraction is dependent on the angle of incidence and the refractive index of the materials on either side of the interface according to ***Snell's Law***:

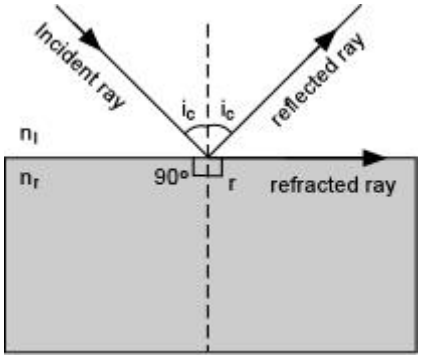


$$n_i \sin(i) = n_r \sin(r)$$

Note that if the angle of incidence is 0^o (i.e. the light enters perpendicular to the interface) that some of the light will be reflected directly back, and the refracted ray will continue along the same path. This can be seen from Snell's law, since $\sin(0^o) = 0$, making $\sin(r) = 0$, and resulting in $r = 0$.

There is also an angle, i_c, called the ***critical angle for total internal reflection*** where the refracted ray travels along the interface between the two substances.

This occurs when the angle $r = 90^o$. In this case, applying Snell's law:



$n_i \sin(i_c) = n_r \sin(90^o) = n_r$ [since $\sin(90^o) = 1$]

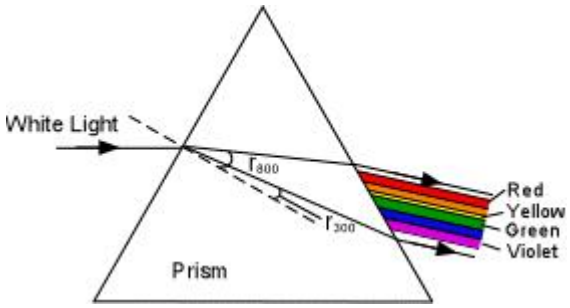
$\sin(i_c) = n_r/n_i$

Dispersion of Light

The fact that refractive indices differ for each wavelength of light produces an effect called ***dispersion***. This can be seen by shining a beam of white light into a triangular prism

made of glass. White light entering such a prism will be refracted in the prism by different angles depending on the wavelength of the light.

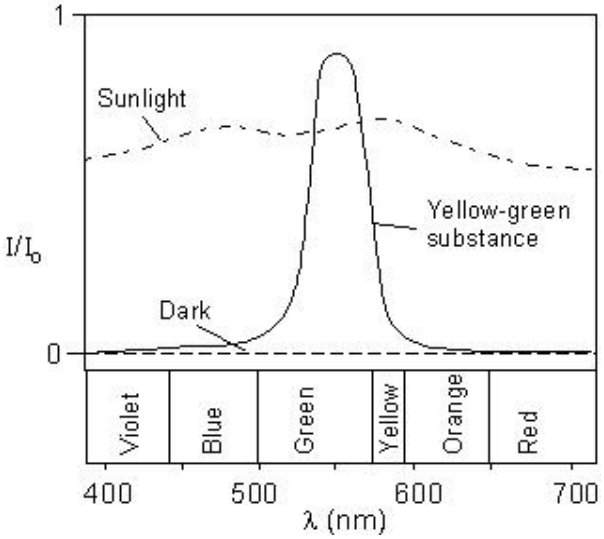
The refractive index for longer wavelengths (red) are lower than those for shorter wavelengths (violet). This results in the a greater angle of refraction for the longer wavelengths than for the shorter wavelengths. (Shown here are the paths taken for a wavelength of 800 nm, angle r_{800} and for a wavelength of 300 nm, angle r_{300}). When the light exits from the other side of the prism, we see the different wavelengths dispersed to show the different colors of the spectrum.



Absorption of Light

When light enters a transparent material some of its energy is dissipated as heat energy, and it thus looses some of its intensity. When this absorption of energy occurs selectively for different wavelengths of light, they light that gets transmitted through the material will show only those wavelengths of light that are not absorbed. The transmitted wavelengths will then be seen as color, called the ***absorption color*** of the material.

For example, if we measure the intensity of light, I_o, for each wavelength before it is transmitted through a material, and measure the intensity, I, for each wavelength after it has passed through the material, and plot I/I_o versus wavelength we obtain the absorption curve for that material as shown here. The absorption curve (continuous line) for the material in this example shows that the light exiting the material will have a yellow-green color, called the ***absorption color***. An opaque substance would have an absorption curve such as that labeled "Dark", i.e. no wavelengths would be transmitted.

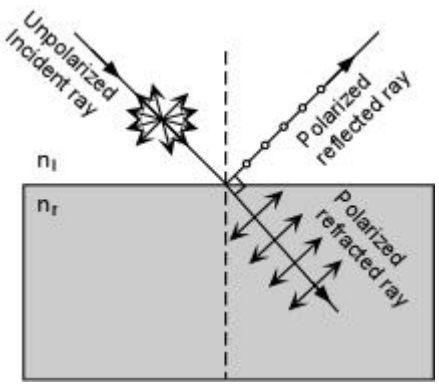


Sunlight, on passing through the atmosphere has absorption curve as shown, thus we see it as white light, since all wavelengths are present.

Polarization of Light

Normal light vibrates equally in all direction perpendicular to its path of propagation. If the light is constrained to vibrate in only on plane, however, we say that it is plane polarized light. The direction that the light vibrates is called the ***vibration direction***, which for now will be perpendicular to the direction. There are two common ways that light can become polarized.

- The first involves reflection off of a non-metallic surface, such as glass or paint. An unpolarized beam of light, vibrating in all directions perpendicular to its path strikes such a surface and is reflected. The reflected beam will be polarized with vibration directions parallel to the reflecting surface (perpendicular to the page as indicated by the open circles on the ray path). If some of this light also enters the material and is refracted at an angle 90° to the path of the reflected ray, it too will become partially polarized, with vibration directions again perpendicular to the path of the refracted ray, but in the plane perpendicular to the direction of vibration in the reflected ray (the plane of the paper, as shown in the drawing).



- Polarization can also be achieved by passing the light through a substance that absorbs light vibrating in all directions except one. Anisotropic crystals have this property in certain directions, called privileged directions, and we will discuss these properties when we discuss uniaxial and biaxial crystals. Crystals were used to produce polarized light in microscopes built before about 1950. The device used to make polarized light in modern microscopes is a Polaroid, a trade name for a plastic film made by the Polaroid Corporation. A Polaroid consists of long-chain organic molecules that are aligned in one direction an placed in a plastic sheet. They are placed close enough to form a closely spaced linear grid, that allows the passage of light vibrating only in the same direction as the grid. Light vibrating in all other directions is absorbed. Such a device is also called a ***polarizer***.

Artificial Light, LED Technology and Lighting Innovation

Artificial light is essential in interior spaces during the day, where the daylight lighting levels are not adequate and of course at night in indoor and outdoor spaces. Each space and activity has different requirements for lighting. Thus, the lighting products and their technical specifications depend on the context of their use. For example in coastal areas the IP rating (IP65 for outdoor areas, IP68 for submerged lighting fixtures) is not sufficient. Anti-corrosal processing needs to be added to the lighting fixture.

Nowadays, the norm for lighting sources are LEDs (Light Emitting Diode). LEDs compared to the fluorescent or incadescent lamps are extremely energy efficient. One can evaluate the energy efficiency of a luminaire by the lumens/W and their product lifetime cycle has extended. Also, they do not produce the high temperatures that older generation lamps used to (ex. Halogen lamps).LEDs have an impressive lifespan compared to traditional light sources. While incandescent bulbs typically last around 1,000 hours and CFLs about 8,000-10,000 hours, LEDs can last up to 50,000 hours or more, depending on usage conditions.
LEDs offer flexibility in color temperature, allowing users to adjust the color of light emitted. This capability is beneficial for creating different atmospheres in indoor spaces. Additionally, LEDs can achieve high Color Rendering Index (CRI) values, indicating their ability to accurately render colors compared to natural light.

With advancements in technology, LED lighting systems can be integrated with smart home automation systems. Users can control LED lights remotely using smartphones or voice commands, adjust brightness and color temperature, and schedule lighting patterns for energy savings and convenience. In the context of this thesis, smart lighting will be specified

for the product, since the users want to customize the conditions of their environments.
Aside from the smartphone and voice commands, Building Automation Systems as KNX or Lutron are broadly used in hospitality and residential spaces. User scenarios can be programmed by the lighting designers (for example Relaxation, Study, Sleep). The user throught the automation systems stated bellow chooses the desired scenario and the whole lighting scene changes.

An important note regarding LEDs is that when designing an interior lighting fixture the designer can choose between LED bulbs (GU10, E27) or integrated LED chips within the product. Both solutions can be dimmed and controlled as long as smart and compatible bulbs are specified.

Lighting Product Design

The expertise that an Industrial Designer needs in order to design a lighting product is interdisciplinary. As stated in the previous Chapter, Lighting is a field of its own and serves functional, aesthetic and emotional purposes. Thus, the Industrial Designer needs to have a good understanding of the principles of Light, material behavior when interacting with light, architecture and construction, electrology and automation systems.

Lighting in general is a field that especially Architects find attractive. The most reknown and popular lighting companies such as Artemide, Nemo Lighting etc have launched lighting fixtures designed by iconic Architects (Le Corbusier, Mario Botta, Zaha Hadid , Bjarke Ingels, Norman Foster etc). A selection of these lighting products, the designers and the companies is presented:

Le Corbusier for Nemo Lighting

Image 4: “Borne Beton”

Image 5: “Applique de Marseille”

Image 6: “Applique De Marseille”

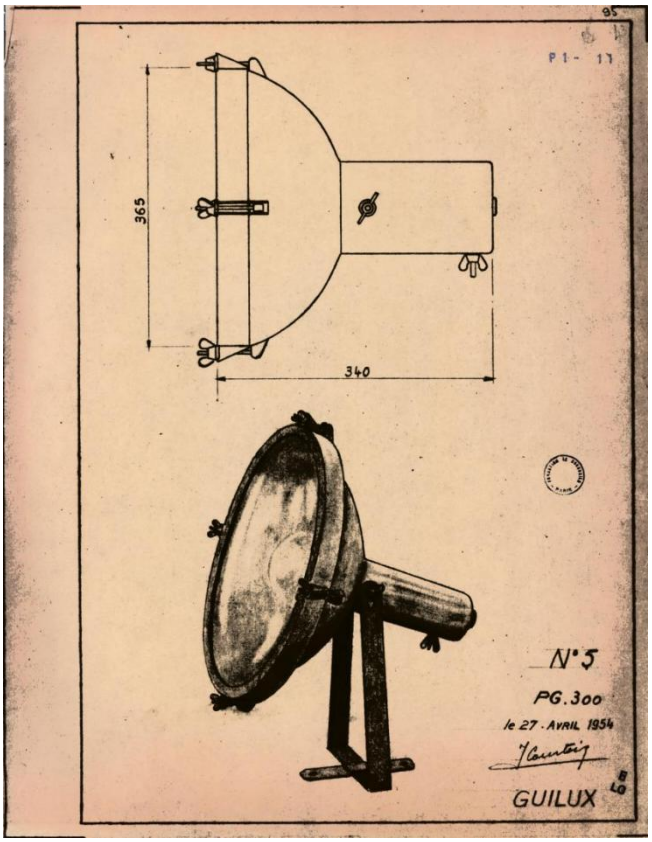


Image 7: Sketch of “Projecteur 365”

Charlotte Perriand for Nemo Lighting

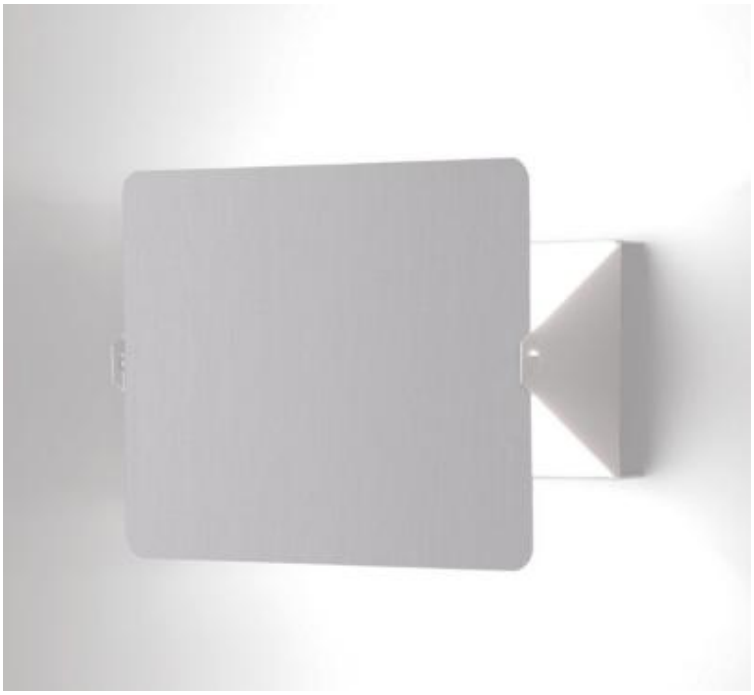


Image 8: “Applique a volent pivotant”

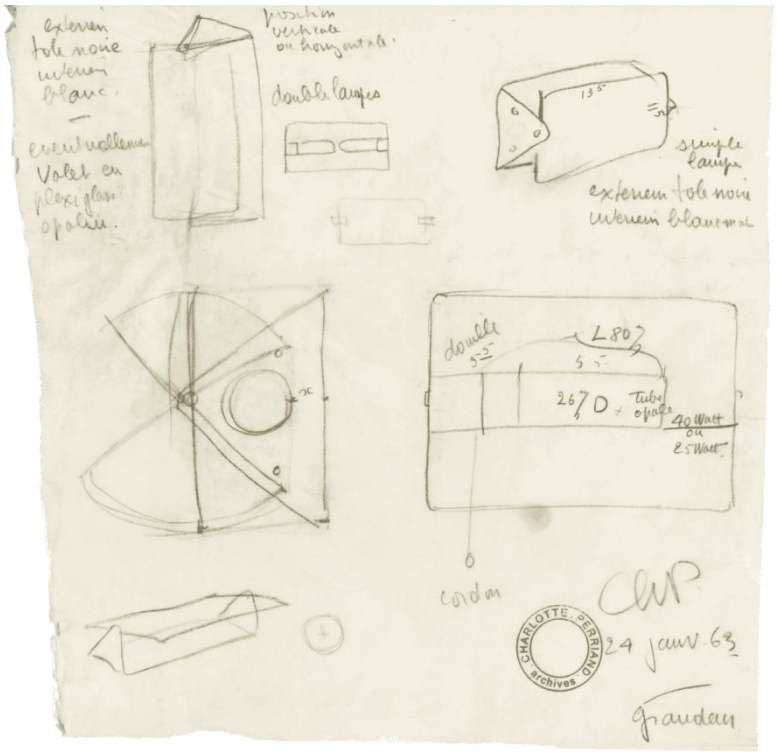


Image 9: Sketch of “Applique a volent pivotant”

Mario Botta for Artemide

Image 10: “Shogun”

Zaha Hadid for Artemide

Image 11: “Genesy”

Bjarke Ingels for Artemide

Image 12: “Alphabet of Light”

Norman Foster for Artemide

Image 13: “IXA”

The products presented above are only a sample of collaborations of reknown Architects with big companies in the Lighting Industry. The interesting and obvious observation is that the charcter, the tamperament and the personal aesthetic and design style of each iconic architect, as well as the designers works (Ettore Sottsass, Ross Lovegroove, Michael Anastassiades), are depicted in the lighting products they designed.

