<u>STUDIES ON ENERGY EFFICIENT LIGHTING SOLUTION FOR SATYAJIT RAY FILM & TELEVISION INSTITUTE</u>

A THESIS

SUBMITTED TOWARDS PARTIAL FULFILLMENTOF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ENGINEERING

IN

ILLUMINATION ENGINEERING

Submitted by

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REGISTRATION NO.: 163496 of 2022-23

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KOLKATA – 700032

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KOLKATA – **700032**
INDIA

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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled "**Studies on Energy Efficient Lighting Solution for Satyajit Ray Film & Television Institute**" is a bonafide work carried out by **Moniruzzaman Sk** under my supervision and guidance for partial fulfillment of the requirement of MASTER OF ENGINEERING IN ILLUMINATION ENGINEERING, during the academic session 2023 - 2024.

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CERTIFICATE OF APPROVAL

This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented in a manner satisfactorily to warranty its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn therein but approve the thesis only for purpose for which it has been submitted.

Committee of final examination for evaluation of Thesis ---

DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS :

It is hereby declared that this thesis contains literature survey and original research work by the undersigned candidate, as part of his MASTER OF ENGINEERING IN ILLUMINATION ENGINEERING, studies during academic session 2023- 2024.

All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by this rules and conduct, I have fully cited and referred all material and results that are not original to this work.

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Content

Abstract:

This thesis investigates the implementation of energy-efficient lighting systems in museums and classrooms to reduce energy consumption and enhance user experience. With lighting accounting for approximately 15% of global electricity use, transitioning to energy-efficient solutions presents significant economic and environmental benefits. Museums and classrooms, with their unique lighting requirements, stand to gain from advancements in lighting technology.

The study begins with an assessment of current lighting systems in the museum and classrooms in SRFTI, using energy audits to measure existing energy consumption. It then explores various energy-efficient lighting technologies, including LEDs, CFLs, and smart lighting systems, considering factors such as illuminance, color rendering, and user comfort.

A cost-benefit analysis evaluates the financial implications of adopting these technologies, while pilot tests and user feedback provide insights into their practical performance and acceptance. The proposed lighting designs aim to achieve optimal energy savings and improved lighting quality tailored to the specific needs of museum displays and educational environments.

Results indicate significant energy and cost savings, along with positive user feedback on lighting quality. This research underscores the importance of energy-efficient lighting in reducing operational costs and environmental impact, while enhancing the functionality and aesthetics of museums and classrooms. The findings offer valuable recommendations for institutions considering similar upgrades and highlight areas for future research in energy-efficient lighting applications.

❖ Overview of the Thesis:

I. **Chapter 1:** Provides the introduction, objective and the overview of about thework.

II. **Chapter 2:** It gives the information about the literature review and background of the work.

III. **Chapter 3:** This chapter provides information about the Human Centric Lighting for Interior space , its necessity, Benefits and Energy Savings.

IV. **Chapter 4:** In this chapter, it dealt about the Survey on Existing Lighting conditions of the interior lighting,and detail of the interior lighting survey of the Satyajit Ray Film & Tele-vision Institute.

V. **Chapter 5 :** This chapter tells us about the different National & International Standards for Museum and Classrooms Lighting.

VI. **Chapter 6 :** In This Chapter We discuss about the Computer Aided Lighting Design solution for a Museum and Classrooms.

VII. **Chapter 7:** This chapter provides the conclusion and future possibilities of this work.

- References
- Appendix
  Contains the brief discussion of the components used in this project.

Chapter : 1

Introduction

1.1 Introduction:

In today's rapidly evolving world, the quest for sustainable solutions has become more imperative than ever. As concerns about energy conservation and environmental impact continue to grow, the focus on optimizing energy efficiency across various sectors has intensified. Within educational settings, where lighting plays a pivotal role in fostering conducive learning environments, the exploration of energy-efficient lighting technologies becomes paramount.

This thesis embarks on a journey to investigate the potential of energy-efficient lighting systems in enhancing classroom environments. At the intersection of sustainability, technology, and education, this study delves into the benefits, challenges, and implications of implementing energy-efficient lighting solutions in educational settings, with a specific focus on classrooms.

Classrooms serve as the foundational spaces where knowledge is imparted, minds are nurtured, and futures are shaped. Yet, the conventional approach to lighting in these spaces often falls short in terms of energy efficiency, sustainability, and overall environmental impact. Outdated lighting fixtures, excessive energy consumption, and suboptimal lighting quality not only contribute to soaring energy bills but also compromise the well-being and productivity of students and educators alike.

Recognizing the pressing need for change, this thesis advocates for the adoption of energy-efficient lighting technologies as a means to mitigate energy consumption, enhance visual comfort, and promote sustainable learning environments. By harnessing the power of Light Emitting Diode (LED) technology, leveraging daylight harvesting techniques, and integrating smart control systems, classrooms can transcend their traditional boundaries and embrace a new era of illumination—one that prioritizes efficiency, effectiveness, and eco-consciousness.Through a comprehensive examination of existing literature, case studies, and empirical data, this thesis aims to shed light on the multifaceted benefits of energy-efficient lighting in classrooms. From improved academic performance and reduced environmental footprint to enhanced occupant comfort and well-being, the potential dividends of embracing sustainable lighting practices are vast and far-reaching.

As we embark on this illuminating journey, it is our collective responsibility to envision a future where classrooms are not just spaces of learning, but beacons of sustainability and innovation. By reimagining the role of lighting in education, we pave the way for a brighter, greener, and more enlightened tomorrow.

Chapter : 2

Literature review & Background of the work

<u>2.1</u> <u>Literature Review:</u>

<u>*2.1.1*</u> <u>*"Criteria for energy efficient lighting in buildings" :*</u>

Introduction to Energy Efficient Lighting:

The article sets the stage by emphasizing the critical role of energy-efficient lighting in reducing energy consumption and environmental impact in buildings.

<u>Key Criteria for Energy Efficiency:</u>

Lighting Power Density (LPD): A fundamental metric for assessing energy efficiency, representing the electrical power used per unit area of a building (measured in watts per square meter). The paper discusses recommended LPD values for various building types and uses.

Daylighting Integration: Emphasizes the importance of incorporating natural daylight into building design to minimize reliance on artificial lighting. Techniques include strategic window placement, skylights, and light shelves to maximize natural light penetration.

Advanced Lighting Technologies: LED Lighting: Highlights the advantages of LED technology, such as high energy efficiency, long lifespan, and excellent controllability. LEDs are shown to outperform traditional incandescent and fluorescent lighting in both efficiency and cost-effectiveness over time.

Emerging Technologies: Discusses the potential of other emerging technologies like Organic LEDs (OLEDs) and smart lighting systems that adapt to user needs and environmental conditions to further enhance energy efficiency.

Lighting Controls: Sensors and Controls: The paper explores various lighting control systems, including occupancy sensors, daylight sensors, and programmable lighting controls. These technologies help ensure that lighting is used only when necessary, significantly reducing energy wastage.

Energy Performance Standards: Regulatory Compliance: Reviews relevant standards and regulations that promote energy-efficient lighting, such as those established by the European Union (EU) and the International Energy Agency (IEA). Compliance with these standards ensures that buildings meet minimum energy performance criteria.

Economic Considerations: Cost-Benefit Analysis: The authors provide an economic analysis comparing the initial investment in energy-efficient lighting systems with the long-term savings in energy costs and maintenance. The study concludes that while the upfront costs may be higher, the overall financial and environmental benefits justify the investment.

Impact on Building Occupants: Human Factors: Examines the effects of lighting on occupant comfort, productivity, and health. Proper lighting design is shown to enhance visual comfort, reduce eye strain, and improve overall well-being, leading to higher productivity and satisfaction.

Case Studies and Practical Applications:

Real-World Examples: The paper includes case studies demonstrating the successful implementation of energy-efficient lighting solutions in different types of buildings, such as offices, schools, and hospitals. These examples illustrate practical applications and benefits of the discussed criteria.

Future Directions and Recommendations:

Research and Development: The authors suggest areas for further research, including the development of even more efficient lighting technologies, better integration of lighting with building management systems, and deeper studies into the human factors associated with lighting.

2.1.2 Lighting for work: A review of visual and biological effects:

Introduction to Lighting for Work:

The article reviews the impact of lighting on both visual performance and biological well-being in work environments, underscoring its importance in occupational settings.

Visual Effects of Lighting:

- **Visual Comfort:** Analysis of how different lighting conditions affect visual comfort, including glare reduction and uniformity of illumination.
- **Task Performance:** The relationship between lighting levels and task performance is explored, demonstrating that appropriate lighting can enhance accuracy and efficiency in various tasks.
- **Color Rendering:** The importance of color rendering index (CRI) in accurately representing colors in the workspace, affecting tasks that require color differentiation.

Biological Effects of Lighting:

- **Circadian Rhythms:** Examination of how lighting influences circadian rhythms and the biological clock, impacting sleep patterns, mood, and overall health.
- **Light Exposure:** The effects of exposure to different light intensities and wavelengths on human physiology, including the production of melatonin and its implications for alertness and sleep quality.
- **Daylight vs. Artificial Light:** Comparison of the effects of natural daylight and artificial lighting on human health and productivity, advocating for the integration of natural light where possible.

Lighting Recommendations for Work Environments:

- **Lighting Levels:** Guidelines for optimal lighting levels for various types of work environments and tasks to ensure both visual comfort and biological well-being.
- **Dynamic Lighting Systems:** The potential benefits of dynamic lighting systems that adjust intensity and color temperature throughout the day to mimic natural light patterns and support circadian health.

- **Ergonomic Lighting Design:** Strategies for designing ergonomic lighting systems that reduce eye strain, prevent glare, and improve overall work performance.

Health Implications:

The authors discuss the long-term health implications of poor lighting conditions, including increased risk of chronic conditions like eye strain, headaches, and sleep disorders.

Economic Considerations:

Cost-benefit analysis of investing in high-quality lighting systems, highlighting the potential for increased productivity and reduced absenteeism to offset initial costs.

Case Studies and Practical Applications:

Real-world examples and case studies demonstrating the successful implementation of improved lighting solutions in workplaces, leading to enhanced employee satisfaction and productivity.

Future Research Directions:

Suggestions for future research to further understand the complex interactions between lighting, visual performance, and biological effects, as well as the development of new lighting technologies and standards.

2.1.3. "Energy-Efficient Lighting in Educational Buildings: A Review of Current Technologies and Best Practices"

This review paper offers a comprehensive overview of various technologies and best practices for implementing energy-efficient lighting in educational buildings. Here are some key points :

LED Lighting:

- LED (Light Emitting Diode) lighting technology is highly energy-efficient, consuming up to 80% less energy than traditional incandescent bulbs.
- LEDs have a longer lifespan, typically lasting 25 times longer than incandescent bulbs, reducing maintenance costs and waste.
- They produce less heat, making them safer and more comfortable in indoor environments.

Daylight Harvesting:

- Daylight harvesting involves utilizing natural daylight to supplement or replace artificial lighting in indoor spaces.
- Light sensors or photocells are used to detect available daylight levels and automatically adjust artificial lighting accordingly.
- This technology reduces energy consumption by dimming or switching off lights when sufficient natural light is available, while also improving occupant comfort and well-being.

Occupancy Sensors:

- Occupancy sensors detect the presence or absence of occupants in a room and control lighting accordingly.
- They automatically turn lights on when occupants enter a space and turn them off when the space is vacant, reducing energy waste.
- Occupancy sensors can be used in conjunction with other lighting controls to optimize energy savings and user comfort.

Lighting Controls:

- Lighting controls encompass a range of technologies and strategies for optimizing lighting performance and energy efficiency.
- Dimming controls allow users to adjust light levels based on task requirements and preferences, reducing energy consumption.

- Time-based controls enable scheduling of lighting operations to align with occupancy patterns and reduce unnecessary energy usage during unoccupied periods.

<u>2.1.4. "Smart Lighting Systems for Educational Facilities: Opportunities and Challenges"</u>

This paper explores the opportunities and challenges associated with implementing smart lighting systems in educational facilities. Here are some key points :

a) <u>Overview of Smart Lighting Systems:</u>

<u>Components of smart lighting systems:</u>

Sensors:

- Sensors are integral components of smart lighting systems that gather data about the environment and user behavior.
- Common sensors include occupancy sensors, which detect the presence of occupants in a space, and daylight sensors, which measure natural light levels.
- Other sensors may include motion sensors, temperature sensors, and humidity sensors, depending on the specific requirements of the application.

Wireless Communication:

- Wireless communication technology enables connectivity between different components of a smart lighting system.
- Wireless protocols such as Zigbee, Bluetooth Low Energy (BLE), Wi-Fi, and Z-Wave facilitate communication between sensors, light fixtures, control devices, and central management systems.
- Wireless communication eliminates the need for complex wiring, simplifying installation and enabling flexible system configurations.

Lighting Fixtures:

- Smart lighting systems utilize LED fixtures equipped with advanced controls and connectivity features.
- LED fixtures offer energy-efficient illumination with customizable light output, color temperature, and dimming capabilities.
- Smart LED fixtures may include built-in sensors, communication modules, and control interfaces for seamless integration into the system.

Control Devices:

- Control devices allow users to interact with and manage smart lighting systems.
- Wall-mounted switches, touch panels, mobile applications, and web-based interfaces are common control devices used to adjust lighting settings, create schedules, and monitor system performance.
- Control devices provide users with flexibility and convenience in customizing lighting conditions according to preferences and requirements.

Central Management Systems:

- Central management systems serve as the backbone of smart lighting installations, providing centralized control, monitoring, and optimization capabilities.
- These systems collect data from sensors and control devices, analyze usage patterns, and optimize lighting operations for energy efficiency and user comfort.
- Central management software may offer features such as remote access, energy reporting, fault detection, and predictive maintenance to streamline system management and maximize performance.