Ettorre Sottsass, Memphis Group

Image 14: “Tahiti”

Image 15: “Alfa” by Sergio Mazza: The first lighting fixture featured in the catalogue of Artemide

Ross Lovegroove for Artemide

Image 16: “Cosmic Lamp”

Michael Anastassiades for Flos

Image 17: “IC Lamp”

The chase of authentic and personalised experience

Social media has been a catalyst in carving a subconsious desire for authentic and personalised experiences which users have an urge to share with their audiences. This phenomenon has affected our social consciousness and in general the behaviour of human. It may seem paradox, but we experience the exact opposite: The moment we share an experience in social media, its authentic and personalised character is cancelled. The analysis of social media impact on human behavior is a research topic on its own.

As stated in the brief of this thesis, the lighting product is designed for a short-term rental bedroom in an accomodation. The market for Airbnb’s has become very competitive and the tenants have high expectations. They expect to have authentic and personalised experiences in the spaces they will book. Thus, the design of these spaces along with its FF&E’s need to be of a non-generic aesthetic but simultaneously to serve a broad target group. In this thesis the right balance for the aesthetic of the lighting fixture that will feature task and ambient lighting for the user will be expored. An extreme concept, if developed (Concept 3) shall be omitted, because it may be considered as “odd” by some tenants. On the otherside, the tenants/users of the space do not want to feel they are in a soulless space, so the possibilities for interesting forms and materials will be explored and integrated in the product to be designed.

The need for authentic and personalised experience and its impact on Industrial Design

In this thesis, the impact of the contemporary common desire for authentic and personalised experience on the design of new products is examined. It is important to clarify that in this thesis an Industrial Product will be designed. In our contemporary era the word Product is mostly associated with digital products and not industrial products.

A debatable point is whether the integration of new digital technologies (ex. IoT) has improved the overall experience of the end user. Integrating features such as interconnectivity and the ability of the user to intervene in the function of an industrial product is not sufficient stand alone for *"A good design".* In Design as generally in any field, it it crucial to be aware of the timeless experts of previous generations. At this point the "10 Principles for Good Design@ by Dieter Rahms will be addressed and used later as an evaluation method for the assessment of the final product to be designed in this thesis.

The 10 Principles for Good Design by Dieter Rahms

Good design is innovative
Good design makes a product useful
Good design is aesthetic
Good design makes a product understandable
Good design is unobtrusive*
Good design is honest
Good design is long-lasting
Good design is thorough down to the last detail
Good design is environmentally-friendly
Good design is as little design as possible

It is important to take into consideration the influence of the *Bauhaus movement* in Dieter Rahm's philosophy and work. Utalitarian objects, inclusive design, modernism and "*Form follows function*"*by Sullivan* is one of the most reknown principles of the Bauhaus movement.

Another crucial point for discusssion is for whom the designer is designing the product. It is common knowledge that the product has to be user-friendly and meet the needs of the end-user. In some cases, as the one examined in this thesis the designer does not design solely for the end-user, who rents a short-term accomodation. The stakeholder that will buy the product (customer) is the owner of the property. Thus, in the next Chapter in the definition of the Design Specification this parameter needs to be taken into account.

Conceptual Framework and Reframe in the Design Process

The theories and methodologies that have been developed in the field of Design, provide the designer with tools that are crucial in the overall design process of the development of a product. Even when a design brief and a "problematic area" seem simple, in the design process and especially in the initial stages when the foundations of the project are set complexities must be identified and analysed.

In the brief of this thesis, one of these complexities is that the end user differs from the client. Thus, material from is used in order to simplify the problem.

"In terms of our logical framework, a 'frame' is the general implication that by applying a certain working principle we will create a specific value."
"Framing in response to paradoxes in the problem situation is a key and rather special element of design's problem solving practices."*(Dorst, 2011)*[ii]

Chapter 2: Targeted Research

Taking into consideration the preliminary research presented in the previous chapter the main feature of the lighting fixtured has been defined. The product to be designed will be a lighting fixture that can perform either as a diffused/ambient light or as a task light, depending on the needs of the user.

Based on the Double Diamond (*Design Council, 2005*)[iii] design thinking method, at the end of this chapter the problem will be definied and the design specifications will be decided.

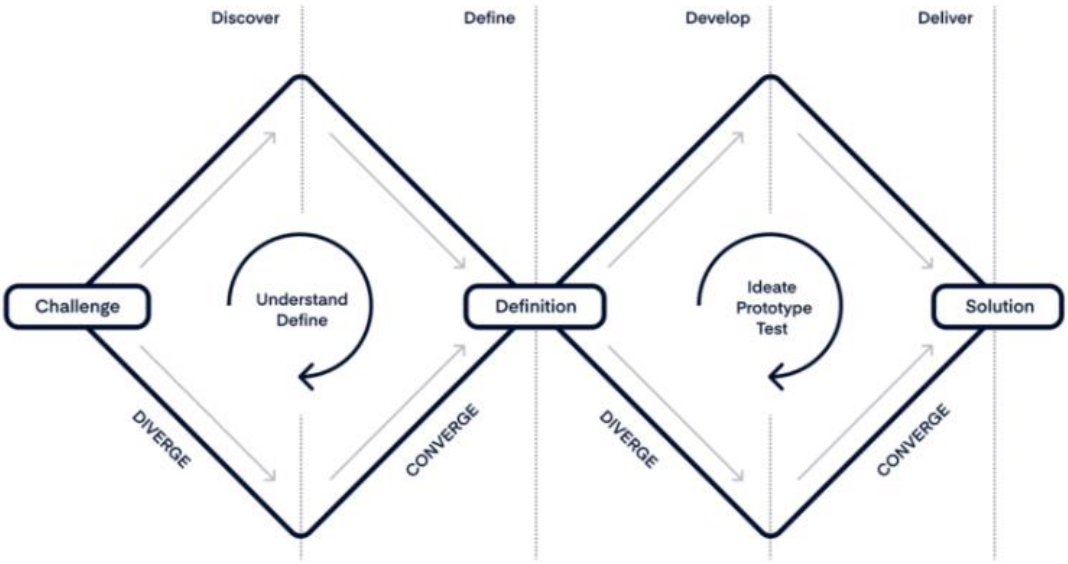


Figure 1: Double Diamond Design Methodology

Market Research of competitive products

Industrial Design and especially when the target is to design a product, market research is more than essential. (*Gordon, I., & Glenn, J. ,2015)*[iv]
(2013,Griffin,A.,& Hauser,J.R)[v]
An innovative product can be launched, after a thorough research in the market. More specifically existing products, emerging trends and technologies and the needs of the end-user. The latter will be presented in the next subchapter (questionnaire input).
Innovation does not mean re-inventing the wheel, but understanding the conditions in the sector of interest, evaluating of what we are capable of designing.

Image 18: Wall mounted direct and indirect lighting, industrial aesthetic

Image 19: Table luminaire ambient light, classic and high-end aesthetic.

Image 20: Table luminaire with tiltable cover, post-modern aesthetic

Image 21: Reference images of ceiling to floor suspended lighting fixtures. (Plug in socket)

The products presented above have the basic feature of giving the user the ability to choose between diffused and/or task lighting.
Also, they feature different ways of changing the state (manually).
Finally, the three products do not fall in the same category of mounting/support.
The first is wall mounted (fixed position), with a cable power supply.
The second is suspended from the ceiling (fixed position), with a cable power subblyThe third is free standing on the table with a socket power supply.

Questionnaire

The purpose of this questionnaire is to collect data in the context of a Master's Thesis (Integrated Product Design and Innovation). The subject of investigation is how we perceive lighting and more specifically in the bedroom of a short-term rental accomodation. The aim is to design a lighting productwith the main feature of making the experience of leisure reading possible and enjoyable.

Παρατηρείτε τον φωτισμό σε έναν χώρο;

40 responses

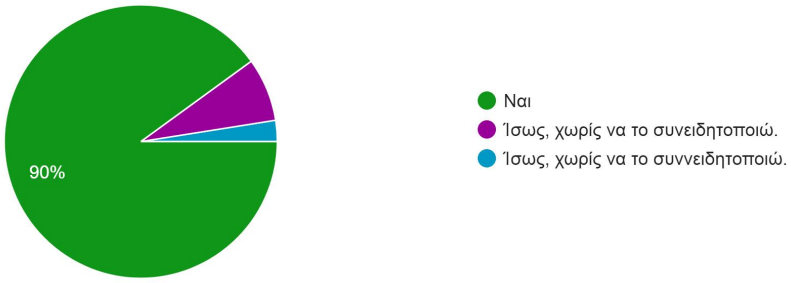


Figure 2

Πόσο σημαντικός θεωρείτε πως είναι ο φωτισμός κατά τον σχεδιασμό ενός χώρου; (1 καθόλου σημαντικός, 5 πολύ σημαντικός)

40 responses

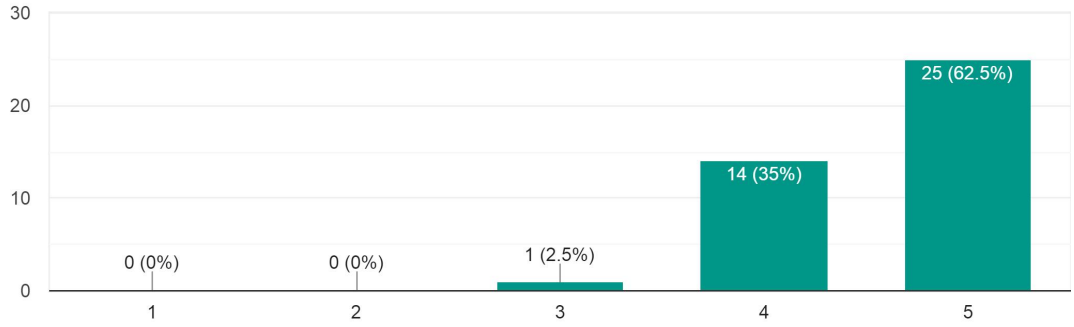


Figure 3

Γνωρίζετε τι είναι η θερμοκρασία μιας πηγής φωτισμού; (μονάδα μετρησης Kelvin)

40 responses

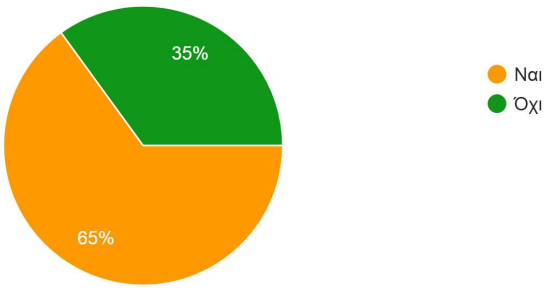


Figure 4

Κατά την διάρκεια της χαλαρής ανάγνωσης (πριν τον ύπνο), τι θερμοκρασία φωτός προτιμάτε;

40 responses

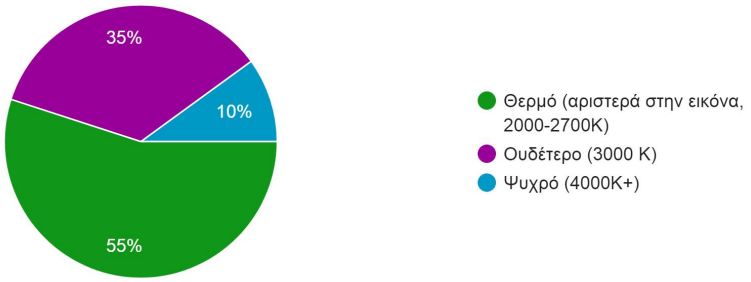


Figure 5

Στο υπνοδωμάτιο σας, έχετε κατάλληλο φωτισμό για διάβασμα:

40 responses

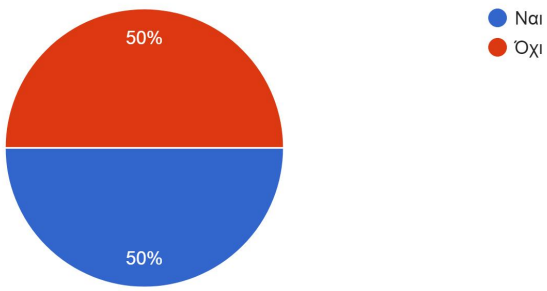


Figure 6

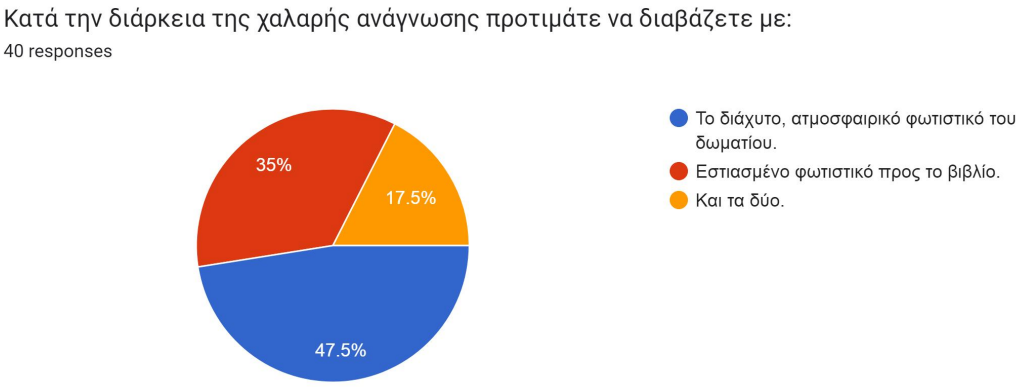
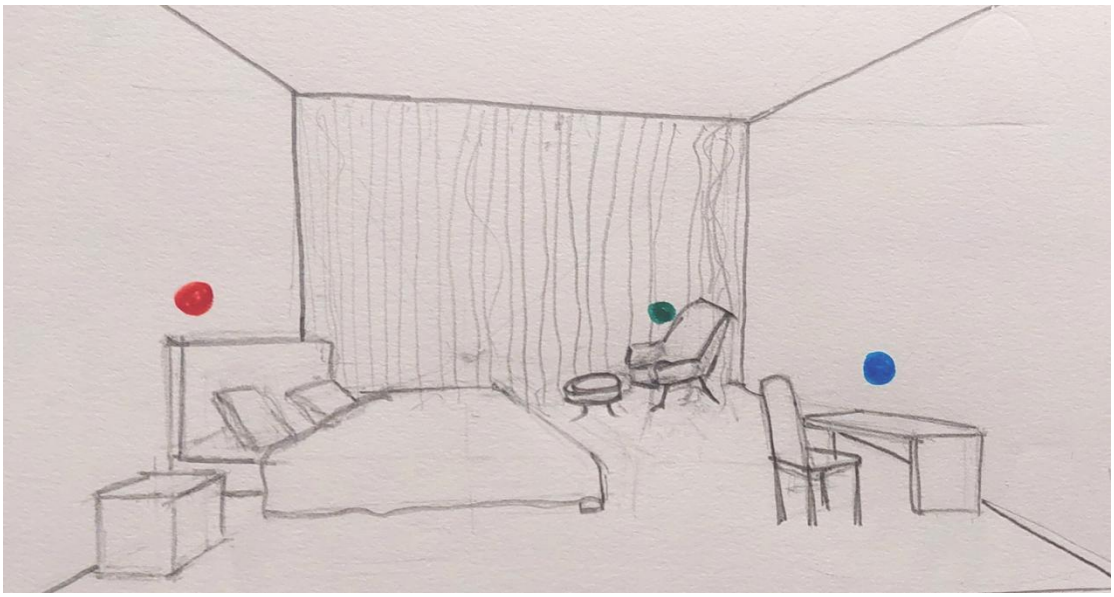