Data Analytics and Artificial Intelligence (AI):

- Data analytics and AI technologies play a crucial role in smart lighting systems by processing large volumes of sensor data to derive actionable insights.
- AI algorithms analyze occupancy patterns, lighting preferences, and environmental conditions to optimize lighting control strategies and energy usage.
- Data-driven decision-making enables smart lighting systems to adapt dynamically to changing conditions and user needs, enhancing efficiency and user experience.

b) <u>Benefits of Smart Lighting:</u>

Energy Efficiency:

- Smart lighting systems optimize energy usage by automatically adjusting light levels based on occupancy patterns, daylight availability, and user preferences.
- By dimming or switching off lights in unoccupied areas, smart lighting systems reduce energy waste and contribute to significant energy savings.

Cost Savings:

- The energy efficiency of smart lighting systems translates into lower electricity bills for building owners and operators.
- Reduced energy consumption also leads to decreased maintenance costs associated with bulb replacement and system upkeep, resulting in long-term financial savings.

Enhanced Comfort and Well-being:

- Smart lighting systems create personalized lighting environments that cater to individual preferences and needs.
- Dynamic lighting control, including adjustments in color temperature and intensity, promotes occupant comfort, productivity, and mood regulation, contributing to improved well-being.

Improved User Experience:

- With intuitive control interfaces and customizable settings, smart lighting systems empower users to personalize their lighting experience according to specific tasks, activities, or preferences.
- Convenient features such as remote access and scheduling further enhance user convenience and flexibility, allowing for seamless integration into daily routines.
- Optimized Lighting Performance:
- Smart lighting systems utilize sensors and data analytics to continuously monitor lighting conditions and adjust lighting parameters in real-time.
- By optimizing light levels, distribution, and quality, smart lighting systems ensure optimal visual comfort, task performance, and safety in various indoor environments.

Environmental Sustainability:

- The energy efficiency of smart lighting systems reduces greenhouse gas emissions and environmental impact associated with electricity generation.
- By promoting sustainable practices and resource conservation, smart lighting systems contribute to broader sustainability goals and initiatives aimed at mitigating climate change and preserving natural resources.

Enhanced Safety and Security:

- Smart lighting systems enhance safety and security in indoor and outdoor spaces by providing adequate illumination and visibility.
- Motion sensors and occupancy detection features can trigger lighting responses to deter intruders, prevent accidents, and ensure safe navigation in dimly lit areas.
- Integration with Smart Building Systems:
- Smart lighting systems can be seamlessly integrated with other building automation and control systems, such as HVAC, security, and occupancy monitoring systems.
- Integration enables centralized management, coordination, and optimization of building operations, resulting in enhanced efficiency, performance, and occupant satisfaction.

Challenges and Considerations:

- **Initial Cost:** Higher upfront investment compared to traditional lighting systems.
- **Complexity:** Requires careful planning, design, and integration due to system intricacies.
- **Interoperability:** Compatibility issues between components and technologies may hinder seamless integration.
- **Data Privacy and Security:** Concerns about unauthorized access, breaches, and privacy violations require robust security measures.
- **Reliability and Maintenance:** Components may experience malfunctions, requiring regular maintenance and diagnostics to ensure consistent performance.
- **User Acceptance and Training:** Users need to adapt to new interfaces and procedures, emphasizing the importance of effective communication and education.

Addressing these challenges is crucial for successful imple mentation and optimization of smart lighting systems in indoor environments.

2.2 Background of the Work:

In recent years, there has been a growing emphasis on sustainability and energy efficiency across various sectors, driven by concerns about climate change, resource depletion, and rising energy costs. Within the realm of building design and operation, efforts to reduce energy consumption and environmental impact have become increasingly prevalent, with a particular focus on optimizing lighting systems.

Educational facilities, including classrooms, represent a significant opportunity for implementing energy-efficient lighting solutions. Classrooms are critical environments where students learn, teachers instruct, and educational outcomes are shaped. However, traditional lighting systems in classrooms often suffer from inefficiencies, excessive energy consumption, and suboptimal lighting quality, which not only contribute to escalating operating costs but also detract from the learning experience.

Conventional lighting technologies, such as incandescent and fluorescent bulbs, have long dominated educational settings despite their limitations in terms of energy efficiency and performance. These outdated lighting systems not only consume significant amounts of electricity but also generate excess heat and require frequent maintenance, resulting in substantial operational expenses for educational institutions.

Against this backdrop, the need for energy-efficient lighting solutions in classrooms has become increasingly apparent. Energy-efficient lighting technologies, such as Light Emitting Diode (LED) lighting, offer a compelling alternative to traditional lighting systems, promising significant energy savings, enhanced performance, and improved user satisfaction.

LED lighting technology has witnessed remarkable advancements in recent years, with improvements in efficiency, lifespan, and color rendering capabilities. LED fixtures consume up to 80% less energy than incandescent bulbs and have a lifespan that is several times longer, making them an attractive option for educational facilities seeking to reduce energy consumption and operating costs.

Moreover, the integration of smart lighting systems in classrooms presents exciting opportunities for further enhancing energy efficiency, user comfort, and overall learning environments. Smart lighting systems leverage advanced sensors, wireless communication, and data analytics to optimize lighting performance in real-time, adjusting light levels, color temperature, and distribution based on occupancy patterns, daylight availability, and user preferences.

By harnessing the power of energy-efficient lighting technologies and smart lighting systems, educational institutions can create classrooms that are not only environmentally sustainable but also conducive to learning, productivity, and well-being. The adoption of energy-efficient lighting solutions represents a tangible step towards achieving sustainability goals, reducing operational expenses, and providing students and educators with healthier and more productive learning environments.

In light of these considerations, this thesis seeks to explore the potential of energy-efficient lighting technologies and smart lighting systems in enhancing classroom environments. By investigating the benefits, challenges, and implications of implementing energy-efficient lighting solutions in educational settings, this research aims to contribute to the advancement of sustainable practices in education and the built environment.

Chapter : 3

Human centric lighting for interior space & Energy savings

3.1 Human centric lighting for interior space:

3.1.1 Introduction:

Human-centric lighting (HCL) is an approach to lighting design that focuses on enhancing the well-being, health, and productivity of occupants by considering the biological and psychological effects of light on human physiology and behavior. Here's how HCL can be applied to interior spaces, taking into account the challenges and considerations previously discussed:

Biologically Tuned Lighting Design:

Human-centric lighting for interior spaces involves designing lighting systems that mimic the natural dynamics of sunlight throughout the day. This includes adjusting light intensity, color temperature, and spectral distribution to align with the body's circadian rhythms.

By incorporating tunable LED fixtures and control systems, interior spaces can transition between different lighting scenes throughout the day, from energizing cool white light in the morning to relaxing warm white light in the evening.

Personalized Lighting Control:

HCL allows for personalized lighting control, empowering occupants to adjust lighting settings based on individual preferences and activities. Control interfaces, such as mobile apps or touch panels, enable users to fine-tune light levels, color temperature, and ambiance according to their needs.

By providing occupants with control over their lighting environment, HCL enhances user satisfaction, comfort, and engagement, fostering a sense of ownership and well-being in interior spaces.

Occupancy-Responsive Lighting:

Occupancy sensors and smart lighting controls play a crucial role in HCL by automatically adjusting lighting levels based on occupancy patterns and activity levels. This not only optimizes energy usage but also ensures that lighting conditions are tailored to the needs of occupants in real-time.

Adaptive lighting schemes, triggered by motion detection or occupancy sensing, create dynamic and responsive environments that promote alertness, concentration, and task performance.

Biophilic Design Integration:

Biophilic design principles, which emphasize the connection between humans and nature, can be integrated with HCL to create interior spaces that promote well-being and productivity. This may include incorporating elements such as daylighting, views of nature, and natural materials to enhance the visual and sensory experience.

By blurring the boundaries between indoor and outdoor environments, biophilic design elements complement HCL strategies, fostering a sense of harmony, vitality, and connectedness in interior spaces.

User Education and Engagement:

Effective implementation of HCL requires user education and engagement to ensure that occupants understand the benefits and functionalities of the lighting system. Training programs, workshops, and educational materials can inform occupants about the principles of HCL, the importance of light on health and well-being, and how to optimize their lighting environment for maximum benefit.

By empowering occupants with knowledge and awareness, HCL fosters a culture of wellness, sustainability, and productivity in interior spaces, encouraging users to actively participate in creating and maintaining a human-centric lighting environment.

In summary, human-centric lighting for interior spaces integrates biologically tuned lighting design, personalized lighting control, occupancy-responsive lighting, biophilic design principles, and user education to create environments that prioritize occupant well-being, comfort, and productivity. By addressing the challenges and considerations associated with smart lighting technology, HCL enhances the quality of indoor environments and promotes a holistic approach to lighting design that benefits both people and the planet.

3.1.2 Human factors in Lighting:

To understand how lighting impacts work, it is essential to explore the ways in which lighting influences human performance. There are three key pathways through which lighting can affect human performance: the visual system, circadian timing system, and mood and motivation. The most evident impact of light on humans is its effect on vision. Vision involves the formation of an image on the retina through the optics of the eye, with some image processing occurring at the retina. From the retina to the visual cortex, different parts of the retinal image are interpreted through various channels. The visual system's spatial structure consists of the fovea, responsible for perceiving small details, and the peripheral retina, which serves as a detection system to determine where the fovea should focus. Moreover, the entire retina is active in the presence of ample light, such as during the day, while the fovea is less functional in low light conditions, relying on the peripheral retina.

Figure 3.1.2 presents a theoretical framework illustrating the three pathways through which lighting conditions can influence human task performance:

I. This framework demonstrates the variables that impact the development along each pathway and how these variables interact. Five dimensions—visual size, luminance contrast, color difference, retinal image quality, and retinal illuminance—describe the stimuli's characteristics and play a crucial role in the visual system's ability to recognize and detect stimuli.

Visual Size: The solid angle subtended by a stimulus at the eye determines its visual size and affects its detectability. Larger solid angles make stimuli easier to recognize. Lighting conditions have minimal effects on the visual size of two-dimensional objects, but shadows can be utilized to enhance the effective visual size of three-dimensional items.

Luminance Contrast: The luminance contrast of a stimulus refers to its luminance relative to the immediate background. Higher luminance contrast makes stimuli easier to perceive.

Lighting parameters, such as adjusting the luminance of constituent parts or inducing disability glare, can alter the luminance contrast of a stimulus.

Color Difference: The color appearance of a stimulus is influenced by the wavelengths it emits. Even with zero luminance contrast, a stimulus can still be recognized based on its distinct color difference from the background. Employing multiple light sources with different spectra can alter the color difference between an object and its background.

Retinal Image Quality: The visual system performs optimally when presented with a sharp image. The sharpness of an image can be assessed by its spatial frequency distribution. A sharp image contains high spatial frequency components, while a blurry image lacks such components.

Retinal Illuminance: The illuminance on the retina affects the visual system's adaptation and significantly influences its capabilities.

The level of achievable visual performance depends on the stimulus and the current state of the visual system's operation. However, visual tasks encompass three components: visual, cognitive, and motor. The visual component involves gathering task-relevant information using the visual sense. The cognitive component encompasses the evaluation of sensory stimuli and the selection of the best course of action. The motor component entails deriving information from inputs and executing chosen actions. The interplay between these three components creates a complex relationship between stimulus and reaction, influencing task performance. The balance between the visual, cognitive, and motor components varies across tasks, as does the impact of lighting conditions on task performance. Therefore, it is impossible to generalize how lighting affects the performance of one task to another.

II. Another pathway through which lighting conditions can impact work is the non-image- forming system. The circadian timing system, a component of the non-image-forming system, has a well-established influence on human performance. The sleep-wake cycle provides external evidence of the existence of the circadian timing system in humans. Light acts on the circadian timing system in two ways to enhance task performance: the phase- shifting mechanism and the acute suppression of the hormone melatonin during the night, which increases alertness.

Additionally, there has been interest in studying whether daytime light exposure can improve task performance by influencing the hormone cortisol. The effects on the rest of the day are not entirely clear, but evidence suggests that exposure to high light levels shortly after waking up can raise cortisol concentration, positively impacting alertness. Studies have shown that exposure to over 2000 lx during the early afternoon also boosts alertness.

The third pathway through which lighting can influence productivity is mood and motivation. The visual environment created by the visual system can evoke emotional reactions, which, among other factors, can impacmood and motivation for work. Furthermore, lighting that causes visual discomfort or pain can directly affect mood and motivation in simple ways.

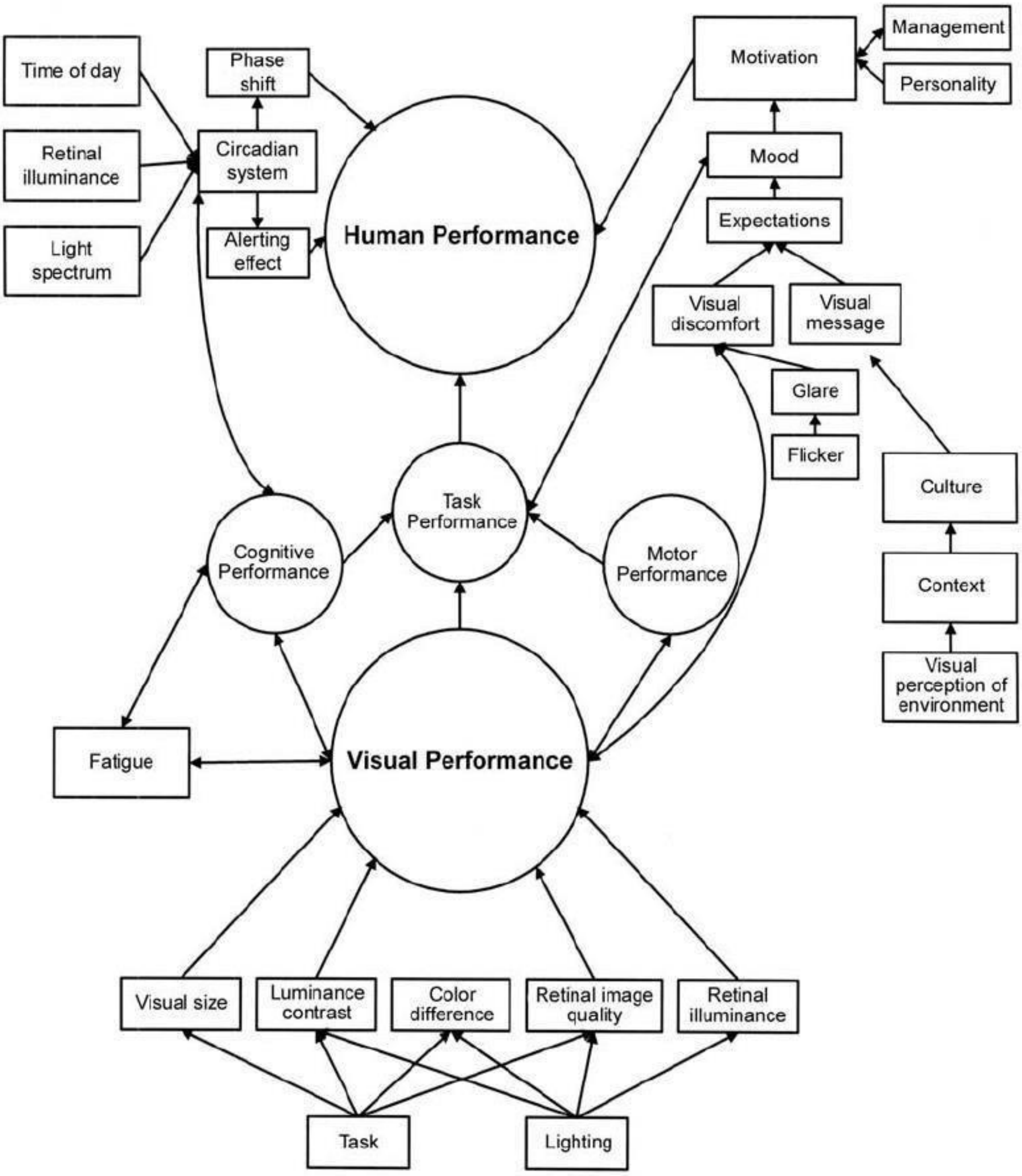

Time of day
Retinal illuminance
Light spectrum
Phase shift
Circadian system
Alerting effect
Human Performance
Motivation
Management
Personality
Mood
Expectations
Visual discomfort
Visual message
Glare
Flicker
Culture
Context
Visual perception of environment
Cognitive Performance
Task Performance
Motor Performance
Fatigue
Visual Performance
Visual size
Luminance contrast
Color difference
Retinal image quality
Retinal illuminance
Task
Lighting

Fig 3.1.2

3.1.3 Human Centric Lighting:

All the previous experimental studies have already proven that human factors should mandatorily be included in lighting. The previous trends of energy efficient lighting design has now been shifted towards human centric lighting with energy efficient approach. As mentioned previously, lighting can contribute to human performance, not only from visual acceptance point to view also from circadian route, motivation and mood. Hence, it is a proven fact that, spectrum color and intensity of light definitely influence human performance. The human centric lighting proposes the proper use of dimming and CCT shifting, which is termed as Kelvin Shifting, can improve circadian rhythms, mood, visual acuity and finally visual performance. Very recently Human Centric Lighting Society has been formed in US. The concept of human centric lighting evolved little lately, specially with the evolution of LED based lighting. As the LED based lighting systems are easy tunable, i.e. it can be dimmed or color can be changed instantly, hence, the image forming and non-image forming effect of light on human performances are thoroughly being investigated as well as implemented easily today.

3.2 Energy savings and Interior Lighting :

3.2.1 Lighting energy in building:

- ❖ Lighting energy usage in buildings covers a significant part of the energy consumption.
- ❖ Significant impact on the environment.
- ❖ A more holistic view with focus in sustainability is required to protect the environment.

ENERGY CONSERVATION BUILDING CODE (ECBC):

- ❖ Provides minimum requirements for energy efficient design & construction of buildings.
- ❖ ECBC provide some limiting values to specify optimum energy requirements for energy efficient lighting designs which is estimated in terms of lighting energy required per unit area, termed as, Lighting Power Density or LPD.
- ❖ Two methods are there for this purpose: Building area method and Space function method.

3.2.1 a) BUILDING AREA METHOD:

Determination of interior lighting power allowance by the Building Area Method:

1. Determination of the allowed lighting power density for each building area type as per ECBC.
2. Calculation of the gross lighted floor area for each building area type.

3. The interior lighting power allowance is the sum of the products the gross lighted floor area of each building area types with the allowed lighting power density for that building area types.

Example: Interior Lighting power density as per Building area method
Office:**10.8W/m^2** Manufacturing Facility **: 14.0 W/m^2**

Hospital:**12.9 W/m^2** Warehouse:**8.6 W/m^2**

3.2.1b) SPACE FUNCTION METHOD:

Determination of interior lighting power allowance by the Space Function Method:

1. Determination of the allowed lighting power density for each Space function area as per ECBC.

2. For each space enclosed by partitions 80% or greater than ceiling height, determination of gross interior floor area by measuring to the center of the partition wall including the floor area of balconies or other projections.

3. The lighting power allowance for a space is the product of the gross lighted floor area of the space with the allowed lighting power density for that space. The interior lighting power allowance is the sum of the lighting power allowances for all spaces.

Example: Interior Lighting power density as per Space function method

Office Enclosed:**11.8W/m^2** conference room:**14 W/m^2**

3.2.2) IS 3646 Standard:

IS 3646 is a standard developed by the Bureau of Indian Standards (BIS) that focuses on the interior lighting requirements for various types of spaces within buildings. It provides guidelines and specifications to ensure that interior lighting systems meet certain quality, performance, and safety standards. Here are some key details about IS 3646:

Scope: IS 3646 covers the design, installation, and maintenance of interior lighting systems for residential, commercial, industrial, and institutional buildings. It applies to both new constructions and renovations.

Types of Spaces Covered: The standard provides specific requirements for different types of interior spaces, including but not limited to:

- Residential buildings: Living rooms, bedrooms, kitchens, bathrooms, etc.
- Commercial buildings: Offices, retail stores, restaurants, hotels, etc.
- Industrial buildings: Factories, warehouses, workshops, etc.
- Institutional buildings: Schools, hospitals, libraries, museums, etc.

Lighting Design Parameters: IS 3646 specifies various parameters related to lighting design, such as:

- Illuminance levels: Minimum recommended illuminance levels for different types of spaces and tasks.
- Uniformity: Requirements for uniform distribution of light within a space to avoid glare and shadows.
- Color rendering: Recommendations for maintaining accurate color perception under artificial lighting.
- Glare control: Guidelines to minimize glare and discomfort caused by excessive brightness or contrast.
- Energy efficiency: Suggestions for selecting energy-efficient lighting fixtures and control systems.

Installation and Maintenance: The standard includes recommendations for the installation and maintenance of lighting systems, including:

- Fixture placement and spacing.
- Wiring, control systems, and switches.
- Maintenance procedures to ensure optimal performance and safety.

Safety Considerations: IS 3646 addresses safety aspects related to interior lighting, such as:

- Electrical safety: Compliance with relevant electrical codes and standards to prevent electrical hazards.
- Fire safety: Recommendations for using fire-resistant materials and fixtures to minimize fire risks.

Adhering to IS 3646 helps ensure that interior lighting systems in buildings are designed, installed, and maintained in a way that promotes visual comfort, energy efficiency, and safety. Compliance with this standard can contribute to creating healthier, more productive, and environmentally sustainable indoor environments.

3.2.2) CIE Measurement Standard:

The International Commission on Illumination (CIE) develops measurement standards and recommendations related to lighting and illumination. These standards provide guidelines for evaluating the performance of lighting systems and ensuring their effectiveness, efficiency, and quality. Here are some key details about CIE measurement standards:

CIE Colorimetry: CIE has established standards for colorimetry, which is the science of measuring and specifying colors. These standards define color spaces, color matching functions, and color rendering indices to quantify how accurately a light source reproduces colors compared to a reference light source. Examples of CIE colorimetry standards include CIE 1931 and CIE 1964 color spaces, as well as color rendering indices such as CRI (Color Rendering Index) and CIE Ra.

CIE Photometry: CIE has developed standards for photometry, which is the measurement of light as perceived by the human eye. These standards specify measurement techniques and metrics for quantifying various photometric properties of light sources, including luminous flux, luminous intensity, illuminance, and luminance. Examples of CIE photometry standards include CIE 127:2007 (Measurement of LEDs) and CIE 69:1987 (Colorimetric and Photometric Characteristics of Projectors).

CIE Glare Assessment: Glare is a sensation caused by excessive brightness or contrast in the field of view. CIE has developed standards for assessing glare and its effects on visual comfort and performance. These standards provide guidelines for measuring glare indices and evaluating glare sources in lighting installations.

CIE Lighting Quality Metrics: CIE has proposed metrics for evaluating the quality of lighting installations beyond just illuminance levels. These metrics include measures of lighting uniformity, color consistency, flicker, and spectral power distribution. By considering these factors, lighting designers can assess the overall quality and performance of a lighting system more comprehensively.

CIE Measurement Methods: CIE standards also cover measurement methods and instrumentation for assessing various aspects of lighting, including photometric and colorimetric measurements. These standards ensure consistency and accuracy in lighting measurements across different laboratories and testing facilities.

Chapter : 4

Survey on Existing Lighting System of the Museum & Classrooms

4.1 Luminaire used in Existing Lighting System in Museum:

We have divided the museum in three sections , which are :-

I. Dark Room space
II. Montage dio space
III. Large room Space (Camera Space, Make up Space, Free Space)

4.1.1 Luminaire used in Dark Room :

- 4 wall mounted LED
- 4 LED Tube
- 2 spot light

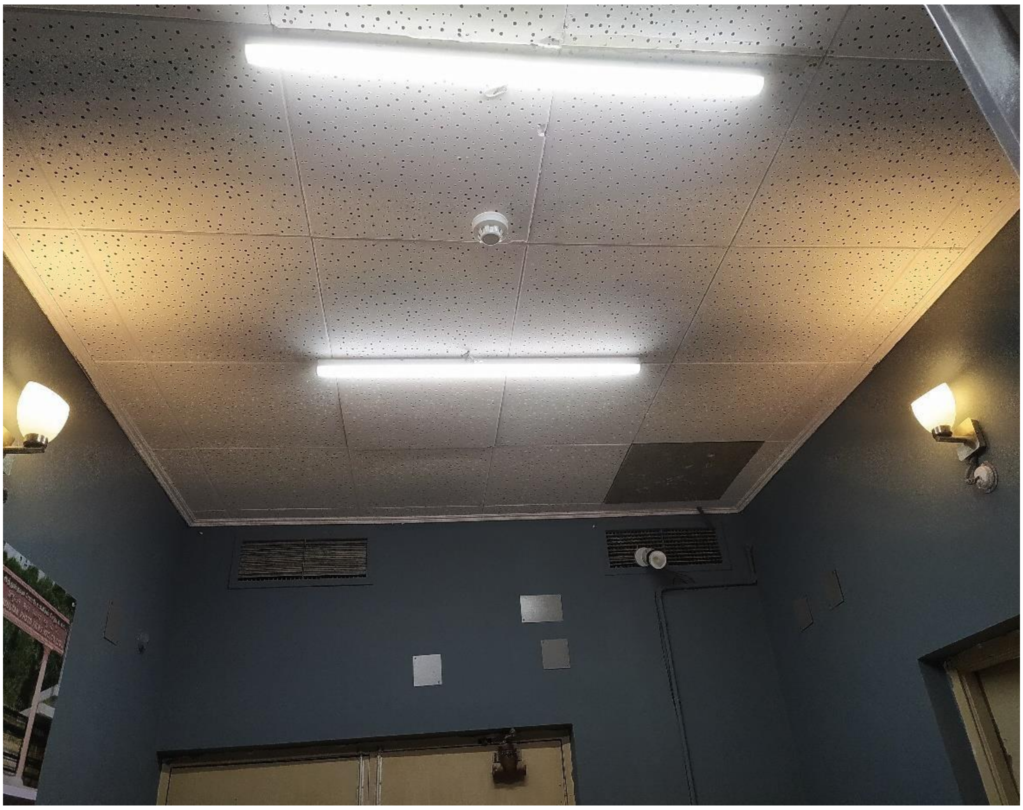


Fig :- half Section of the Dark Room

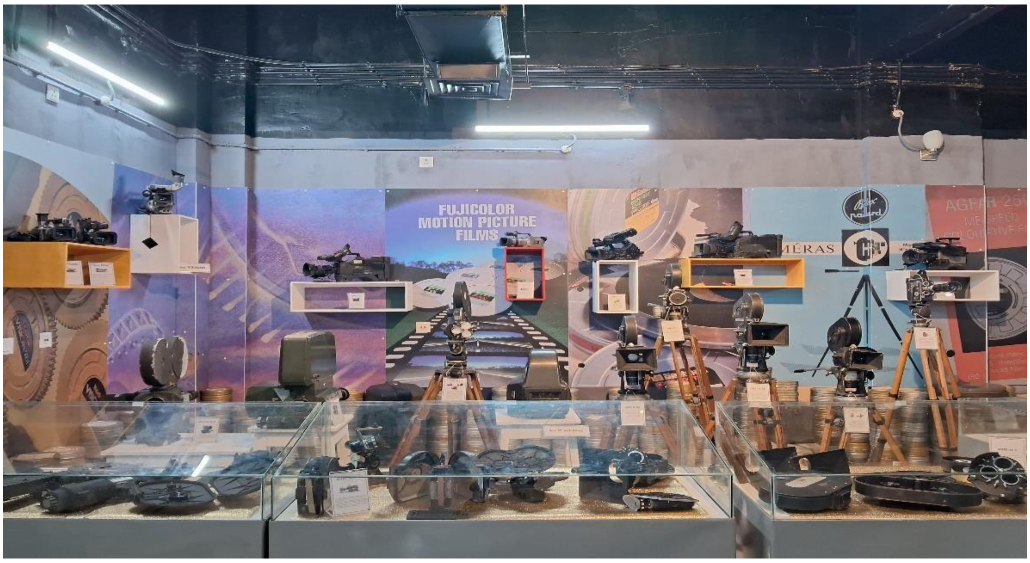
4.1.2 Luminaire used in Montage Studio Space:

- 6 recessed LED
- 6 Spot Light LED

Fig 4.1.2:- The Montage Studio

4.1.3 Luminaire used in Large Room Space:

- 11 LED Tube
- 10 Wall Mounted LED
- 22 Spot Light LED



Camera Space

Make up Space

4.2 Luminaire used in Existing Lighting System in Classrooms:

Here we have consider two classrooms in SRFTI , which are :-

I. Producing Department Classroom
II. Editing Department Classroom

4.2.1 Luminaire used in Producing Department Classroom :

- 12×2 Fluorescent Tube light

Fig 4.2.1 :- Producing Dept Classroom

4.2.2 Luminaire used in Editing Department Classroom :

- 14 Recessed LED Cool White

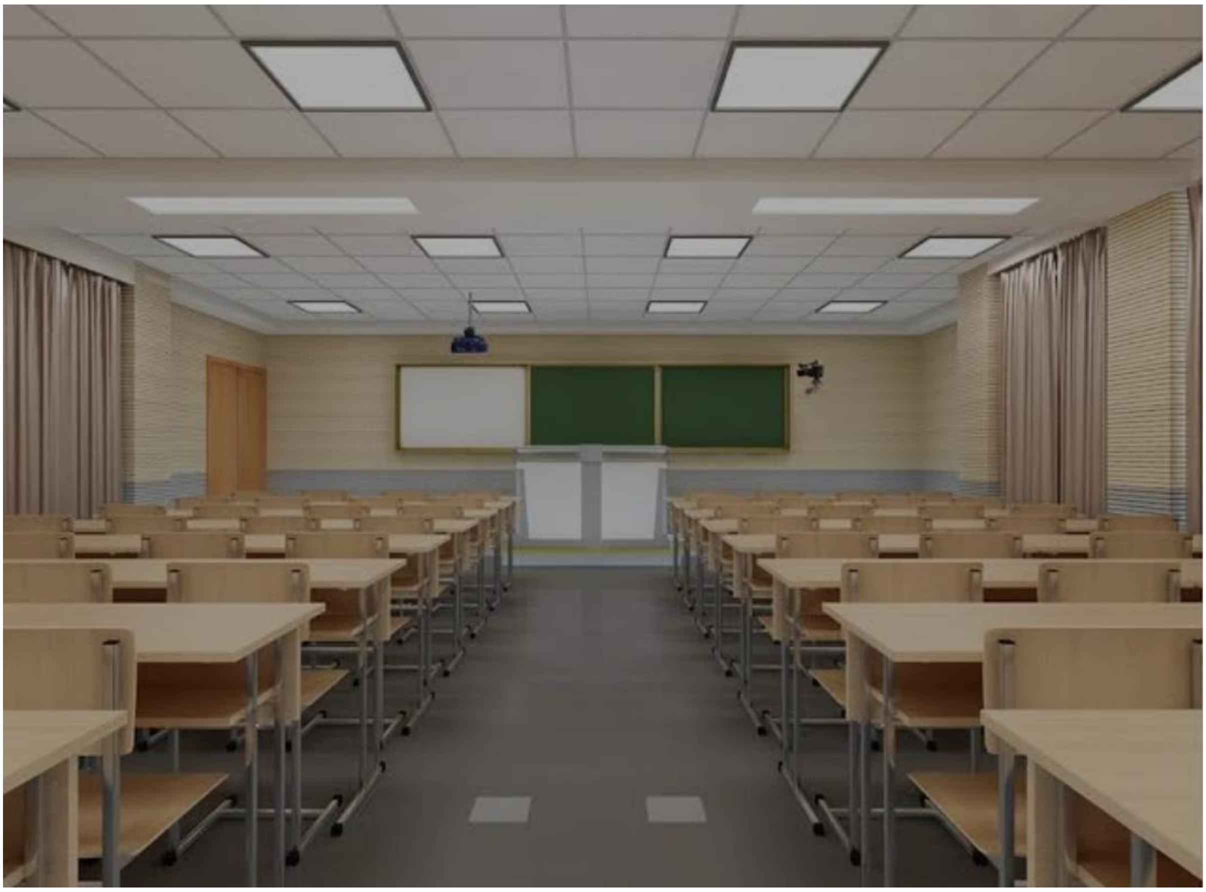


Fig 4.2.2 :- Class Room With Recessed Lighting

Chapter : 5

Studies on different National and International standard for Museum & Classrooms Lighting

National Standard Organizations:

ANSI (American National Standards Institute):

- Location: United States
- Role: ANSI oversees the development and accreditation of voluntary consensus standards in the United States, including standards related to museum and classroom lighting.

IESNA (Illuminating Engineering Society of North America):

- Location: United States
- Role: IESNA is a professional organization focused on advancing the art and science of lighting. They develop standards and guidelines for various aspects of lighting design, including classroom lighting.

CIBSE (Chartered Institution of Building Services Engineers):

- Location: United Kingdom
- Role: CIBSE is a professional body for building services engineers. They provide guidance and standards for various aspects of building design and operation, including museum and classroom lighting.

DIN (Deutsches Institut für Normung):

- Location: Germany
- Role: DIN is the German Institute for Standardization. They develop and publish technical standards for various fields, including lighting design, through collaboration with industry experts and stakeholders.

International Standard Organizations:

ISO (International Organization for Standardization):

- Location: Geneva, Switzerland
- Role: ISO is an independent, non-governmental international organization that develops and publishes voluntary international standards. They cover a wide range of topics, including museum and classroom lighting.

CIE (International Commission on Illumination):

- Location: Vienna, Austria
- Role: CIE is an international organization devoted to lighting and illumination. They develop technical standards, recommendations, and guidelines related to light and lighting, including those for museum and classroom environments.

IEC (International Electrotechnical Commission):

- Location: Geneva, Switzerland
- Role: IEC is an international standards organization that prepares and publishes international standards for all electrical, electronic, and related technologies. While not specific to lighting, some of their standards may be relevant to lighting design and technology.

These organizations play crucial roles in developing and promoting standards that ensure quality, safety, and interoperability in various industries and sectors worldwide, including museum and classroom lighting.

5.1 National Standard Data for Museum and Classroom Lighting:

5.1.1 Museum Lighting Standards (ANSI/NEMA LL 9-2018):

Purpose: To guide the design and implementation of lighting systems in museums and art galleries.

Key Parameters:

1.Illuminance Levels: Recommended illuminance levels vary depending on the type of exhibit and materials displayed such as,

- General Galleries: 150-300 lux
- Sculpture and Artifacts: 150-750 lux
- Textiles and Paper: 50-150 lux
- Paintings: 150-750 lux
- Special Exhibits: Variable, based on exhibit requirements

2. Color Rendering: Criteria for color rendering index (CRI) to ensure accurate representation of artwork colors**.**

- Minimum CRI: 80 for general applications; higher for artwork (90+ recommended).

3. UV and IR Radiation Control: Recommendations to minimize UV and IR radiation to prevent damage to sensitive materials.

- UV Radiation: Less than 75 μW/lm at 1 meter from source.
- IR Radiation: Control to minimize heat generation and potential damage to artifacts.

4.Energy Efficiency:

- Guidelines for energy-efficient lighting solutions to reduce operational costs and environmental impact.
- Compliance with relevant energy efficiency standards and regulations recommended.

5.1.2 Classroom Lighting Standards (ANSI/IESNA RP-3-13):

Purpose: To optimize lighting design in educational facilities for enhanced visual comfort and learning efficiency.

Key Parameters:

1. Illuminance Levels: Recommended illuminance levels for different areas within classrooms, such as the board, desks, and circulation spaces.

- Board: 500 lux
- Desks: 300-500 lux
- Circulation Spaces: 100-300 lux

2. Glare Control: Guidelines for minimizing glare to ensure visual comfort and reduce eye strain for both students and teachers.

- Maximum UGR: 19 for general lighting; 16 for task lighting.

3. Uniformity: Criteria for achieving uniform lighting distribution to avoid contrast and shadowing issues.

- Horizontal Illuminance Uniformity: 0.7 or higher.
- Vertical Illuminance Uniformity: 0.5 or higher.

4. Lighting Controls:

Dimming and occupancy sensors recommended for energy-efficient lighting control.

Conclusion:

The adherence to national standards for museum and classroom lighting ensures the creation of environments that prioritize visual comfort, safety, and energy efficiency. These standards serve as vital references for architects, lighting designers, and facility managers, contributing to the enhancement of visitor experiences in museums and the optimization of learning environments in classrooms.

5.2 International Standard Data for Museum and Classroom Lighting:

5.2.1 Museum Lighting Standards (ISO/CIE):

Purpose: To establish guidelines for lighting design in museums and art galleries worldwide.

Key Parameters:

1. Illuminance Levels:

- General Galleries: 150-300 lux
- Sculpture and Artifacts: 150-750 lux
- Textiles and Paper: 50-150 lux
- Paintings: 150-750 lux
- Special Exhibits: Variable, based on exhibit requirements

2. Color Rendering:

- Minimum CRI: 80 for general applications; higher for artwork (90+ recommended).

3. UV and IR Radiation Control:

- UV Radiation: Less than 75 μW/lm at 1 meter from source.
- IR Radiation: Control to minimize heat generation and potential damage to artifacts.

4. Energy Efficiency:

Compliance with relevant energy efficiency standards and regulations recommended.

5.2.2 Classroom Lighting Standards (ISO/IEC/CIE):

Purpose: To provide international recommendations for lighting design in educational facilities.

Key Parameters:

1. Illuminance Levels:

- Board: 500 lux
- Desks: 300-500 lux
- Circulation Spaces: 100-300 lux

2. Glare Control:

- Maximum UGR: 19 for general lighting; 16 for task lighting.

Uniformity:

- Horizontal Illuminance Uniformity: 0.7 or higher.
- Vertical Illuminance Uniformity: 0.5 or higher.

Lighting Controls:

- Dimming and occupancy sensors recommended for energy-efficient lighting control.

Conclusion:

International standards for museum and classroom lighting provide a framework for designing environments that prioritize visual comfort, safety, and energy efficiency on a global scale. By adhering to these standards, professionals in the fields of museum curation and educational pedagogy can ensure the creation of optimal lighting environments that enhance visitor experiences and facilitate effective learning.

Chapter : 6

Computer Aided Lighting Design Solution for a Museum & Classrooms

6.1 Introduction:

Lighting plays a crucial role in shaping the ambiance, functionality, and aesthetic appeal of both museums and classrooms. In museums, lighting must enhance the visual presentation of exhibits, ensure the preservation of artifacts, and provide a comfortable viewing experience for visitors. In classrooms, optimal lighting is essential for creating an environment conducive to learning, reducing eye strain, and supporting the diverse visual tasks required by students and teachers. Given these varied requirements, achieving effective lighting design can be a complex task.

Traditional lighting design methods often rely on manual calculations and empirical rules of thumb, which can be time-consuming and prone to errors. Moreover, these methods may not fully exploit the potential of modern lighting technologies, such as LED systems, dynamic lighting controls, and energy-efficient solutions. As the demand for more sophisticated and sustainable lighting systems grows, there is a need for advanced tools that can streamline the design process, improve accuracy, and enable the creation of customized lighting solutions.

Computer-aided lighting design (CALD) solutions have emerged as powerful tools to address these challenges. By leveraging computational techniques and software, CALD solutions facilitate the precise modeling, simulation, and visualization of lighting scenarios. These tools enable designers to experiment with various lighting configurations, analyze their impacts, and optimize designs to meet specific criteria. In the context of museums, CALD solutions can help in designing lighting schemes that highlight artifacts while minimizing damage from light exposure. In classrooms, these solutions can aid in creating lighting environments that enhance visibility, comfort, and energy efficiency.

This thesis explores the application of computer-aided lighting design solutions in the specific contexts of museums and classrooms. It aims to demonstrate how these tools can be used to improve lighting quality, enhance user experience, and promote sustainability. By examining case studies, reviewing current literature, and conducting practical experiments, this research seeks to provide insights into the benefits and limitations of CALD solutions, as well as guidelines for their effective implementation.

The following sections will delve into the historical background of lighting design, the development of CALD technologies, and the specific requirements of museum and classroom lighting. Subsequent chapters will present detailed analyses of case studies, experimental results, and recommendations for best practices in the field. Through this comprehensive investigation, this thesis aims to contribute to the ongoing advancement of lighting design and its critical role in educational and cultural settings.

6.2 Historical Background of Lighting Design:

The evolution of lighting design is deeply intertwined with the advancement of technology and the changing needs of human environments. From the early use of natural light to the sophisticated artificial lighting systems of today, the history of lighting design reflects a continuous quest to improve visibility, aesthetics, and functionality.

- **Early Lighting Methods:**

In ancient times, natural light was the primary source of illumination. Architectural designs, such as the placement of windows and the orientation of buildings, were crucial in maximizing the use of daylight. The Egyptians, Greeks, and Romans made significant contributions to the early understanding of natural lighting, using it to enhance the beauty and functionality of their structures.

The invention of fire marked a significant leap in artificial lighting. Torches, oil lamps, and candles became the primary means of illumination, each with its own set of limitations. These early lighting methods were relatively inefficient and posed significant safety hazards, yet they laid the foundation for future innovations.

- **The Gas Lighting Era:**

The 19th century witnessed a major transformation with the advent of gas lighting. Introduced in the early 1800s, gas lighting provided a more reliable and brighter source of artificial light compared to candles and oil lamps. Urban areas, in particular, saw widespread adoption of gas lighting, which illuminated streets, homes, and public buildings. This period also marked the beginning of formalized lighting design, as architects and engineers began to consider the impact of lighting on space and human behavior more systematically.