Figure 7

Figure 8



Για το διάβασμα πριν τον ύπνο προτιμάτε:
40 responses

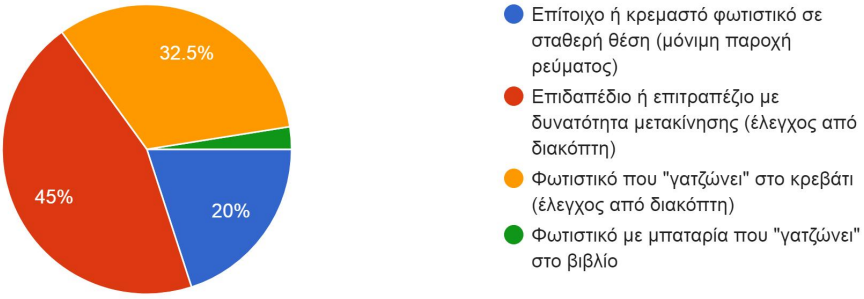


Figure 9

Με δεδομένο ότι ο φωτισμός είναι ο κατάλληλος κατά την χαλαρή ανάγνωση, πόσο σημαντικό είναι για εσάς το φωτιστικό σώμα να έχει ενδιαφέρον design: (1 καθόλου, 5 πολύ σημαντικό).
40 responses

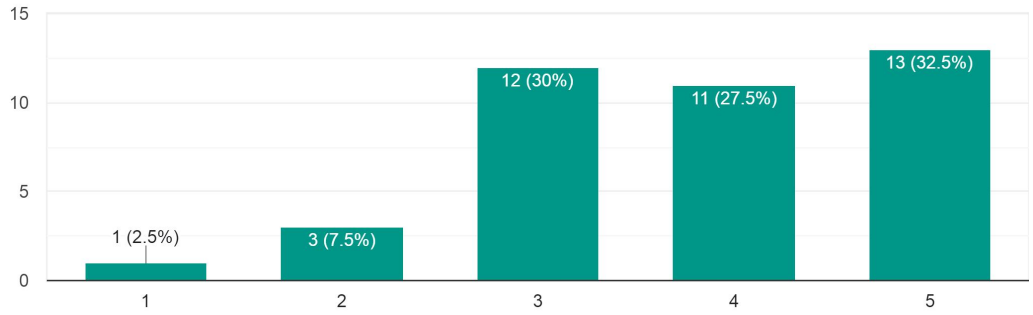


Figure 10

Έχετε νιώσει ποτέ κόπωση στα μάτια κατά την διάρκεια της ανάγνωσης λόγω του ακατάλληλου φωτισμού; Στην περίπτωση που η απάντηση είναι θετική τι πιστεύετε πως ευθύνεται για αυτό:
40 responses

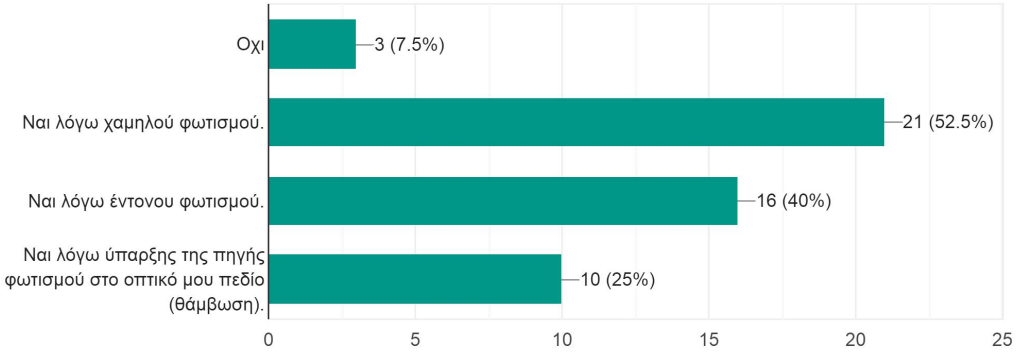


Figure 11

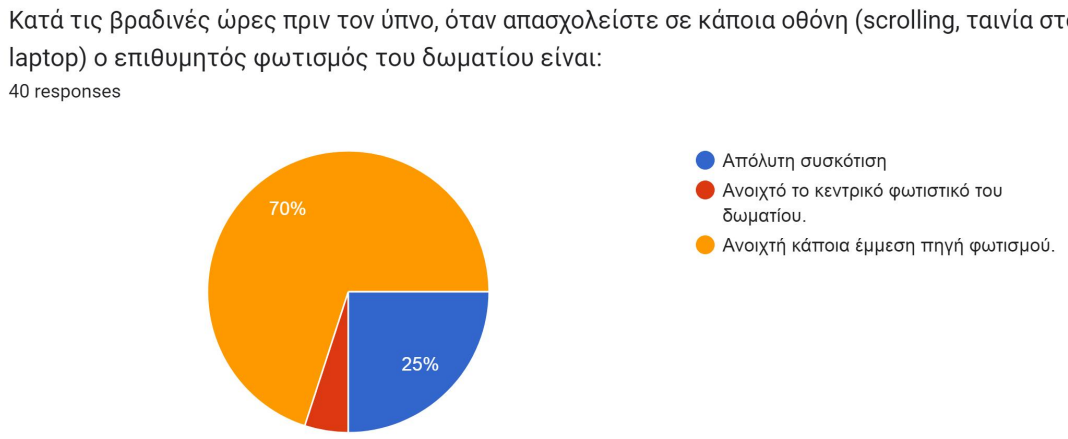


Figure 12

Figure 13

Ergonomic and Photometric Parameters

In the process of designing industrial products for users, input from Ergonomics is crucial for the succesful dimensioning of the product. In this thesis, the product to be designed is an interior luminaire for ambient and/or lighting, the user is a tenant of a short-term room/accomodation (so the user does not belong in a specific target group for example age group). Regarding the context, the space is a bedroom of the short-rental accomodation and the activity conducted by the user is leisure reading.

Three different areas in the room will be examined: (1) bed, (2) lounge, (3) desk.
The input from the questionnaire (40 responses) conducted in the context of this thesis is of major importance, since 77.5% of the users answered that their preferred area for leisure reading would be the lounge chair, 35% answered the bed and only 2,5% or 1 person answered they would prefer the desk. Considering the fact that the sample was taken from people aged 20-40 years old, it would be reasonable to split the focus of this study between the bed and the lounge.

There is an undefiened parameter that depends solely on the owner of the short-term rental room and this is whether the potential lounge area will include a small-sized table or not. In the latter case, as presented in *Image 22* the lighting fixture to be designed shall be either a free standing floor lamp or a ceiling to floor suspended luminaire *Image 21*.

As far as the ergonomic criteria are concerned, input is needed from bibliography and more specifically:

- optimal angle of book when reading
- height of eyes when sitted
- height of hands when sitted
- height of eyes when lying in bed (depend whether in the exact position of the person), some people for example leisure read by lying in the prone position.
- angle of the book in the cases mentioned above

Apart from the input from ergonomy regarding the anatomy of the human body photometric parameters must be taken into account, since the product to be designed is a luminaire.

Area	Illuminance in Lux	Limiting glare index	Minimum colour rendering
General lighting	100	19	80
Waiting rooms	200	22	80
Corridors: during the day	200	22	80
Corridors: at night	50	22	80
Day rooms	200	22	80
Staff office	500	19	80
Staff rooms	300	19	80
Reading lighting	300	19	80
Simple examinations	300	19	80
Examination and Treatment wards	1000	19	80

Figure 14: Photometric parameters depending on activity[vi]

- Lux levels based on the protocol for lighting (EN 12464-1) 100-150lux
(the above table refers to more intense reading, thus 200 lux is sufficient on the surface of the book for leisure reading)
- UGR (Unified Glare Rating) < 19

Since the product to be designed is a lighting fixture and the field of Lighting Design as well as it is basic principles are not widely known, some basic information by the *International*

Comittion for Illumination (CIE)[vii] is provided.

"The purpose of photometry is to measure light as perceived by human eyes. The brightness of a luminous surface depends not only on the amount of radiation it emits, transmits or reflects, but also on its spectral composition and on the visual response function of the observer viewing it. Because human visual response varies at different light levels and from person to person, precise photometry requires the definition of representative standard observers. The CIE system of physical photometry specifies procedures for the quantitative evaluation of optical radiation in terms of internationally agreed spectral luminous efficiency functions for human vision"

More specifically the Guide for Interior Lighting by the publication of (*CIE, Lighting of Work Places Part 1: Indoor*)[viii] contains general information about task lighting, which is part of the design specifications that will be developed at the next chapter.

"Good lighting requires equal attention to the quantity and quality of the lighting. While the provision of sufficient illuminance on the task is necessary, in many instances the visibility depends on the way in which the light is applied, the colour characteristics of the light source and surfaces together with the amount of glare the system gives. In this standard opportunity was taken to specify for various work places and task types not just the illuminance but also the limiting discomfort glare and minimum colour rendering index of the source. Parameters to create comfortable visual conditions are proposed in the body of this standard. The recommended values are considered to represent a reasonable balance, having regard to the requirements for safe, healthy and efficient work performance. The values can be achieved with practical energy efficient solutions.

There are also visual ergonomic parameters such as perceptual ability and the characteristics and attributes of the task, which determine the quality of the operator's visual skills, and hence performance levels. In some cases enhancement of these influencing factors can improve performance without the need to raise illuminance. For example by improving the contrast of the task attributes, enlarging the task by the use of up to date visual aids (glasses) and by the provision of special lighting systems with local directional lighting capability."

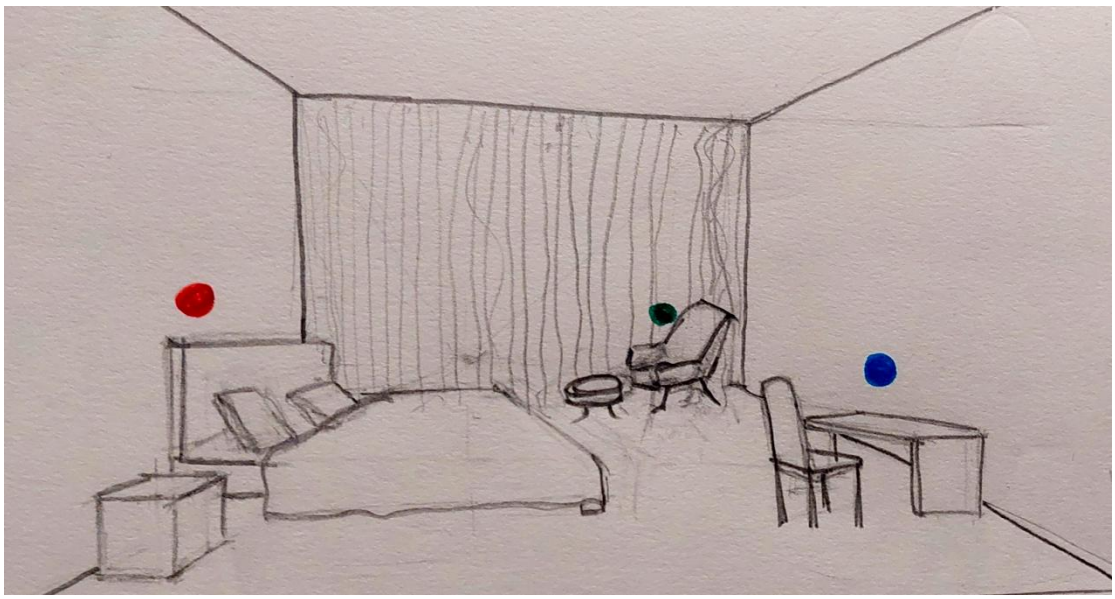


Image 22: Personal Sketch, exploring possible areas for leisure reading

Taking into consideration typical dimensions of a hotel bedroom furniture *(Neufert, 2019)*[ix] the following room 4m x 4m x 2,80m has been designed in Dialux software, where the photometric simulations will be conducted.

The dimensions of the typical bedside table are 400mmx 500mm x 500mm *(Neufert, 2019)*[x] . Based on that and the photometric needs for a comfortable leisure reading session, the maximum height of the product will be 400-450mm and the diameter max 250mm.