- **The Electric Lighting Revolution:**

The invention of the incandescent light bulb by Thomas Edison in 1879 revolutionized lighting design. Electric lighting offered unprecedented control, safety, and efficiency. The early 20th century saw rapid advancements in lighting technology, including the development of fluorescent lamps, which provided a more energy-efficient alternative to incandescent bulbs.

Electric lighting fundamentally changed the way spaces were illuminated. It enabled the creation of more complex and controlled lighting environments, facilitating the rise of modern interior design and architecture. Designers began to explore the use of light to shape mood, highlight architectural features, and create visual interest.

- **Modern Lighting Design:**

The latter half of the 20th century and the early 21st century brought about significant innovations in lighting technology and design. The introduction of halogen lamps, compact fluorescent lamps (CFLs), and light-emitting diodes (LEDs) provided designers with a wide range of tools to create more efficient, versatile, and dynamic lighting systems.

The emergence of computer-aided design (CAD) and computer-aided lighting design (CALD) tools has further revolutionized the field. These technologies allow designers to model, simulate, and visualize lighting schemes with high precision. They enable the optimization of lighting for various parameters, such as energy consumption, visual comfort, and aesthetic appeal.

- **Contemporary Trends and Sustainability:**

Today, lighting design is increasingly driven by considerations of sustainability and human well-being. The integration of smart lighting systems, which can be controlled and adjusted via digital interfaces, allows for greater customization and energy efficiency. Sustainable lighting practices, such as the use of daylight harvesting, energy-efficient fixtures, and renewable energy sources, are becoming standard in both new construction and retrofitting projects.

In museums and classrooms, the emphasis on creating environments that support specific functional and aesthetic goals has led to the adoption of advanced lighting solutions. Museums require lighting that enhances the visual presentation of exhibits while protecting sensitive artifacts from light damage.

Classrooms benefit from lighting that supports various learning activities, reduces eye strain, and fosters a conducive educational environment.

This historical overview highlights the continuous evolution of lighting design and the pivotal role of technological advancements. The transition from simple natural and artificial light sources to sophisticated, computer-aided lighting solutions underscores the dynamic nature of this field. As we move forward, the integration of new technologies and a focus on sustainability will continue to shape the future of lighting design.

6.3 Lighting Design Software:

The advent of computer technology has revolutionized many fields, including lighting design. The development and proliferation of lighting design software have provided designers with powerful tools to create more efficient, accurate, and sophisticated lighting solutions. These tools enable the precise modeling, simulation, and visualization of lighting scenarios, allowing designers to experiment with various configurations and optimize their designs to meet specific requirements.

Evolution of Lighting Design Software:

The early stages of lighting design software development were closely tied to the advancements in computer-aided design (CAD) technology. In the 1980s and 1990s, basic CAD programs began to incorporate lighting simulation features, which allowed designers to include simple lighting models in their architectural plans. These early tools, while rudimentary by today's standards, marked the beginning of a significant shift towards digital design processes.

As computer processing power increased and software algorithms became more sophisticated, specialized lighting design software emerged. Programs such as Radiance, developed in the early 1990s, introduced advanced ray-tracing techniques that allowed for the detailed simulation of light behavior in complex environments. This software set the stage for a new era of lighting design, where designers could analyze the interplay of light and materials with unprecedented accuracy.

Key Features of Modern Lighting Design Software:

Modern lighting design software offers a wide range of features that facilitate the creation of optimized lighting solutions. These features include:

- **3D Modeling and Visualization:** Designers can create detailed 3D models of spaces and apply various lighting scenarios. This allows for the visualization of how light will interact with architectural elements and materials in a realistic manner.

- **Daylight Simulation:** Many lighting design programs include tools for simulating natural light. This is particularly useful for assessing daylight penetration and optimizing window placements to enhance natural lighting while minimizing glare and heat gain.

- **Artificial Lighting Simulation:** These tools enable designers to experiment with different types of artificial light sources, such as LEDs, fluorescents, and incandescent. They can adjust light placement, intensity, color temperature, and other parameters to achieve the desired lighting effects.

- **Energy Analysis:** Advanced software can perform energy consumption analyses, helping designers to create energy-efficient lighting systems. This is crucial for meeting modern sustainability standards and reducing operational costs.

- **Lighting Controls:** The integration of smart lighting controls within design software allows for the simulation of dynamic lighting systems. Designers can create and test automated lighting scenarios that adjust based on time of day, occupancy, or specific activities.

- **Compliance and Standards:** Many lighting design tools include features to ensure compliance with local and international lighting standards and regulations. This helps designers to create safe and legally compliant lighting environments.

6.3.1 Popular Lighting Design Software:

Several lighting design software programs are widely used in the industry today. These include:

- **DIALux:** A comprehensive lighting design software that allows for detailed planning, calculation, and visualization of indoor and outdoor lighting. DIALux supports a wide range of lighting manufacturers, enabling designers to use real-world products in their simulations.

- **AGi32:** Known for its robust calculation capabilities, AGi32 is used for both daylight and electric lighting design. It is particularly popular for its detailed analysis and presentation features, making it suitable for complex projects.

- **Relux:** This software offers advanced simulation and visualization tools for both interior and exterior lighting. Relux is often used in conjunction with CAD programs and supports various lighting standards and protocols.

- **LightTools:** Focused on optical design, LightTools is used for designing and analyzing complex lighting systems, including luminaires and light pipes. It is particularly useful for projects that require precise optical control.

Applications in Museums and Classrooms:

- In museums, lighting design software is instrumental in creating environments that enhance the visual impact of exhibits while protecting sensitive artifacts. Designers can simulate different lighting conditions to determine the best way to highlight artwork and sculptures, ensuring that colors are rendered accurately and details are visible without causing damage through excessive light exposure.

- In classrooms, lighting design software helps create environments that support learning and well-being. Proper lighting can reduce eye strain, improve concentration, and enhance the overall educational experience. By simulating various lighting scenarios, designers can optimize natural and artificial light sources to create flexible lighting solutions that accommodate different activities, from lectures to group work.

- The integration of lighting design software has transformed the field of lighting design, enabling the creation of more effective, efficient, and aesthetically pleasing lighting solutions. As technology continues to advance, these tools will become even more integral to the design process, helping to meet the evolving needs of spaces such as museums and classrooms. This thesis will further explore the specific applications and benefits of these tools, providing a comprehensive analysis of their impact on modern lighting design practices.

6.4 DIALux: A Comprehensive Tool for Lighting Design:

Overview of DIALux

DIALux is a leading software tool used by lighting designers and engineers to create, calculate, and visualize lighting schemes for a variety of applications. Developed by DIAL GmbH, DIALux is widely recognized for its robust functionality, user-friendly interface, and integration with a vast database of lighting products from numerous manufacturers. The software supports both indoor and outdoor lighting projects, making it a versatile tool for various environments, including museums and classrooms.

Key Features of DIALux:

- **3D Modeling and Visualization:**

DIALux allows designers to create detailed 3D models of spaces. Users can import CAD drawings and other 3D models to build an accurate representation of the project environment. This feature enables designers to visualize the impact of lighting in a realistic context, assessing how light interacts with architectural elements and materials.

- **Daylight and Artificial Lighting Simulation:**

The software provides powerful simulation tools for both daylight and artificial lighting. Designers can model the penetration of natural light through windows and skylights, optimizing the use of daylight to enhance energy efficiency. Additionally, DIALux supports the simulation of various artificial light sources, enabling precise control over intensity, distribution, and color temperature.

- **Energy Analysis:**

DIALux includes tools for performing detailed energy consumption analyses. Designers can compare different lighting solutions to determine the most energy-efficient options, helping to meet sustainability goals and reduce operational costs. The software can generate comprehensive reports that detail energy usage and potential savings.

- **Integration with Manufacturer Databases:**

One of DIALux’s standout features is its integration with extensive databases of lighting products from leading manufacturers. This allows designers to select real-world lighting fixtures and sources, ensuring that their designs are both practical and feasible. The software provides detailed photometric data for these products, enhancing the accuracy of simulations.

- **Compliance with Standards:**

DIALux supports compliance with various international lighting standards and regulations. The software includes tools for ensuring that designs meet criteria such as illuminance levels, uniformity, and glare control, which are essential for creating safe and comfortable environments.

- **User-Friendly Interface and Visualization Tools:**

The intuitive interface of DIALux makes it accessible to both novice and experienced users. The software offers a range of visualization options, including false color renderings, iso-lux diagrams, and photorealistic images, which help designers and stakeholders understand the lighting effects in the space.

- **<u>Applications in Museums:</u>**

In museum settings, DIALux can be used to design lighting schemes that enhance the visual presentation of exhibits while protecting artifacts from potential damage caused by light exposure. Key applications include:

- **Highlighting Exhibits**:

DIALux enables designers to experiment with different lighting angles, intensities, and colors to find the optimal setup for highlighting artwork and sculptures. This ensures that exhibits are presented in the best possible light, enhancing the visitor experience.

- **Conservation Lighting:**

Museums must balance the need for visibility with the requirement to protect sensitive materials from light damage. DIALux allows for precise control over light levels, helping to minimize UV and infrared exposure and prolong the life of artifacts.

- **Flexible Lighting Solutions:**

The software's ability to simulate various lighting scenarios allows museums to design flexible lighting systems that can be adjusted for different exhibitions and events. This adaptability is crucial for dynamic museum environments that host a variety of displays over time.

Applications in Classrooms:

For classroom environments, DIALux helps create lighting designs that support educational activities and promote a healthy learning atmosphere. Key applications include:

- **Optimizing Natural Light:**

DIALux can simulate daylight penetration in classrooms, helping designers to maximize natural light use while minimizing glare and heat gain. This is particularly important for creating a comfortable learning environment and reducing energy consumption.

- **Task Lighting:**

Classrooms require specific lighting conditions for different tasks, such as reading, writing, and using digital devices. DIALux allows designers to create layered lighting solutions that address these varied needs, ensuring adequate light levels and minimizing eye strain.

- **Energy Efficiency:**

With the ability to perform detailed energy analyses, DIALux helps schools implement energy-efficient lighting systems. This not only reduces operational costs but also supports sustainability initiatives, which are increasingly important in educational institutions.

- **Smart Lighting Controls:**

DIALux can model the integration of smart lighting controls, such as dimming and occupancy sensors. These systems enhance energy efficiency and allow for the adjustment of lighting conditions based on classroom activities and occupancy levels.

Conclusion:

DIALux stands out as a powerful and versatile tool for lighting design, offering comprehensive features that cater to the specific needs of both museums and classrooms. Its ability to model and simulate complex lighting scenarios, combined with its extensive database of real-world products and compliance with standards, makes it an essential tool for creating optimized lighting environments. This thesis will further explore practical applications and case studies using DIALux, demonstrating its effectiveness in enhancing the visual and functional qualities of spaces in educational and cultural settings.

6.5 DIALux 4.13: An Overview:

DIALux 4.13 is a previous version of the DIALux software suite that continues to be popular among lighting designers for its reliability and extensive features. Although DIALux evo represents the latest advancements, DIALux 4.13 remains widely used due to its familiarity, stability, and specific functionalities that some professionals still prefer. This version offers robust tools for designing, calculating, and visualizing lighting solutions, making it suitable for various applications, including museums and classrooms.

Key Features of DIALux 4.13:

- **Indoor and Outdoor Lighting Design:**

DIALux 4.13 supports comprehensive lighting design for both indoor and outdoor environments. This versatility is crucial for projects that require a cohesive lighting strategy across different spaces.

- **Luminaire Selection and Placement:**

The software allows users to select and place luminaires from a vast database of products. Detailed photometric data for each luminaire ensures accurate simulations and realistic visualizations.

- **Calculation of Lighting Parameters:**

DIALux 4.13 excels in calculating essential lighting parameters, including illuminance, luminance, uniformity, and glare. These calculations help designers create well-balanced and comfortable lighting environments.

- **Emergency Lighting:**

The software includes tools for designing emergency lighting systems, ensuring compliance with safety standards. This feature is particularly important in public spaces like museums and educational institutions.

- **Detailed Documentation and Reporting:**

DIALux 4.13 generates comprehensive reports that include all relevant lighting calculations, visualizations, and product specifications. These reports are essential for project documentation and stakeholder approval.

3D Visualization:

The software provides 3D visualization capabilities, allowing designers to create photorealistic renderings of their lighting designs. This helps in understanding how the final lighting setup will look and perform in real-world conditions.

6.6 DIALux evo: An Overview:

DIALux evo is the most advanced version of the DIALux software, designed for professional lighting planning.

It combines several key features and capabilities:

- **Integrated Planning:**

DIALux evo allows for the integration of both indoor and outdoor lighting design within a single project. This is particularly beneficial for museums that require cohesive lighting strategies for exhibit spaces and surrounding areas, as well as for classrooms with adjoining hallways or outdoor learning areas.

- **Detailed 3D Modeling:**

Users can create detailed 3D models of entire buildings, including individual rooms and exterior landscapes. This enables a holistic approach to lighting design, ensuring that all aspects of the environment are considered.

- **Dynamic Daylight Simulation:**

The software provides advanced daylight simulation tools that can model natural light throughout the day and year. This is crucial for museums and classrooms aiming to maximize daylight use while minimizing glare and controlling heat gain.

- **Comprehensive Energy Analysis:**

DIALux evo includes robust energy analysis tools, allowing designers to evaluate the energy efficiency of their lighting designs. This is essential for educational institutions and museums that prioritize sustainability and cost-effectiveness.

- **Quick Calculations:**

This mobile app is ideal for conducting quick lighting calculations and assessments directly on-site. Museum curators and classroom planners can use it to make immediate adjustments to lighting setups during installations or renovations.

- **Portable and User-Friendly:**

The mobile version is designed for ease of use, making it accessible for users who may not have extensive technical expertise. This ensures that even non-specialist staff can participate in the lighting planning process.