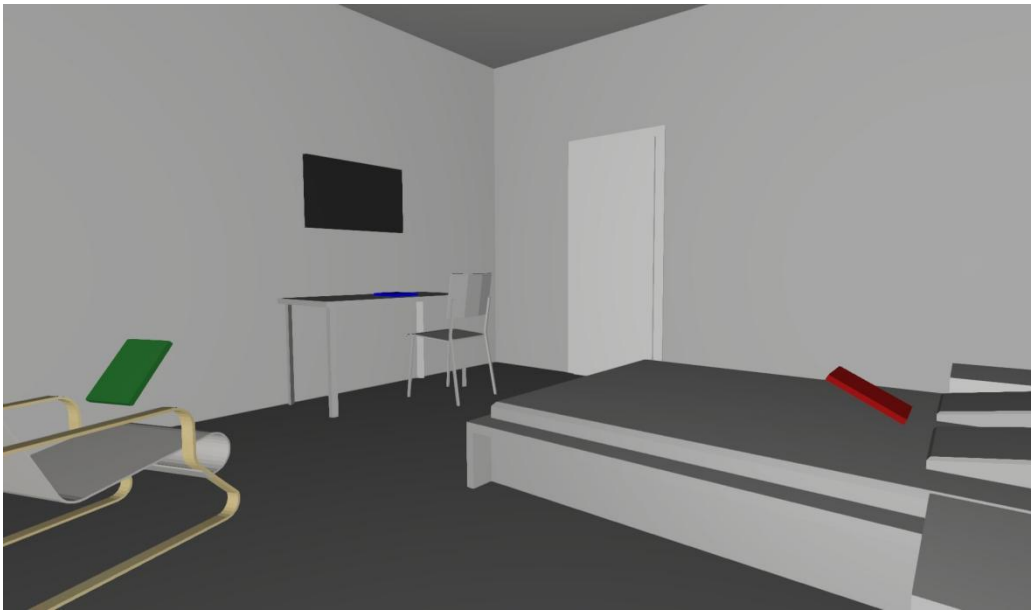


Image 23: Typical Bedroom (Dialux) - perspective view

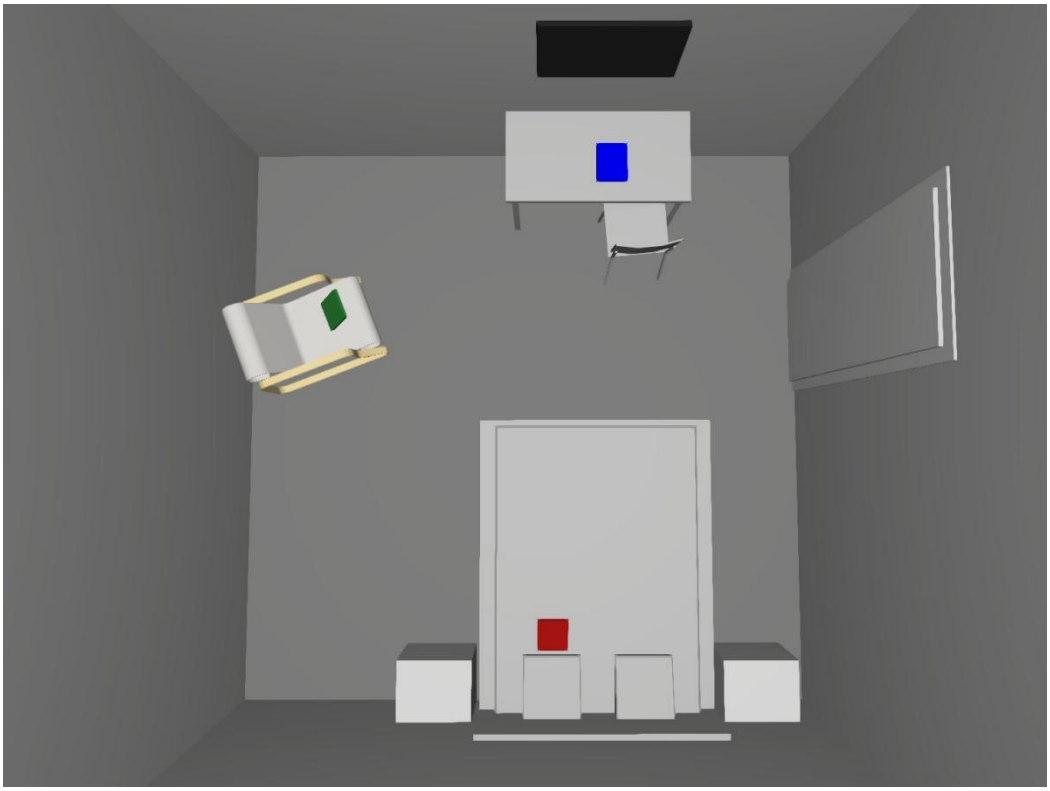


Image 24: Typical Bedroom (Dialux) - top view

Image 25: Indicative photometric simulation in Dialux, different light color temperatures (left 3000K right 2200K)

Image 26: Indicative photometric simulation in Dialux, differenr typologies of lighting for each area in the typical bedroom

Design Specifications

Design Specifications are the main axis of the development of the desired product. Not only they set the direction of design but act as an evaluation tool when the design is finalised. The research input is used among other parameters to the creation of the design specifications. In this point the problem is defined. Features of the product, functionality and problem constraints are the subcategories of design specifications. After the design specifications are defined they should be ranked based on their importance. This hierarchy is crucial for the opportunity tournament stage and the final evaluation of the final design.

The role of design specifications according to (*Sudin,M.N , Andreansen, M.M, Ahmed-Kristensen, S,2010*)[xi] :

“As the role of specification during the design process influences it’s development, this also formed
part of the investigation. The specification plays a vital role in the product development process and
was found to have various roles including :

- Guidance to designers
- Identify trade-off between requirements
- A checklist e.g. during milestone meeting
- Evaluation of solutions to select the one that is most suited to the specification
- An agreement within the design team, and as an agreement with the client e.g. company supplier agreement on fulfilling the design task.
- To trace the likelihood of change propagation.
- Product overview “

Design Specifications

1. Indoor lighting fixture featuring task and/or ambient lighting.
2. The user will change the state of the lighting manually (analogue mechanism).
3. The lighting fixture will be free standing (plug in, socket).
4. The lighting fixture will have a high-end, non-generic aesthetic.
5. Curved form.
6. Dimensions: Max height of body 450mm, max diameter 250m. Floor light: max height 1500mm.
7. Weight : Max 2,5 kg (table light)
8. Maximum retail price 100 euro (table light) and 180 euro (floor light)
9. LED light source.
10. Photometric performance
11. The color temperature of the lighting source will be tunable white (1800K-5000K)
12. The user will have the ability to control the light intensity (dimming).

Chapter 3: Ideation & Concept Development

The design specifications have been set and in this phase a balance between free ideation and the “limits” of the specifications needs to be preserved in order to converge to the three final concepts.

Morphological Chart

Task / Ambient lighting	*Image 27*			
Material for ambient (diffused) lighting	Glass	Ceramic porcelain	PLA - 3D Printed	Fabric
Free standing luminaire	Table	Floor	(Ceiling to floor suspended)	
Analogue mechanism*	The exact form and functionality of the analogue mechanism is an item of research for the detail phase of the product, which is not in the scope of this thesis.			
LED light source	Integrated LED	E27 lamp	GU10 lamp	
Dimming	On board	Wifi smart IoT	DALI (automation system)	Touch sensor
Tunable White	There are options is the range of light color temperature Min. 1800K, Max. 6000K			

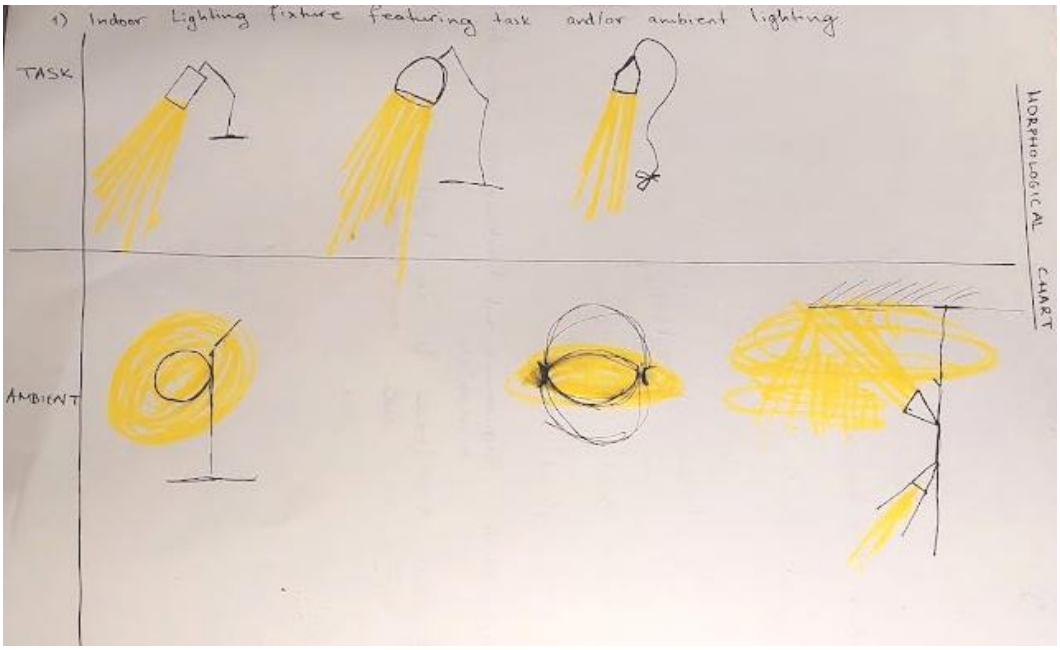


Image 27: Exploring ambient / task lighting alternatives

Lighting source alternatives

The ideal solution of the final design, would be the light source to be LED integrated (ex PCB LED). In that way the design would be more elegant.

Alternatives that comply with the specifications (luminosity dimming and dynamic white color temperature) do exist.

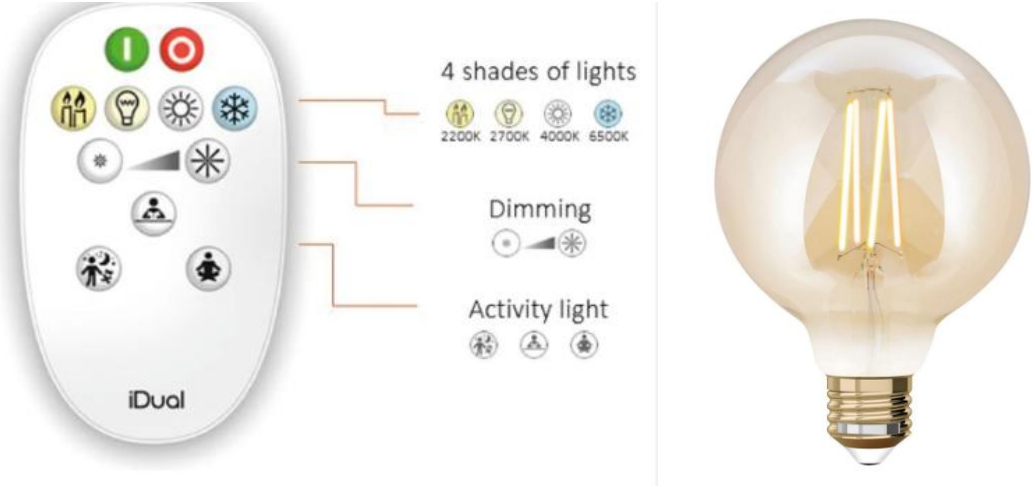
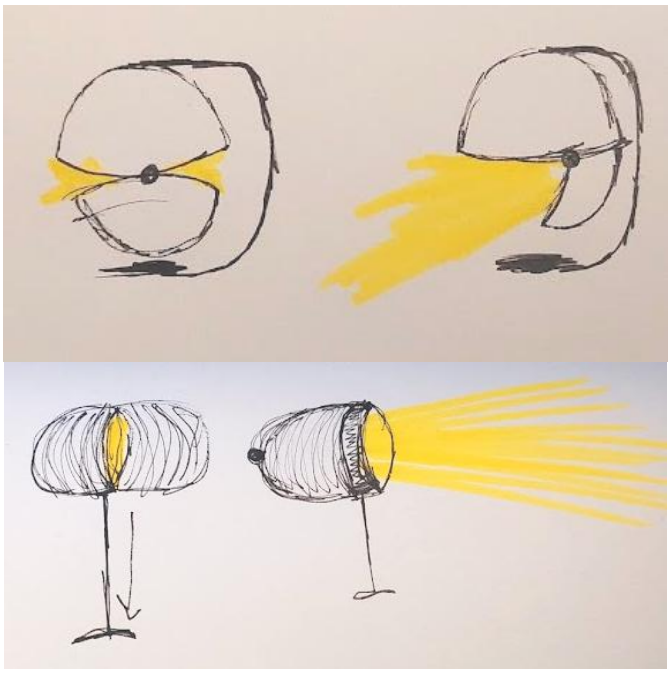
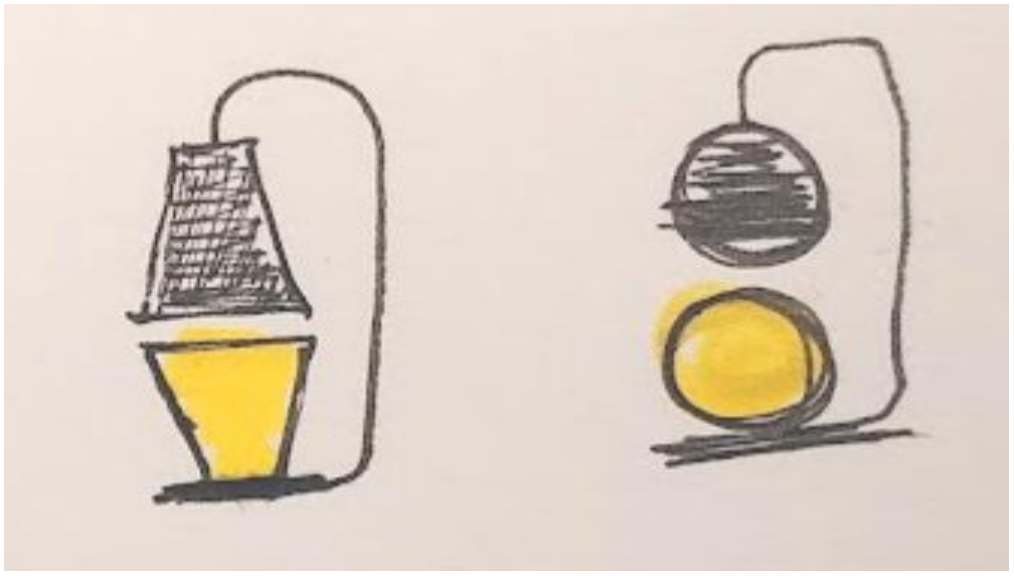
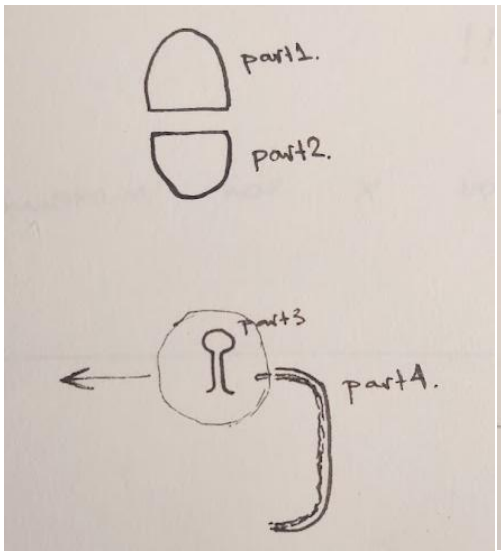


Image 28: Smart E27 LED lamp (9W, 806lumen, dynamic white and dimmable), retail price 20euro

Ideation Sketches






part1.
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part3
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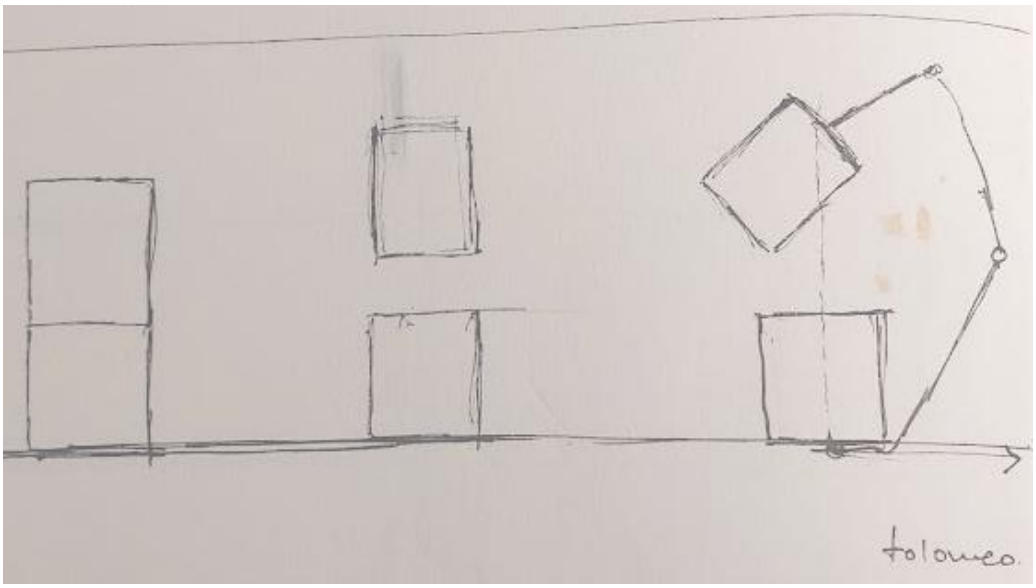
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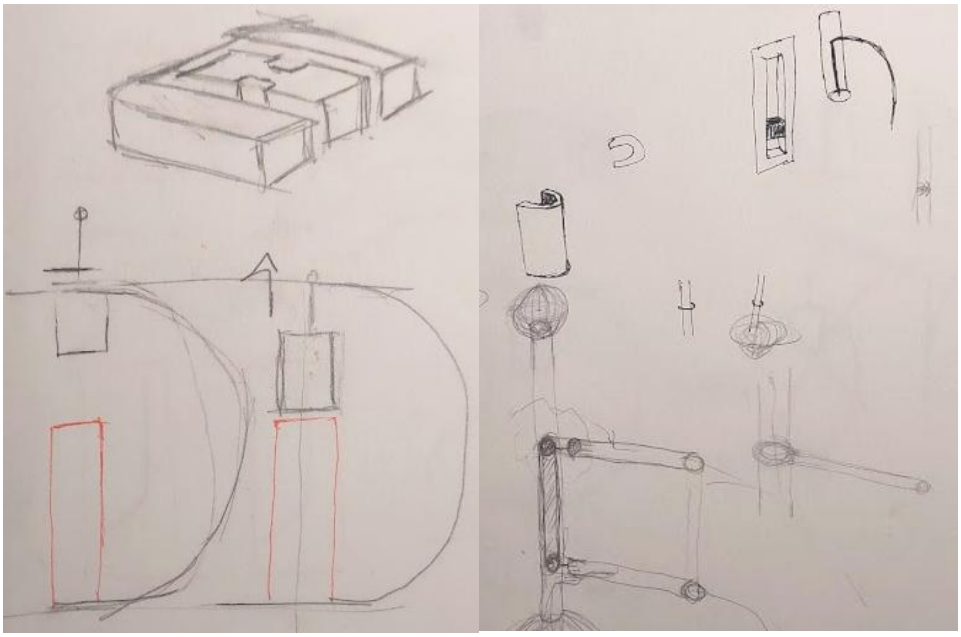
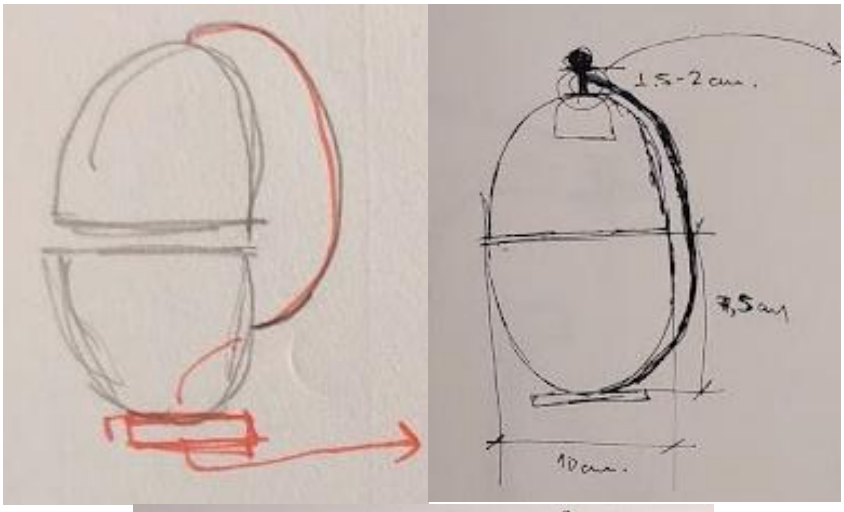
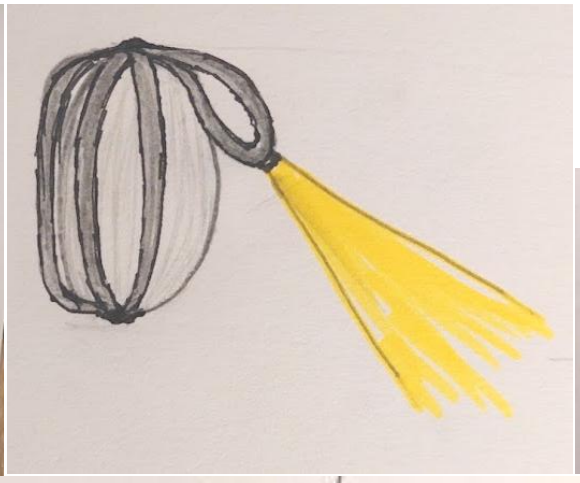
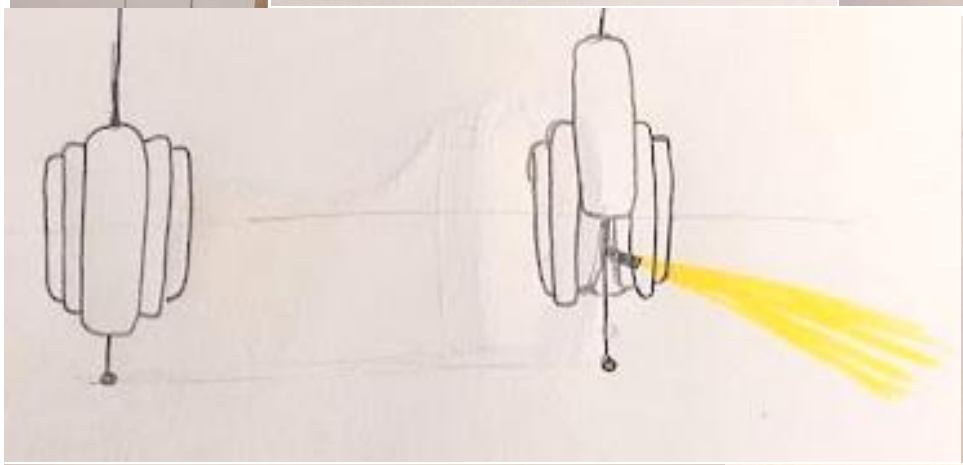
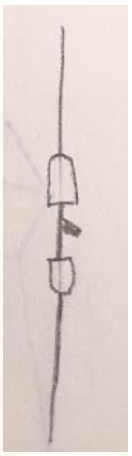
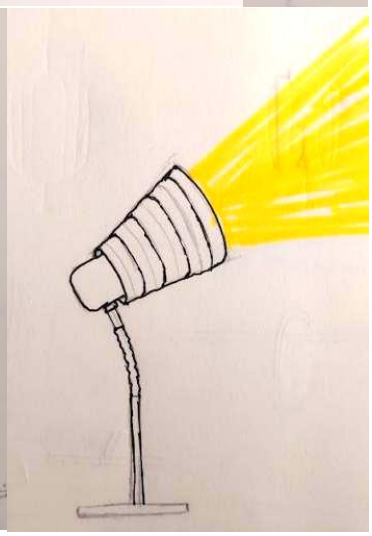



1.5-2 cm.
7,5 cm
10 cm.









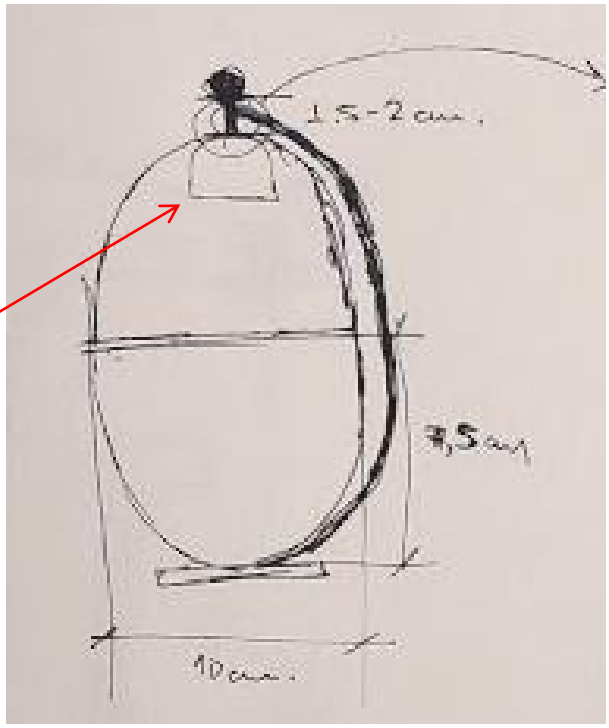
Concept 1

The aesthetic of the first concept is high-end and the composition of geometries / elements led to the design of a balanced form inspired by the art - decomovement. Personally, in this preliminary phase I was sure that my final design would be the development of this concept.
The oval shape of this design resembles of an egg and the overall aesthetic is unique and elegant. As far as the analogies are concerned the ones presented in *Image 28* are the desired ones. At start the support of the upper part and the cabling passage was designed as a central axis *Image 29*.

The LED light source is placed in the center of the upper part and it can be either a GU10 lamp (solution for possible prototype) or an integrated LED with a beam angle of 30 degrees.
The presence of the lighting source in the center of the geometry is one of the basic reasons that led to omitting the support element to be a central axis. The next solution, regarding both the support of the upper part and the cabling passage is as presented in
Image 28 a curved metal shell structure, that follows the form of the main body.

As far as the materiallity of the proposed preliminary design is concerned the upper part is an Aluminum 6060 metal shell (approximate thickness of the shell 1-3mm). The Al6060 for the specific design will be coated with a matt champagne gold or copper finish.
The lower part of the design is preferably thin and transluscent porcelain. Alternatively it could be a transluscent marble (ex. Onyx). But in the later case, the weight as well as the cost of the product would increase which is undesirable for a product that will be placed in a short-term rental apartment. A high-end aesthetic is desirable but it can achieved with more cost-effective materials. Another solution would be opaque / frosted glass, which is also fragile as the initial proposed material of porcelain. Between the two material, the choice is the porcelain. As stated in the research chapter, a general need / desire of the user of the product is authenticity. Porcelain feels more authentic, handmade and adds value in the overall aesthetic and aesthetic of the product. Additionaly, porcelain is a ceramic, thus it is one of the best high voltage insulation materials, and is also a good thermal insulator.

An efficient solution are materials that could be 3D printed, such as marble PLA which are considered a composite filament because of the additional materials used in the filament composition. Composite fillaments have the important advantage of infragibility, low thermal conductivity (Islam,Bhat,Sikdar, 2023)[xii]. For the particular application of diffusing light, 3D materials are a good choice since their composition can be adjusted depending on the need.



Light source
Cable passage throught the side curved arm

Image 29: Sketch Concept 1, initial dimensioning

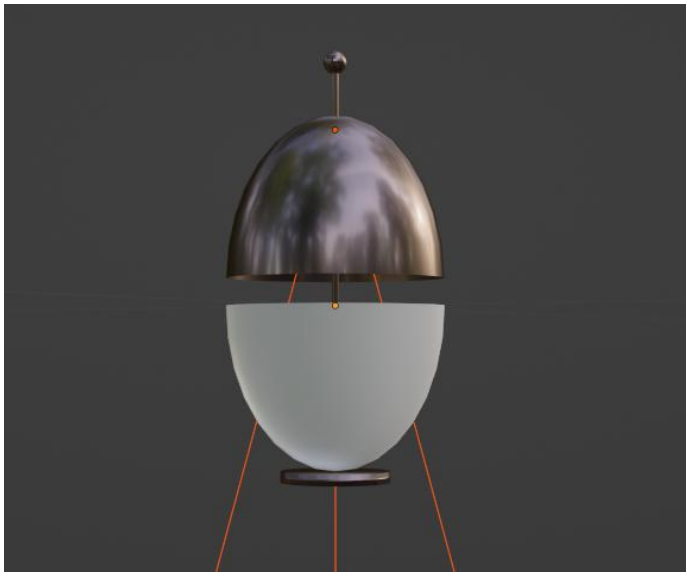


Image 30: Initial 3D of Concept 1 - ambient lighting

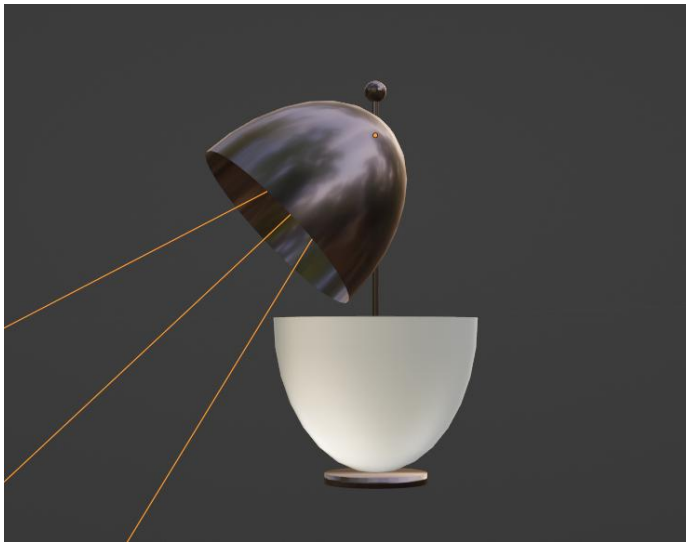


Image 31: Image 32: Initial 3D of Concept 1 - task lighting state 35 degrees tilted

The main challenge of this preliminary design, is the analogue mechanism that allows two degrees of freedom for the product, which are : vertical motion (approximately 50mm) and tilting of 30-40 degrees (rotation in one axis) when the user wants to leisure read (task lighting mode). The user can control and define the movement of the upper part from the sphere on the top off the structure. A preliminary idea for the relative movement of the two parts is similar to the railing motion (ex. drawers). The curved side arm is in a fixed position and the upper part is moved.