- **Plug-ins and Manufacturer Databases**

DIALux supports a wide range of plug-ins and integrates with extensive databases of lighting products from various manufacturers:

- **Product Integration:**

Designers can access detailed photometric data for real-world lighting products, ensuring that simulations and calculations are accurate. This is particularly useful for museums and classrooms that require specific lighting fixtures for their unique needs.

- **Customizable Plug-ins:**

Plug-ins from different manufacturers allow designers to incorporate specific lighting technologies and controls into their projects. For instance, museums can use plug-ins for specialized display lighting, while classrooms can benefit from plug-ins that offer smart lighting controls.

- **DIALux Calculations and Simulations:**

DIALux excels in performing detailed calculations and simulations, which are critical for optimizing lighting designs:

- **Illuminance Calculation:**

The software calculates illuminance levels across different surfaces, ensuring that lighting meets the required standards for visibility and comfort. This is essential for both exhibit displays in museums and various learning tasks in classrooms.

- **Glare Evaluation:**

DIALux includes tools to evaluate and minimize glare, enhancing visual comfort. In museums, this ensures that visitors can appreciate exhibits without discomfort, while in classrooms, it helps prevent eye strain for students and teachers.

- **Uniformity Analysis:**

Ensuring uniform lighting distribution is vital for creating balanced environments. DIALux's uniformity analysis helps in designing lighting setups that avoid hotspots and shadows, providing a consistent lighting experience in both museums and classrooms.

- **DIALux Reports and Documentation:**

Comprehensive reporting and documentation features in DIALux support the communication and implementation of lighting designs:

- **Detailed Reports:**

The software generates detailed reports that include all relevant calculations, simulations, and visualizations. These reports are essential for stakeholders in museums and educational institutions to review and approve lighting designs.

- **Visualization and Presentation:**

High-quality visualizations and presentations created in DIALux help convey the design intent clearly. This is particularly useful for presenting lighting concepts to non-technical stakeholders, such as museum curators and school administrators

❖ 6.7 Comparison Between DIALux 4.13 & DIALux evo :

While DIALux 4.13 remains a powerful tool, DIALux evo offers several advanced features that enhance its functionality:

- **Integrated Planning:** DIALux evo allows for integrated indoor and outdoor lighting planning within a single project, offering more comprehensive design capabilities.
- **Enhanced 3D Modeling:** DIALux evo provides more detailed and dynamic 3D modeling and visualization tools, enabling designers to create more complex and accurate representations of their projects.
- **Dynamic Daylight Simulation:** DIALux evo offers more advanced daylight simulation tools, allowing for a more detailed analysis of natural light throughout the day and year.
- **Smart Lighting Controls:** DIALux evo supports the integration of smart lighting controls, providing more flexibility and efficiency in lighting management.

▪ Conclusion:

DIALux 4.13 continues to be a reliable and effective tool for lighting design, particularly valued for its stability and familiarity among professionals. Its comprehensive features support the creation of optimized lighting solutions in museums and classrooms, addressing both functional and aesthetic requirements. However, for more advanced needs and integrated planning capabilities, DIALux evo represents the future of lighting design software. This thesis will further explore practical applications and case studies using DIALux 4.13, highlighting its strengths and contributions to effective lighting design in educational and cultural settings.

6.8 Lighting Design for Museum and Classroom using DIALux Evo:

▪ Classrooms Design:

6.8.1 Producing Department classroom with Existing Lighting Systems:

- **Room Dimension:**
  - Length: 12 m
  - Width: 6 m
  - Floor to Ceiling Height: 2.66 m

- **Luminaire Used :**

  - 12×2 FTL of 36 watts

- **Averrage Illuminance Value : 201.2 lx**
- **Minimum Illuminance value: 118 lx**

Calculated Uniformity: 0.58 [We can see the value is less than desired value i.e. 0.7)

- **Energy Cost Per Year:**

Total FTL Wattage = 24 × 36 = 864 watts

Let suppose per day effective burning time 10 hrs .

So per day wattage = 864 × 10 = 8640 watts

Now FTL wattage in 30 Days = 8640 × 30 = 259200 watt

= 259.2 kw

So Annual Energy Consumption = 259.2 × 12

= 3110.4 kw

Let suppose 1 BOT cost = 10 rupees

So annual cost = 3110.4 × 10 = 31100.4 rupees

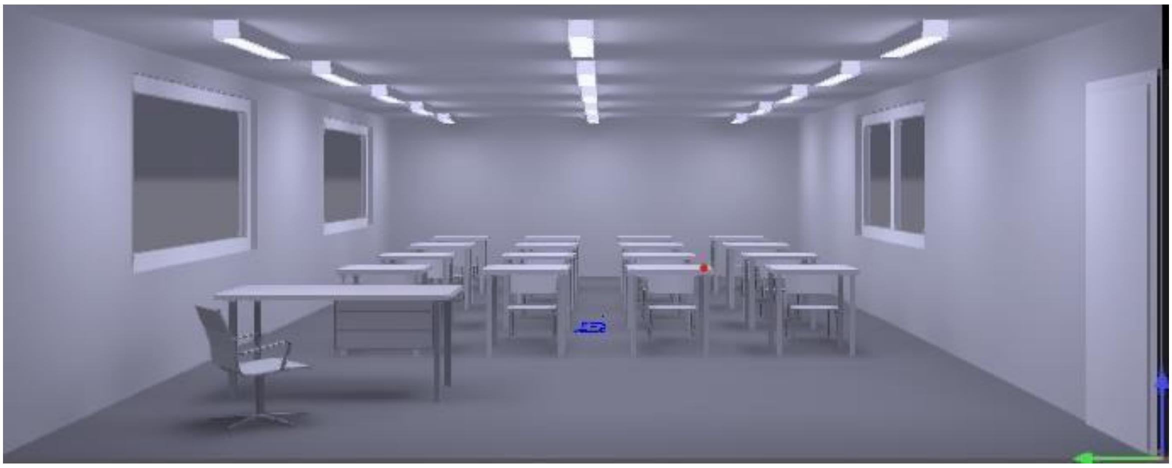
6.8.1 a) Producing Department classroom with LED Lighting Systems design in DIALux Evo:

We have design the Producing Department Classroom with same dimension in DIALux Evo.

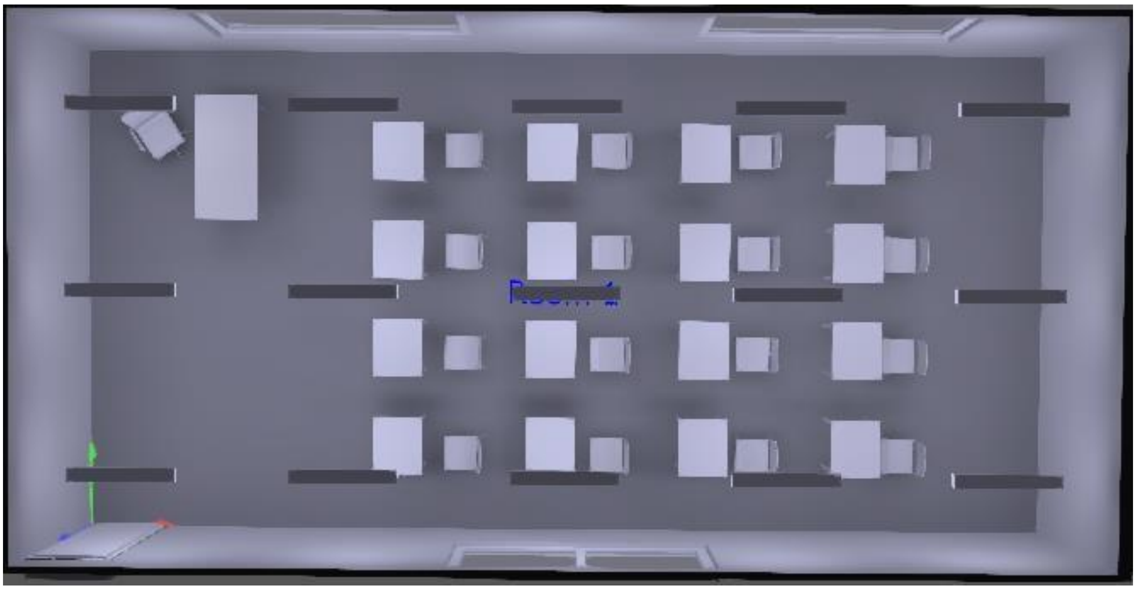
Luminaire Used:

15 LED Tube Lights of 31 watts

DIALux Designed Producing Department Classroom:



Front view



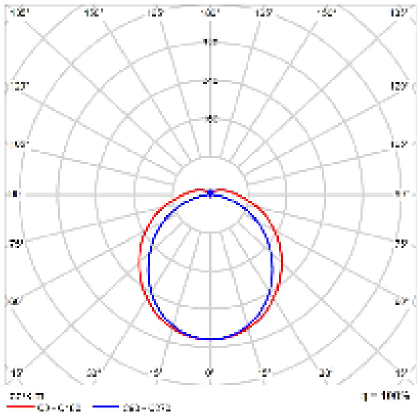
Top View

Product data sheet

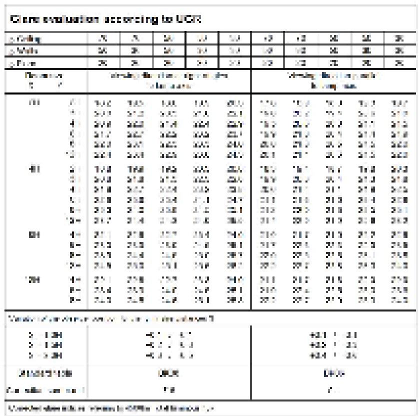
AIRAM - Futura Abs IP66 IK06 31W/840 DA2 AC

Article No.	4338559
P	31.0 W
Φ_{Lamp}	4500 lm
$\Phi_{Luminaire}$	4502 lm
η	100.04 %
Luminous efficacy	145.2 lm/W
CCT	4000 K
CRI	80

A LED luminaire designed for agricultural buildings, cattle shelters, industrial facilities, warehouses and parking facilities. The ABS housing and acrylic diffuser are resistant to ammoniac fumes, lye and alkaline compounds. Meets the requirements for low ambient temperatures, D classification. Wall brackets and lighting track brackets are available as accessories. Please also read about the other luminaires in the Futura range: Futura PC, Futura NB and Futura Max.



Polar LDC



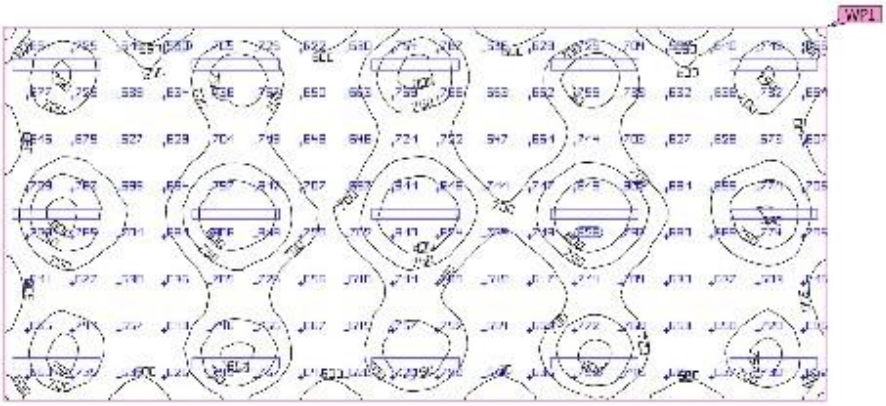
UGR diagram (SHR: 0.25)

Project

DIALux

Building 1 · Storey 1 · Room 1 (Light scene 1)

Working plane (Room 1)



Properties	Ē (Target)	E_{min}	E_{max}	U_o (g_1) (Target)	g_2	Index
Working plane (Room 1) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.500 m	693 lx (≥ 500 lx) ✓	527 lx	870 lx	0.76 (≥ 0.60) ✓	0.61	WP1

Utilisation profile: DIALux presetting (34.2 Standard (office))

Energy Cost With the Modified Designed System for ProducingDepartment:

Total LED Wattage = 15 × 31 = 465 watts

Let suppose per day effective burning time 10 hrs .

So per day wattage = 465 × 10 = 4650 watts

Now FTL wattage in 30 Days = 4650 × 30 = 139500 watt

= 139.5 kw

So Annual Energy Consumption = 139.5 × 12

= 1674 kw

Let suppose 1 BOT cost = 10 rupees

So annual cost = 1674 × 10 = 16740 rupees

❖ Comparative Cost & Efficiency Analysis:

- We have seen that the energy cost in producing department with existing lighting system is 31100.4 rupees . but with this modified design system that cost is reduced to 16740 rupees that is almost **1/2** of the previous cost is being saved per year.
- Although the initial cost of establishment of the system is little bit more than the existing system but the in the long run the modified system is fruitful to us.
- And Also We can see that the Light level is significantly low in previous system.
  - **Previous average illuminance value: 201.2 lx**
  - **Modified average illuminance value: 693 lx**
- The overall uniformity is also low in comparison with the modified designed system.
  - **Previous Overall uniformity: 0.58**
  - **Modified Overall uniformity: 0.76**

6.8.2 Editing Department classroom with Existing Lighting Systems:

- **Room Dimension:**
  - Length: 10m
  - Width: 6 m
  - Floor to Ceiling Height: 2.66 m

- **Luminaire Used :**

  - 10×2 LED recessed Light of 36 watts

- **Averrage Illuminance Value : 465 lx**
- **Minimum Illuminance value: 228 lx**

Calculated Uniformity: 0.49 [We can see the value is less than desired value i.e. 0.6)

- **Energy Cost Per Year:**

Total Recessed Light Wattage = 20 × 36 = 720 watts

Let suppose per day effective burning time 10 hrs .