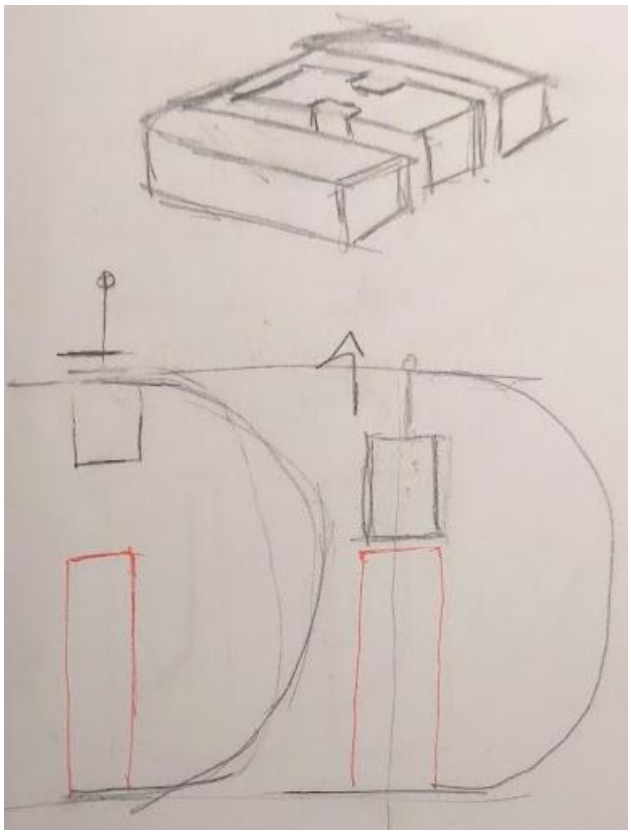


Image 33: Fixed curved side arm, vertical motion of the upper part and rotation at its final

position.

Image 34: Reference image of lit onyx - soft and ambient lighting

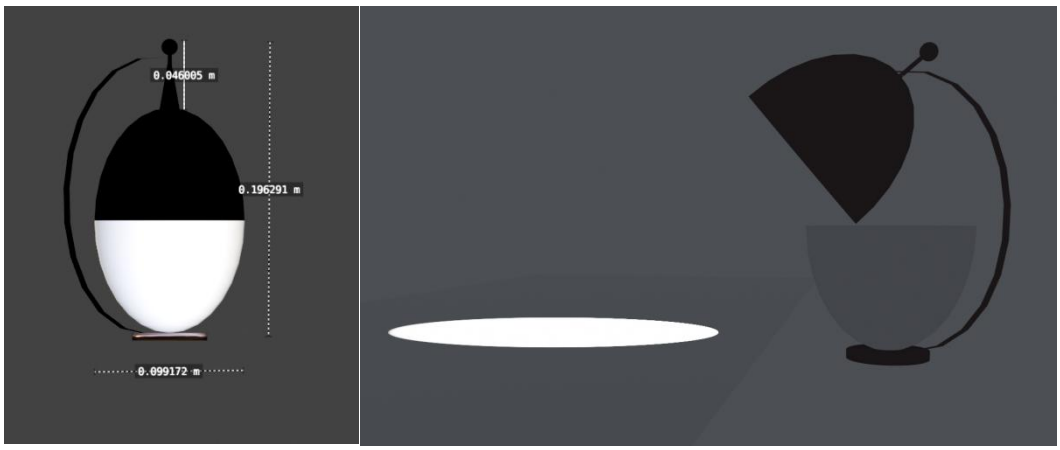


Image 35: Concept 2 diffusive and task lighting.

In order for this design to be successful, the upper part has to close on the lower part. Any gap, will spill light out of the shell and the desired effect of ambiet / diffusive lighting will not be achieved.

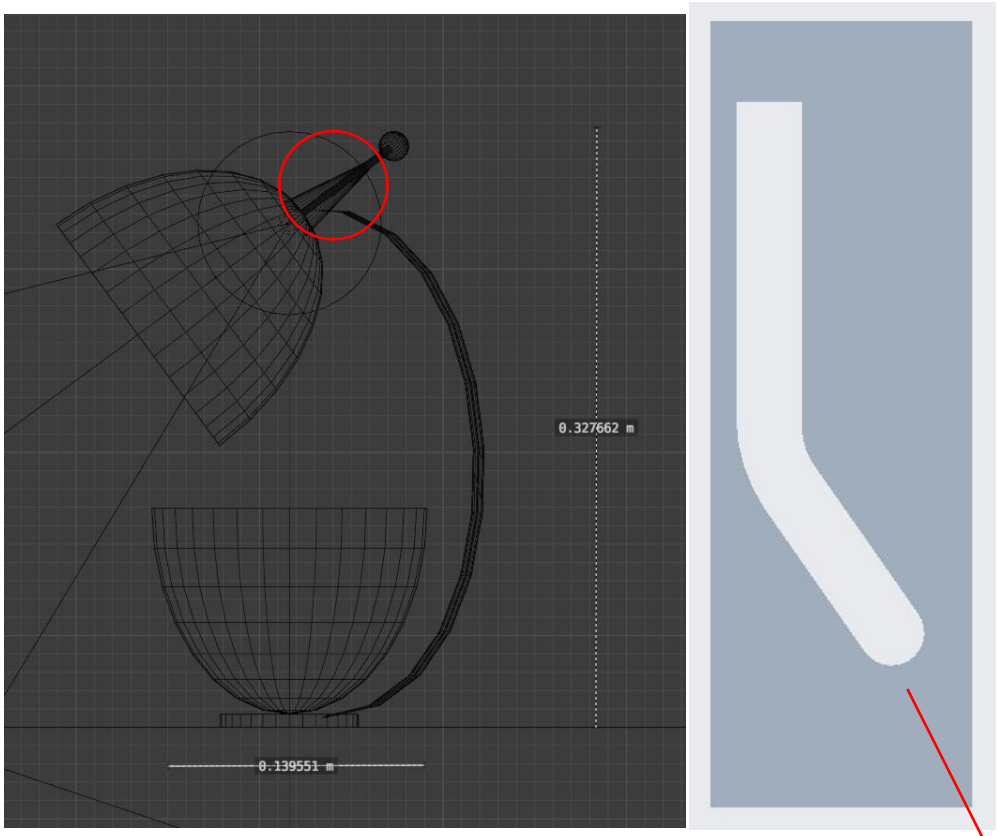


Image 36: Side view of second concept - task lighting tilted 35 degrees.

As presnted above, the element that is marked with red has been altered from a cylinder to a cone, in order for the inner engraved trail (motion mechanism) to fit.

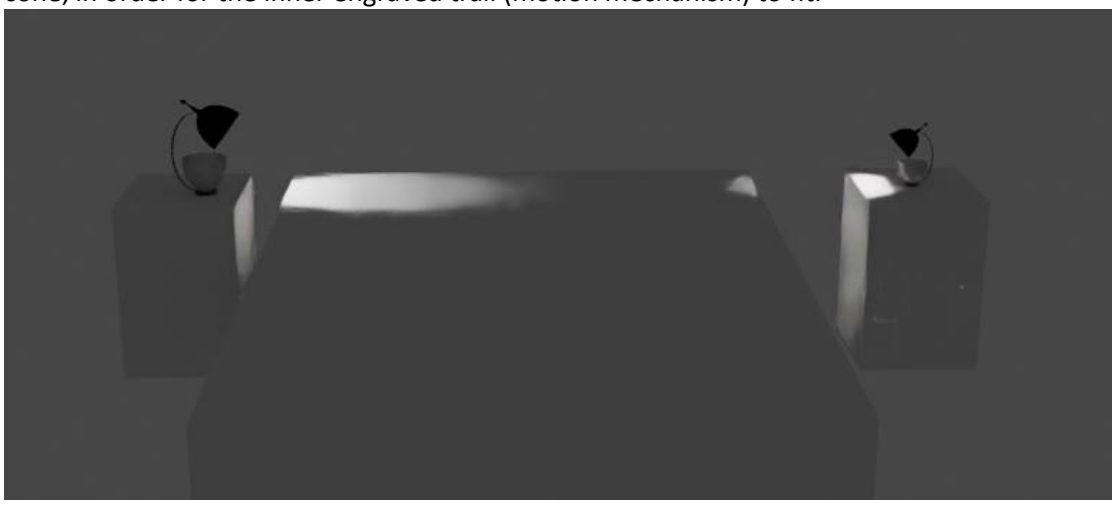
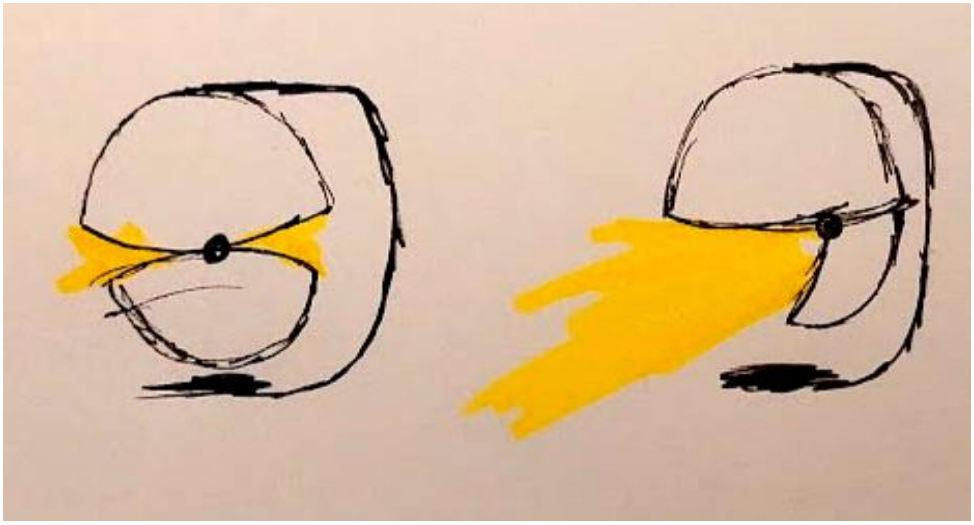


Image 37: Resizing of the initial design.

In order to achieve the lighting targets, the analogies of the product are the same but the porduct is scaled up 1,5*initial size. The maxiumum height is 350 mm and the final diameter 150mm.

Concept 2



The form of the second concept is based on two deformed shells of a hemisphere.
The initial dimensions of the product are presented bellow:

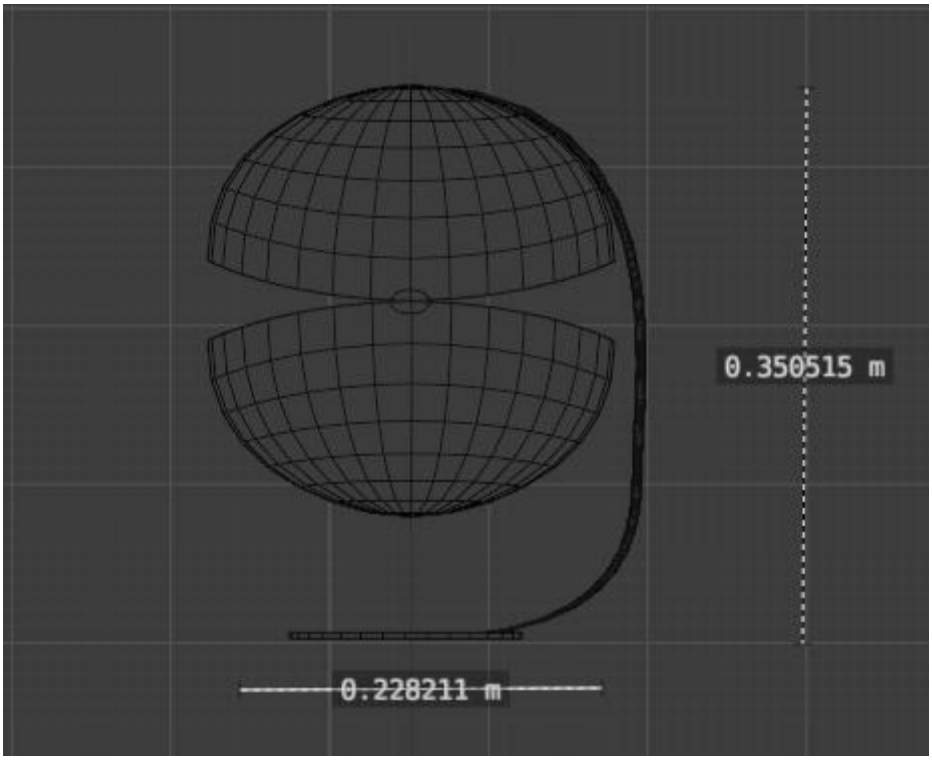


Image 38: Side View of the second concept

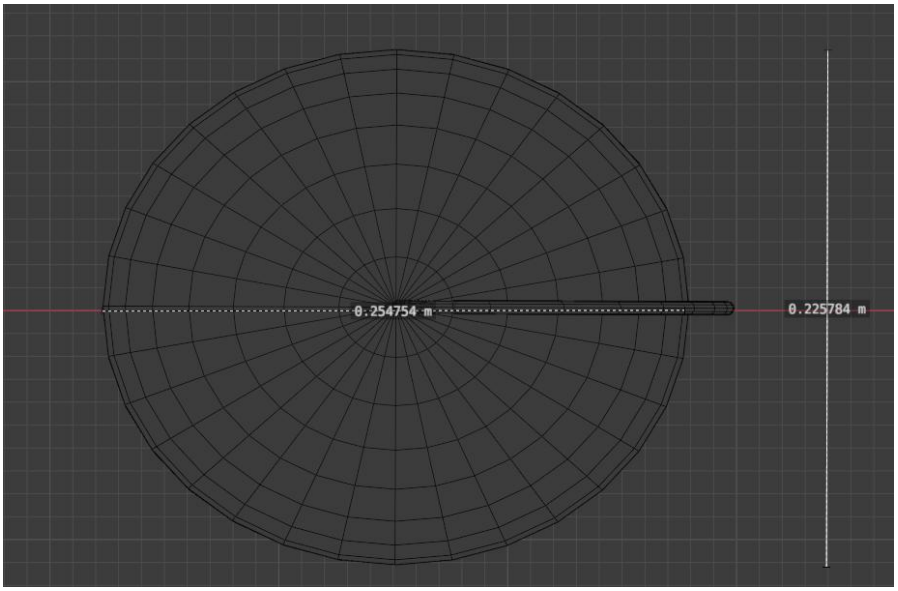


Image 39: Top view of second concept

The material of the product is metal, it could either have a high gloss or not it is not yet decided. As far as the outer surfaces are concerned it would be interesting to have a high gloss and low roughness, in order to resemble a mirror-effect. The inside of the shell should not have the same mirror-effect, because the light source will be reflected and it is possible to cause glare, especially in the case of leisure reading in the bed.

The way the user alters the functionallity of the lamp from ambient to task lighting and vice versa is by rotating the bottom shell within the upper. In this case there is one degree of freedom (rotation in one axis) and the motion is swivelling depending on the placement of the luminaire. The advantage of this case, is as shown in *Image 26)* the user can cut-off the light when lying in bed. (The light is directed towards the other side).

Regarding the light source, a GU10 lamp with a minimum beam angle of 45 degrees can be placed on the inner side of the top shell or an integrated LED can be placed in the same position. The advantage of the later solution is that the height of the light source will be lower and the color of the light can be adjusted by the user, tunable white as specified in the previous chapter.

For the adjustment by the user of the intensity and the color temperature there are three possible solutions.

- Two rotatable mini switches could be adjusted on the base of the lamp
- The LED (intensity of light) can be controlled by the automation building system (if existing KNX, Lutron) and the color temperature by a smart system. The luminaire can be an IoT device and the user can adjust the desired intensities alternative from an app.
- These two parameters (luminosity levels and light temeperature) can be adjusted from a touch sensor on the base of the luminaire.

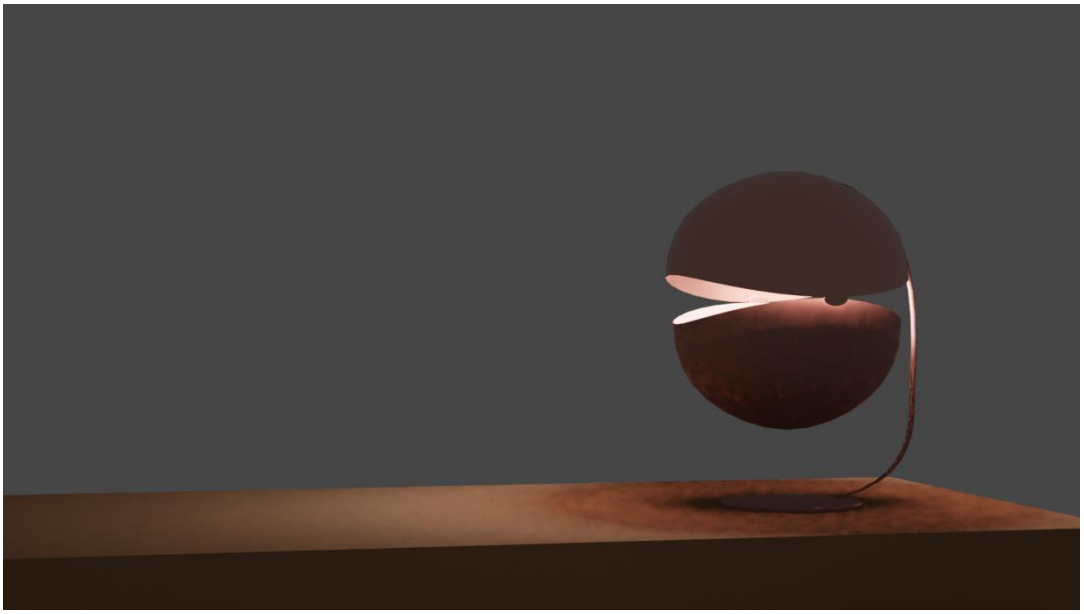


Image 40: desk, ambient lighting

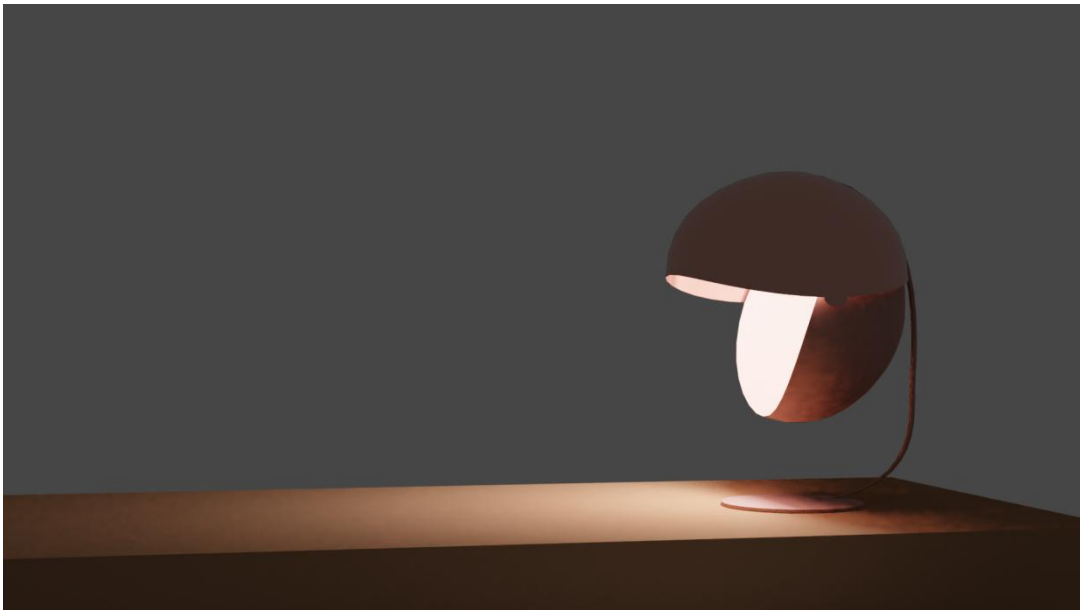


Image 41: desk, task lighting

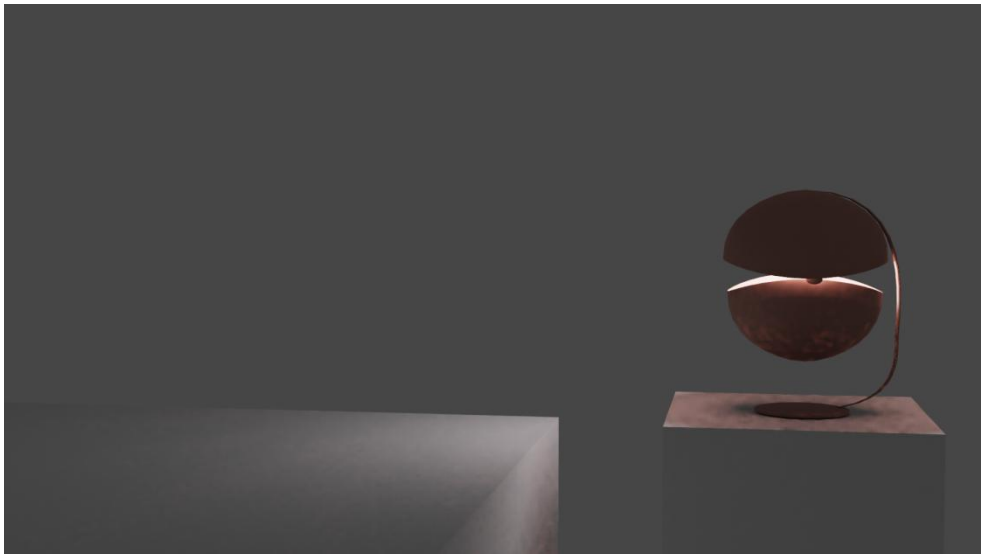


Image 42: bedside, ambient (state 1)

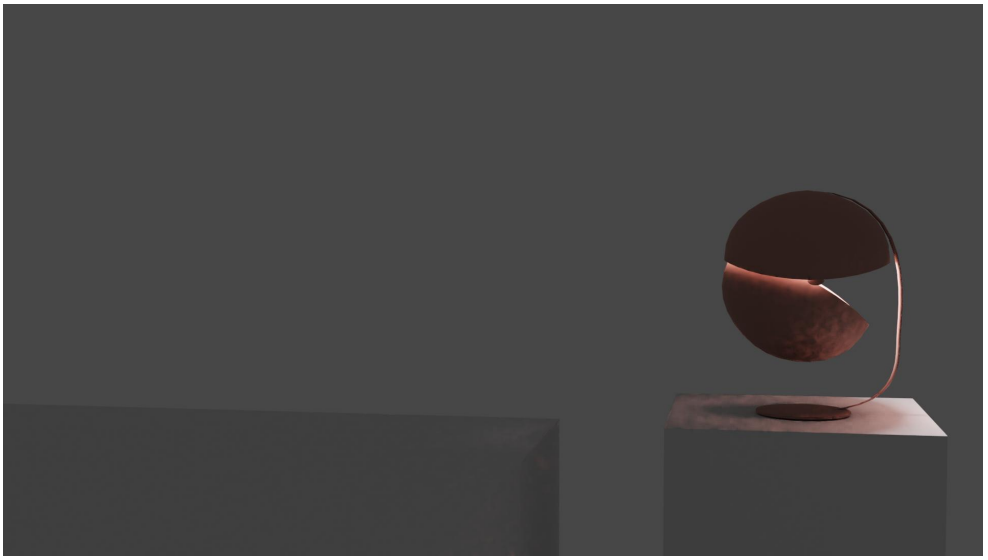


Image 43: bedside, ambient (state 2 - cutting off lighting at bed)

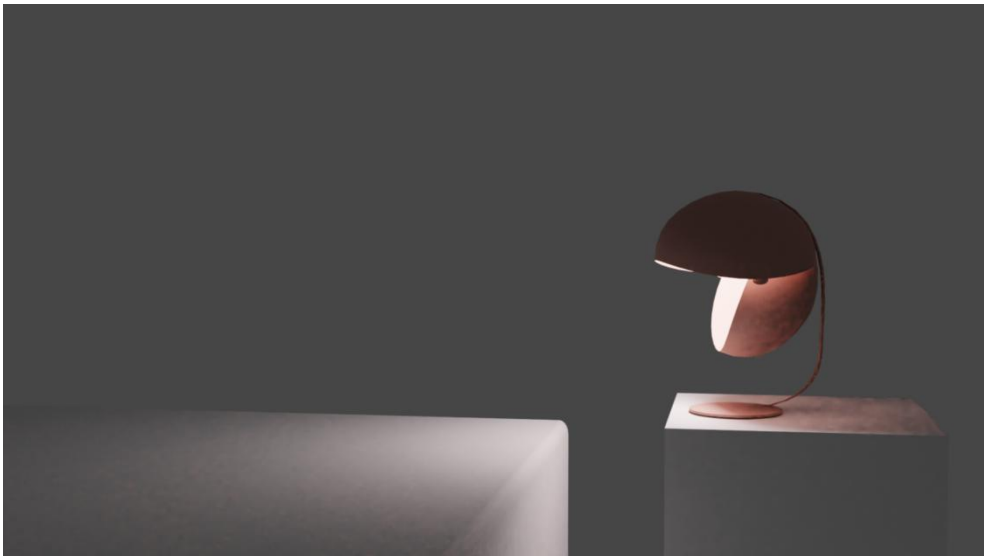


Image 44: bedside, task light - leisure reading

Concept 3

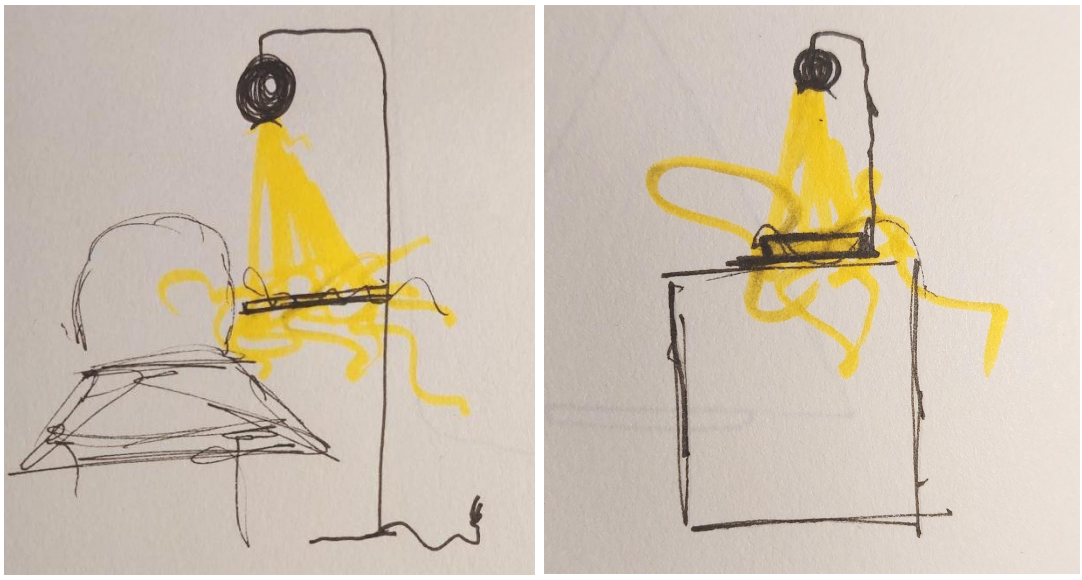


Image 45: Personal Sketch, Third Concept (floor and table version)

In the presentation of the third concept, the differentiation from the first and the second is profound: In this case the floor free standing version of the preliminary luminaire concept. Thus, in the final concept a “family” of products is generated. The reason why the floor lamp version is introduced, is because in the questionnaire 77.5% of the users answered that theiw preferred place to leisure-read in a short-term rental, is the lounge.

The form of this concept (Aluminum structure, glossy anthracite finish), as far as its task lighting function is concerned is basic including the tilting mechanism. The dimensioning has been conducted in order to comply with the ergonomic criteria(anatomy and photometry). The interesting feature of this concept is the unique feature that has been integrated, an acrylic element (tensile and bending strength is needed in the case of the surface presented in the floor version). This element will be transparent and purposedly have a distorted and anisotropic structure. Thus, when the LED source is vertical on the horizontal plane, lighting rays are diffused and refracted in a randomized manner. This behaviour of the material is captivating for the user.
In this concept, as presented in *Image 47* the dynamic white feature of the LED source (ability of the user to change color light temperature from 1800K warm to 5000K) is well visualised with the transparent-distorted acrylic that resembles of ice and diffuses light.

This concept was inspired by the refraction that occurs in diamonds. In the context of ideation and exploration with the 3D rendering software the following abstract visuals of “peculiar” and extreme aestheticwhere produced. They are not part of the concept, they are presented in order to comprehend the indeed iterative and sometimes chaotic procedure of concept development. The concept of this material that resembles in a way the behavior of diamond ignited the development of the third concept.