So per day wattage = 720 × 10 = 7200 watts

Now FTL wattage in 30 Days = 7200 × 30 = 216000 watt

= 216 kw

So Annual Energy Consumption = 216 × 12

= 2592 kw

Let suppose 1 BOT cost = 10 rupees

So annual cost = 2592 × 10 = 25920 rupees

6.8.2 a Editing Department classroom with Efficient LED Lighting Systems design in DIALux Evo:

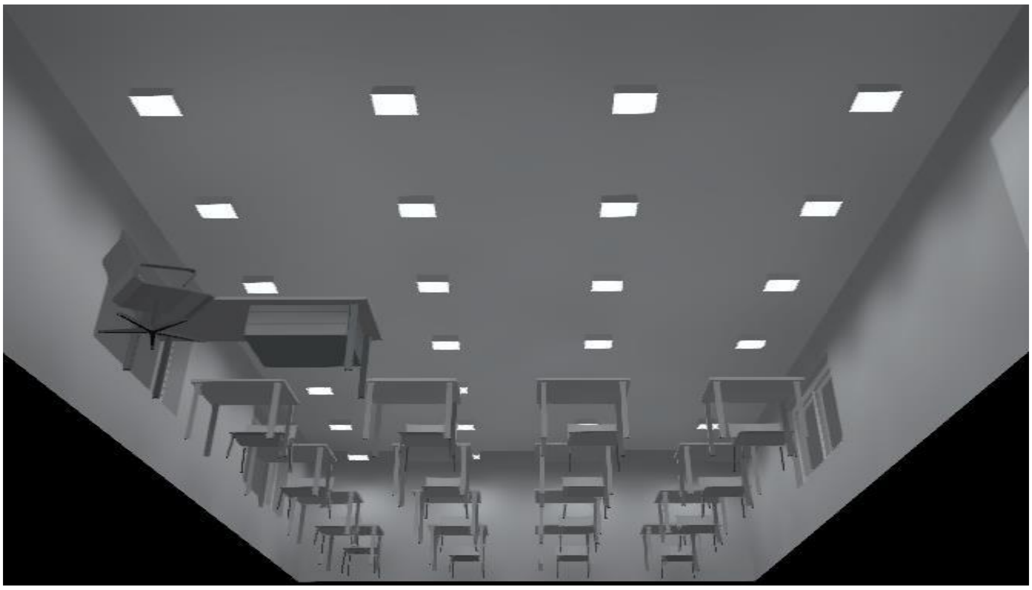
We have design the Editing Department Classroom with same dimension in DIALux Evo.

Luminaire Used:

28 LED Recessed Lights of 18 watts

DIALux Designed Editing Department Classroom:

Top view

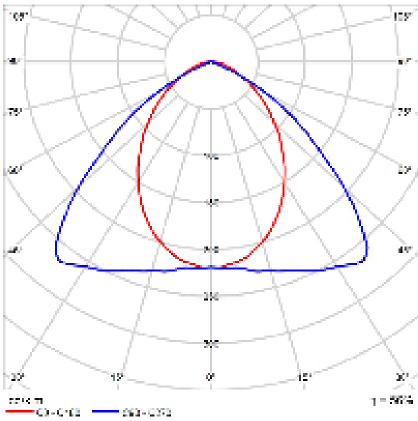


Down to Up View

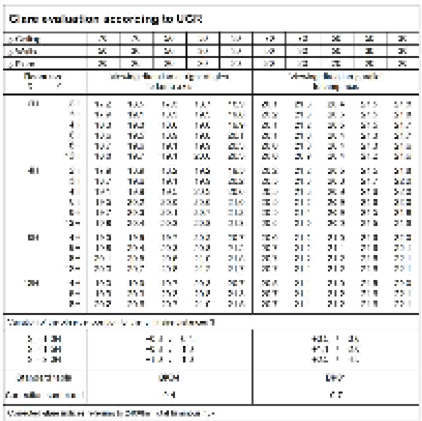
Product data sheet

Philips - FBS285/218 NORMAL

P	48.0 W
Φ_{Lamp}	2400 lm
$\Phi_{Luminaire}$	1356 lm
η	56.49 %
Luminous efficacy	28.2 lm/W
CCT	3000 K
CRI	100



Polar LDC

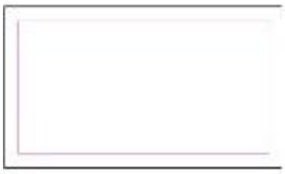


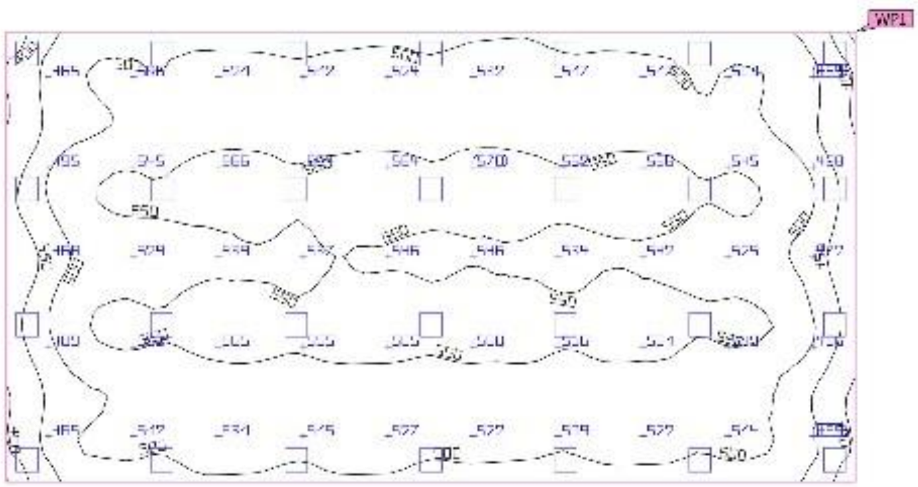
UGR diagram (SHR: 0.25)

Project

Building 1 · Storey 1 · Room 3 (Light scene 1)

Working plane (Room 3)





Properties	$\bar{E}$ (Target)	E_{min}	E_{max}	U_o (g_1) (Target)	g_2	Index
Working plane (Room 3) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.500 m	520 lx (≥ 500 lx) ✓	371 lx	583 lx	0.71 (≥ 0.60) ✓	0.64	WP1

Utilisation profile: DIALux presetting (34.2 Standard (office))

- **Energy Cost With the Modified Designed System for Editing Department:**

Total LED Wattage = 28 × 18 = 504 watts

Let suppose per day effective burning time 10 hrs .

So per day wattage = 504 × 10 = 5040 watts

Now FTL wattage in 30 Days = 5040 × 30 = 151200 watt

= 151.2 kw

So Annual Energy Consumption = 151.2 × 12

= 1814.4 kw

Let suppose 1 BOT cost = 10 rupees

So annual cost = 1814.4 × 10 = 18144 rupees

❖ Comparative Cost & Efficiency Analysis:

- We have seen that the energy cost in producing department with existing lighting system is 25920 rupees . but with this modified design system that cost is reduced to 18144 that is almost **1/3** of the previous cost is being saved per year.
- Although the initial cost of establishment of the system is little bit more than the existing system but the in the long run the modified system is fruitful to us.
- And Also We can see that the Light level is significantly low in previous system.
  - **Previous average illuminance value: 465 lx**
  - **Modified average illuminance value 520 lx**

- The overall uniformity is also low in comparison with the modified designed system.
  - **Previous Overall uniformity: 0.49**
  - **Modified Overall uniformity: 0.71**

6.8.3) Museum Design:

6.8.3 a Museum with Existing Lighting Systems:

- **Room Dimension:**
  - Length: 9.3 m
  - Width: 7 m
  - Floor to Ceiling Height: 3.5 m

- **Luminaire Used :**

  - 10 FTL of 36 watts
  - 10 wall mounted LED of 20 watts

- **Averrage Illuminance Value : 198 lx**
- **Minimum Illuminance value: 101 lx**

Calculated Uniformity: 0.51 [We can see the value is less than desired value i.e. 0.6)

- **Energy Cost Per Year:**

Total FTL Wattage = 10 × 36 = 360 watts
Total LED wattage = 10 × 20 = 200 watts
Total wattage = 360 + 200 =560 watts

Let suppose per day effective burning time 10 hrs .

So per day wattage = 560 × 10 = 5600 watts

Now FTL wattage in 30 Days = 5600 × 30 = 168000 watt

= 168 kw

So Annual Energy Consumption = 168 × 12

= 2016 kw

Let suppose 1 BOT cost = 10 rupees

So annual cost = 2016× 10 = 20160 rupees

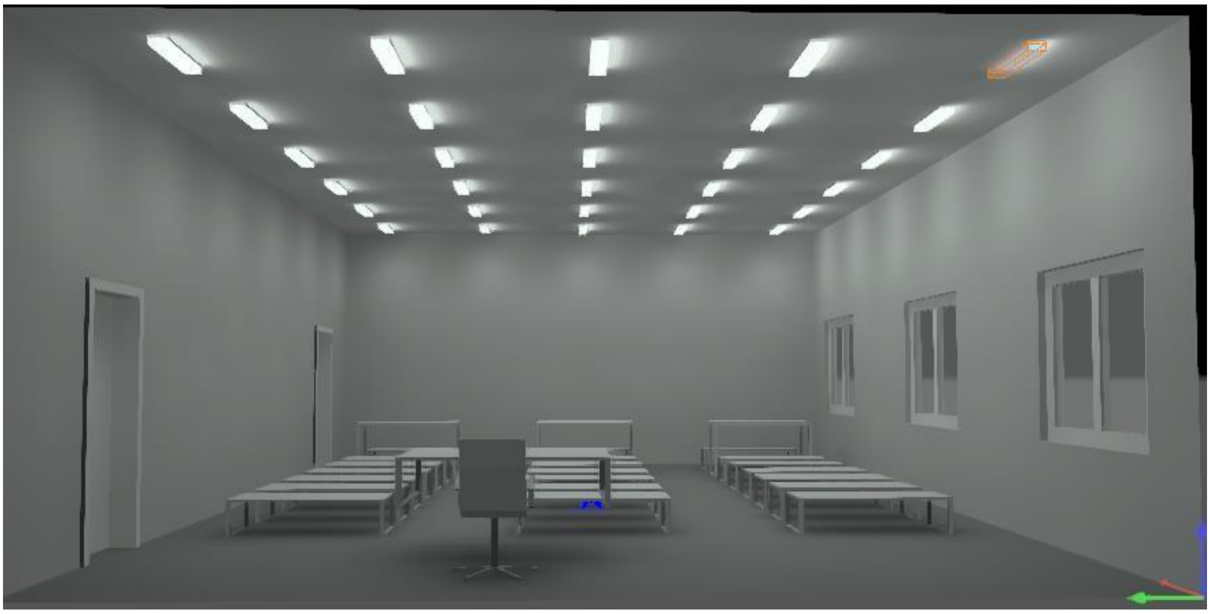
6.8.3 b) Museum with Efficient LED Lighting Systems design in DIALux Evo:

We have design the Museum of SRFTI with same dimension in DIALux Evo.

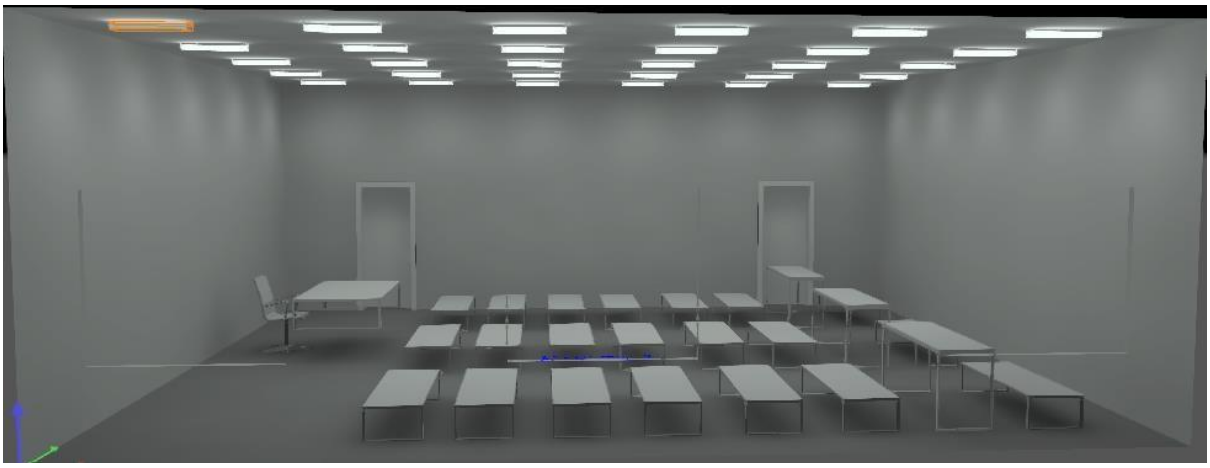
Luminaire Used:

6×5 LED Tube Lights of 14 watts

DIALux Designed Museum:



Front View

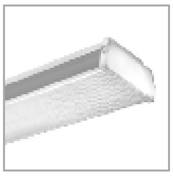


Side View

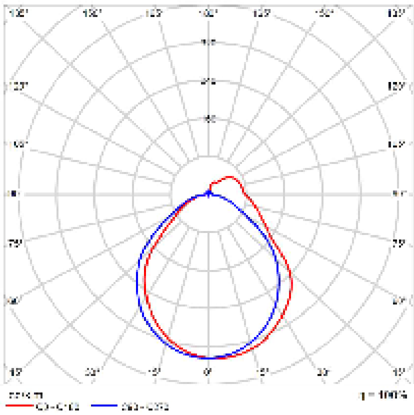
DIALux

Product data sheet

3F Filippi S.p.A. - 03F 14W/830 AS L620



Article No.	1825
P	16.0 W
Φ_{Lamp}	1850 lm
$\Phi_{Luminaire}$	1850 lm
η	100.00 %
Luminous efficacy	115.6 lm/W
CCT	3000 K
CRI	80