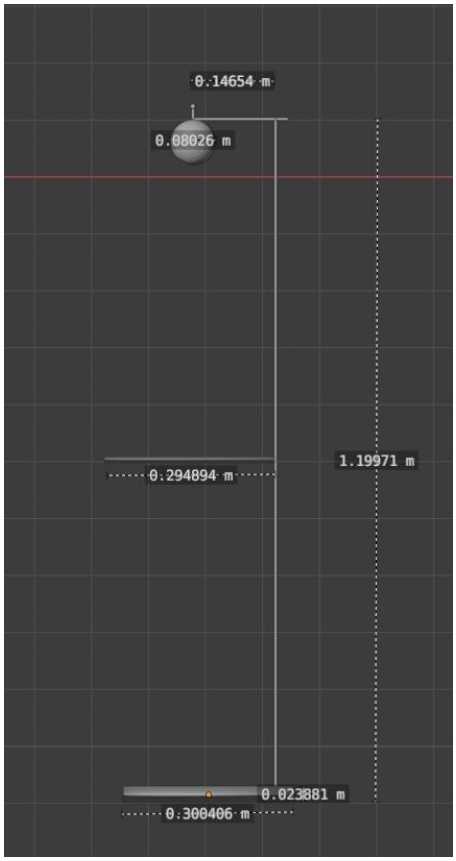


Image 46: Floor version of concept3, initial dimensions

Image 47: Floor luminaire version of concept 3

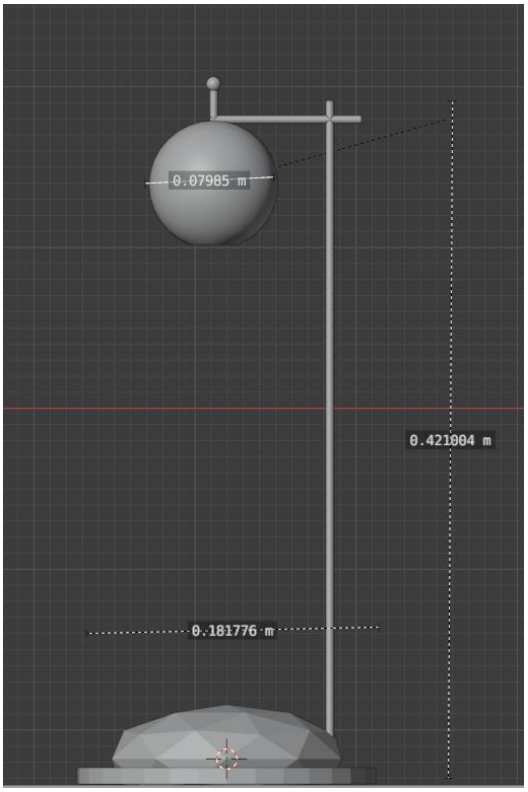


Image 48: Table luminaire version of concept 3, initial dimensions

Image 49: Table version of concept 3, cool 5000K - warm 1800K light color temperature (dynamic white)

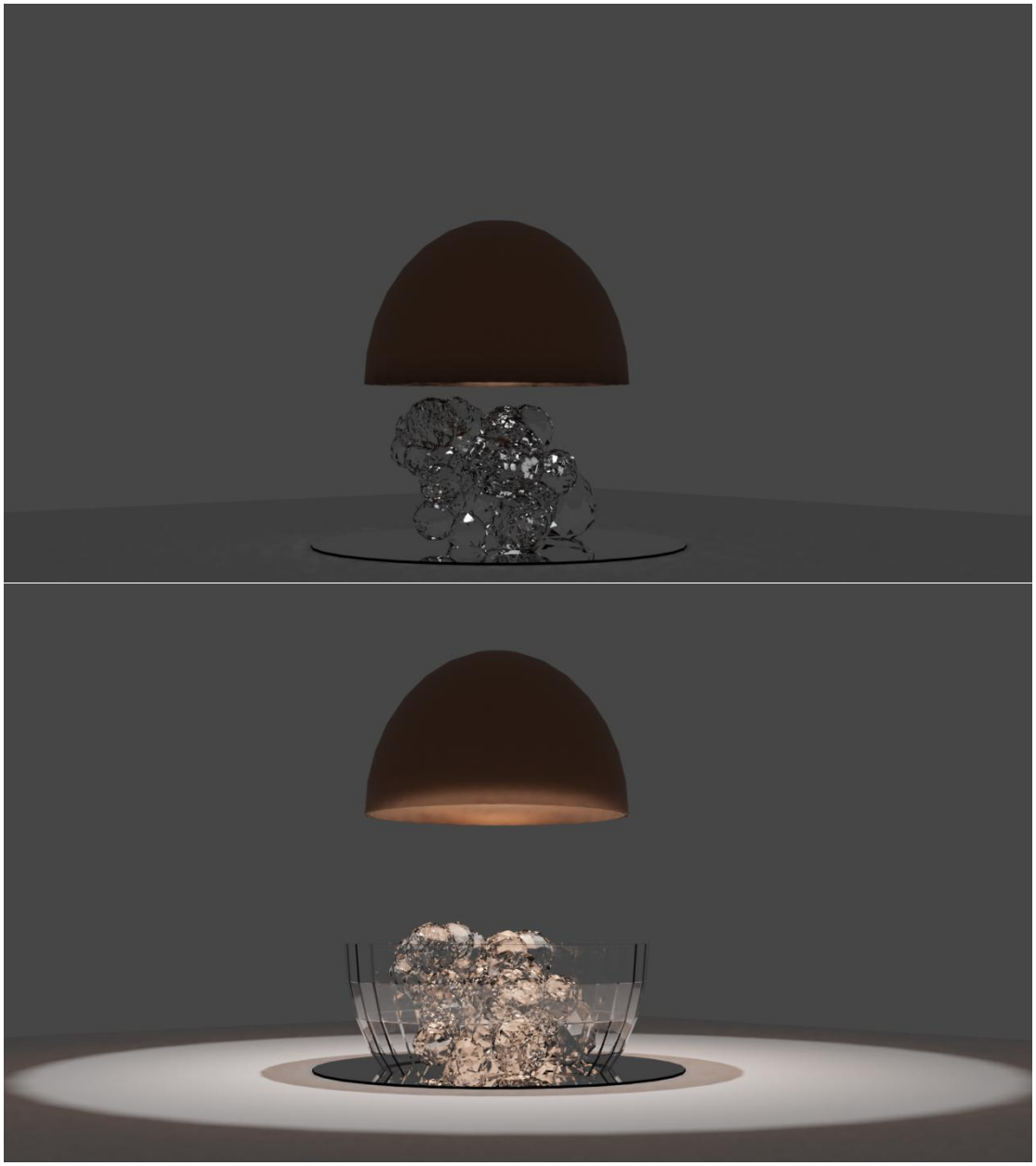


Image 50: Abstract visual exploration of the interaction of transparent isospheres with light.

Chapter 4: Final Design Development

Opportunity Tournament

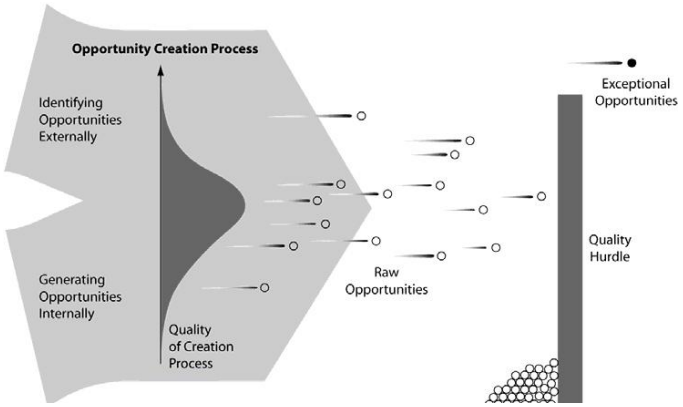


Figure 15: Opportunity Tournament, *(Christian Terwiesch and Karl T. Ulrich,2008)*[xiii]

The three concepts is essential to follow the design specifications.
In industrial design and especially prior to the process of the final product development an intermediate evaluation of the preliminary designs is conducted, there can be cases when the context is reframed and specifications may be adjusted.

As stated above concept 3 is omitted, due to its very specific aesthetic that is not desirable.
The need for a floor version of the lighting product occurred after gaining the results from the questionnaire, where the majority of the users (77.5%) stated that their preferred space of studying is the lounge area. So the lighting product of concepts 1 and 2 should be able to be adapted in a free standing floor version.

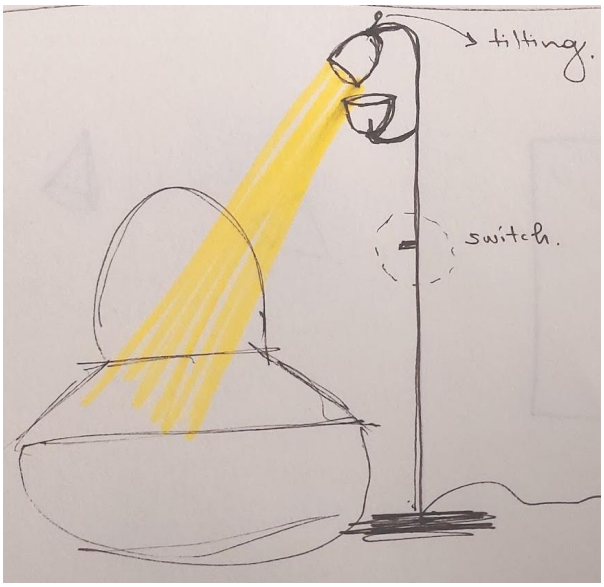


Image 51:Personal sketch, floor version of concept 1

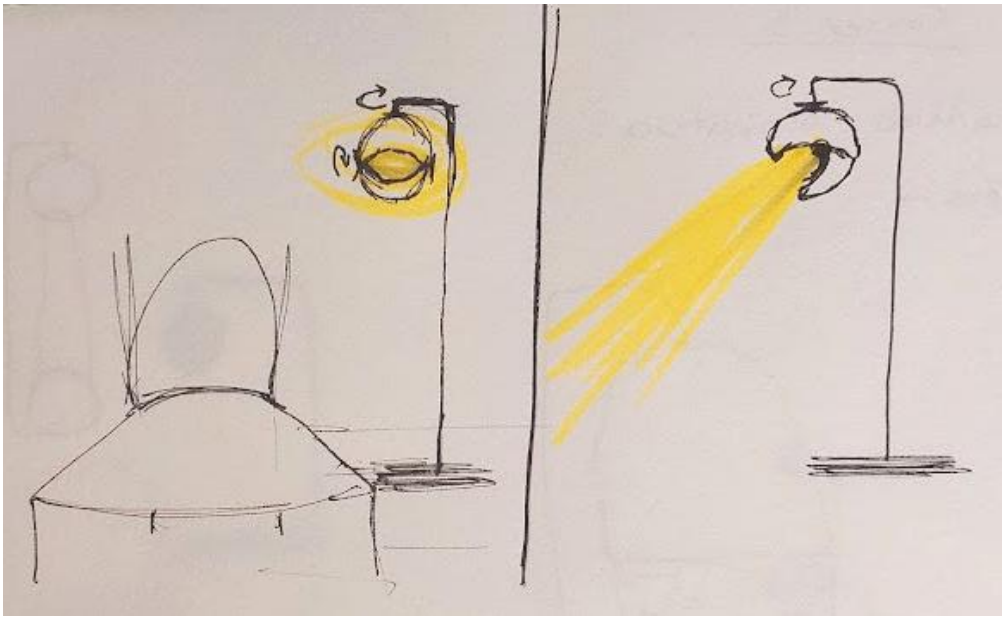


Image 52: Personal sketch, floor version of concept 2

The comparative / evaluation table regarding the 2 concepts and the design specifications:

Design Specification	Concept 1	Concept 2
Task / Ambient Lighting		
User controls the state (mechanism)	More complex	
Free Standing version (table and floor)		
High-end, non-generic aesthetic	Porcelain:adds aesthetic value (authentic experience)	
Curved form		
Dimensions		
Weight	Heavier	
Cost (retail price)	More expensive	
LED light source		
Photometric performance (task state)	Better in the task lighting state	
Tunable/dynamic white	Better effect due to porcelain	
Light intensity dimming		

Table 1: Comparison of two concepts / Opportunity tournament.

From the table above, which is a tool for comparing the two concepts as far as the design specifications are concerned both of the concepts seem to have a balanced share of pros and cons. The decision parameter in this case which is crucial because it is part of the brief, is that the context of use of the lighting product is a short-term rental accomodation. Thus the customer (owner of the property) that will buy the product is not the end - user and for this reason the parameters of cost and fragility lead to the conclusion that **the Lighting Product of Concept 2 is qualified at the opportunity tournament** and that this is the final product (preliminary design, in this thesis the detailed design phase is not examined) corresponding to the brief .

Chapter 5: Conclusion

For the specific brief, **Concept 2 is assessed as the suitable** at the opportunity tournament decision-making phgase of the previous chapter. It is crucial to state that this thesis has a conceptual and preliminary design orientation and thus the detail design process is not conducted.

In case of a prototype, the table lamp version will be tested. As far as the floor lamp is concerned its dimensioning and detail design (the possibility of overturn should be taken into consideration) will be simulated in CAD software. The aim of this thesis is to develop the preliminary designs, thus the detailed design is for future research.

An interesting part of the design process is that every step is insightful and useful and that it is an iterative process which many times can lead to a re-frame of the “problem”. Specifically for the lighting product design of this thesis, a personal conclusion is that Concept 1 is more suitable for a private residence and thus it would be desirable to test both at a personal future prototyping procedure. Both of the forms are unique and could add value in the residential lighting design industry for featuring both task and ambient lighting.

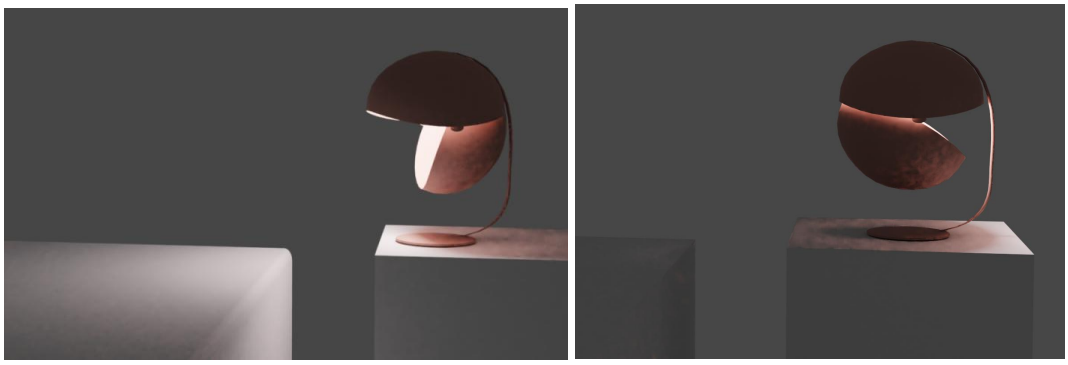


Image 53: The final product of Concept 2 “The Shell Lamp” (bedside)

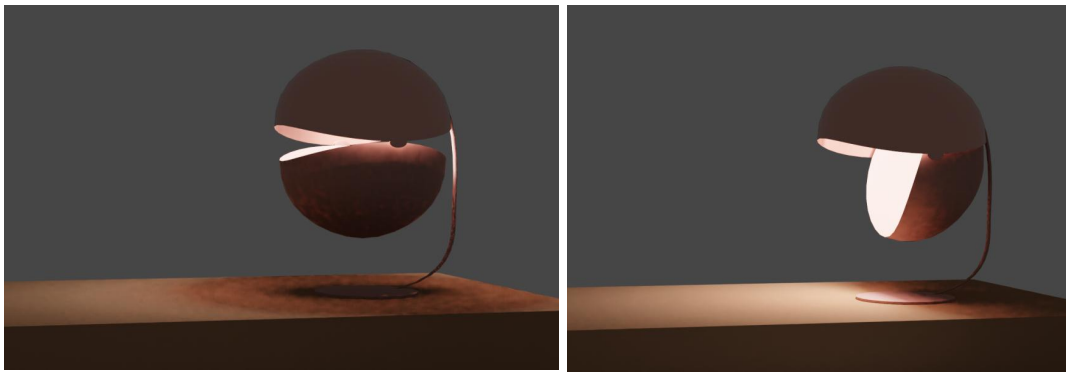


Image 54: The final product of Concept 2 “The Shell Lamp” (desk)

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