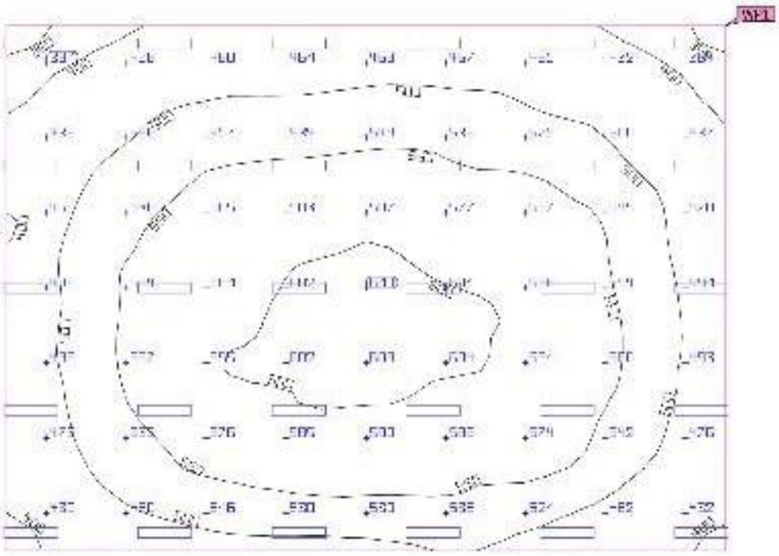
Polar LDC

ILLUMINOTECHNICAL
Luminous efficiency 100% (DLOR 88%, ULOR 12%).
Initial luminous flux of the luminaire 1850 lm.
Asymmetric distribution.
Tabular UGR (CIE 117 - 4H-8H; S=0.25H; 70/50/20): RUG 16.6 - 19.7.
Beam angle: 99° - 100°.
Luminous efficacy 116 lm/W.
Lifetime (L93/B10): 30000 h. (tq+25°C)
Lifetime (L90/B10): 50000 h. (tq+25°C)
Lifetime (L85/B10): 80000 h. (tq+25°C)
Lifetime (L80/B10): 100000 h. (tq+25°C)
Sudden decreased luminous flux after 50000 hours: 0% (C0).
Photobiological safety in compliance with IEC/TR 62778: RG0 risk exempt, (IEC 62471).
In compliance with IEC/EN 62722-2-1 - IEC/EN 62717 standards.

SOURCE
Linear LED module 14W/830.
Energy efficiency class (UE 2019/2020 - UE 2019/2015): D.
CIE 13.3 Colour rendering index: CRI >80 (R9 <50%).
IES TM-30 Fidelity Index: Rf = 84 Rg = 95.

Building 1 · Storey 1 · Room 1 (Light scene 1)

Working plane (Room 1)



Properties	Ē (Target)	E_{min}	E_{max}	U_o (g_1) (Target)	g_2	Index
Working plane (Room 1) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.500 m	522 lx (≥ 500 lx) ✓	330 lx	612 lx	0.63 (≥ 0.60) ✓	0.54	WP1

Utilisation profile: DIALux presetting (34.2 Standard (office))

Energy Cost With the Modified Designed System for Museum:

Total LED Wattage = 30 × 14 = 420 watts

Let suppose per day effective burning time 10 hrs .

So per day wattage = 420×10 = 4200 watts

Now FTL wattage in 30 Days = 4200 × 30 = 126000 watt

= 126 kw

So Annual Energy Consumption = 126 × 12

= 1512 kw

Let suppose 1 BOT cost = 10 rupees

So annual cost = 1512 × 10 = 15120 rupees

❖ Comparative Cost & Efficiency Analysis:

- We have seen that the energy cost in producing department with existing lighting system is 20160 rupees . but with this modified design system that cost is reduced to 15120 rupees that is almost **1/4** of the previous cost is being saved.
- Although the initial cost of establishment of the system is little bit more than the existing system but the in the long run the modified system is fruitful to us.
- And Also We can see that the Light level is significantly low in previous system.
    - **Previous average illuminance value: 198 lx**
    - **Modified average illuminance value 522 lx**

- The overall uniformity is also low in comparison with the modified designed system.
    - **Previous Overall uniformity: 0.51**
    - **Modified Overall uniformity: 0.63**

6.8.4 Seminar Room Design:

6.8.4a) Seminar Room Design with Existing Lighting Systems:

- **Room Dimension:**
  - Length: 12 m
  - Width: 6.8 m
  - Floor to Ceiling Height: 3.13 m

- **Luminaire Used :**

  - 6×3 FTL of 20 watts

- **Averrage Illuminance Value : 180 lx**
- **Minimum Illuminance value: 85 lx**

Calculated Uniformity: 0.47 [We can see the value is less than desired value i.e. 0.6)

- **Energy Cost Per Year:**

Total FTL Wattage = 18× 20 = 360 watts

Let suppose per day effective burning time 10 hrs .

So per day wattage = 360× 10 = 3600 watts

Now FTL wattage in 30 Days = 3600 × 30 = 108000 watt

= 108 kw

So Annual Energy Consumption = 108 × 12

= 1296 kw

Let suppose 1 BOT cost = 10 rupees

So annual cost = 1296 × 10 = 12960 rupees

6.8.4b) Seminar room with Efficient LED Lighting Systems design in DIALux Evo:

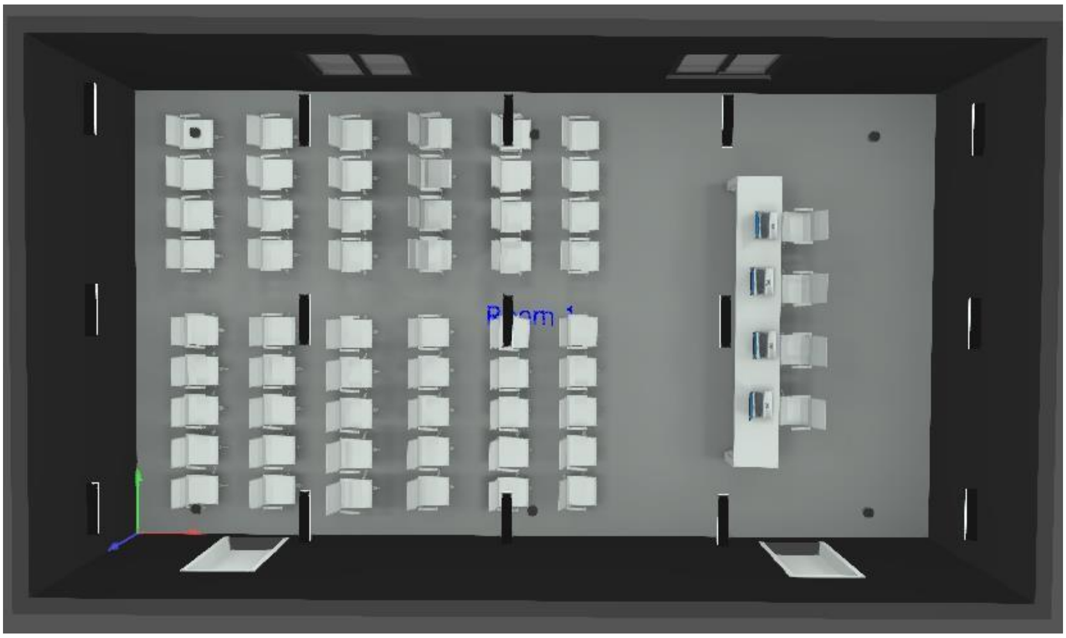
We have design the Seminar room of SRFTI with same dimension in DIALux Evo.

Luminaire Used:

5×3 LED Tube Lights of 14 watts

DIALux Designed Seminar room:

Front view



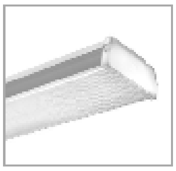
Top View

DIALux

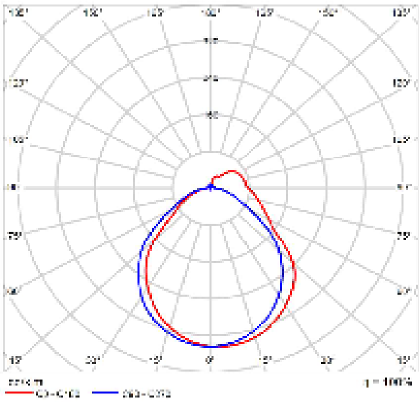
Product data sheet

3F Filippi S.p.A. - 03F 14W/830 AS L620

3F Filippi



Article No.	1825
P	16.0 W
Φ_{Lamp}	1850 lm
$\Phi_{Luminaire}$	1850 lm
η	100.00 %
Luminous efficacy	115.6 lm/W
CCT	3000 K
CRI	80



Polar LDC

ILLUMINOTECHNICAL
Luminous efficiency 100% (DLOR 88%, ULOR 12%).
Initial luminous flux of the luminaire 1850 lm.
Asymmetric distribution.
Tabular UGR (CIE 117 - 4H-8H; S=0.25H; 70/50/20): RUG 16.6 - 19.7.
Beam angle: 99° - 100°.
Luminous efficacy 116 lm/W.
Lifetime (L93/B10): 30000 h. (tq+25°C)
Lifetime (L90/B10): 50000 h. (tq+25°C)
Lifetime (L85/B10): 80000 h. (tq+25°C)
Lifetime (L80/B10): 100000 h. (tq+25°C)
Sudden decreased luminous flux after 50000 hours: 0% (C0).
Photobiological safety in compliance with IEC/TR 62778: RG0 risk exempt, (IEC 62471).
In compliance with IEC/EN 62722-2-1 - IEC/EN 62717 standards.

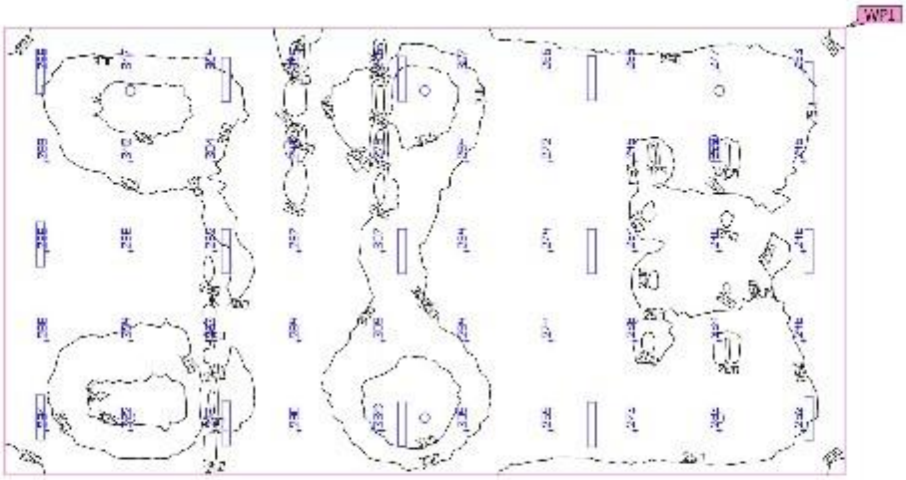
SOURCE
Linear LED module 14W/830.
Energy efficiency class (UE 2019/2020 - UE 2019/2015): D.
CIE 13.3 Colour rendering index: CRI >80 (R9 <50%).
IES TM-30 Fidelity Index: Rf = 84 Rg = 95.

Project

DIALux

Building 1 · Storey 1 · Room 1 (Light scene 1)

Working plane (Room 1)



Properties	Ē (Target)	E_{min}	E_{max}	U_o (g_1) (Target)	g_2	Index
Working plane (Room 1) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.300 m	280 lx (≥ 155 lx) ✓	170 lx	345 lx	0.61 (≥ 0.60) ✓	0.49	WP1

Utilisation profile: Educational premises - Educational buildings (44.1 Classroom - general activities)

Energy Cost With the Modified Designed System for Seminar Room:

Total LED Wattage = 15 × 14 = 210 watts

Let suppose per day effective burning time 10 hrs .

So per day wattage = 210×10 = 2100 watts

Now FTL wattage in 30 Days = 2100 × 30 = 63000 watt

= 63 kw

So Annual Energy Consumption = 63 × 12

= 756 kw

Let suppose 1 BOT cost = 10 rupees

So annual cost = 756 × 10 = 7560 rupees

❖ Comparative Cost & Efficiency Analysis:

- We have seen that the energy cost in producing department with existing lighting system is 12960 rupees . but with this modified design system that cost is reduced to 7560 rupees that is almost ½ of the previous cost is being saved.
- Although the initial cost of establishment of the system is little bit more than the existing system but the in the long run the modified system is fruitful to us.
- And Also We can see that the Light level is significantly low in previous system.
  - **Previous average illuminance value: 180 lx**
  - **Modified average illuminance value 280 lx**

- The overall uniformity is also low in comparison with the modified designed system.
  - **Previous Overall uniformity: 0.47**
  - **Modified Overall uniformity: 0.61**

Chapter : 7

Future Scope & Conclusion

7.1 Future Scope:

I. **Technological Advancements:** As technology continues to evolve, there will be advancements in energy-efficient lighting solutions. Future research can focus on integrating emerging technologies such as smart lighting systems, IoT-enabled sensors, and advanced controls to further enhance energy savings and lighting quality in museums and classrooms.

II. **Sustainability Initiatives:** With increasing global focus on sustainability, future studies can explore how energy-efficient lighting solutions align with broader sustainability initiatives in educational institutions and cultural organizations. This includes investigating the environmental impact of lighting systems, life cycle assessments, and the integration of renewable energy sources.

III. **Human-Centric Lighting:** Research can delve deeper into the concept of human-centric lighting, which aims to optimize lighting conditions to support human health, well-being, and performance. Future studies can explore the effects of dynamic lighting, circadian lighting, and personalized lighting solutions on occupants in museum and classroom settings.

IV. **Data-Driven Approaches:** There is potential for utilizing data-driven approaches, such as machine learning algorithms and occupancy sensors, to optimize lighting strategies based on real-time usage patterns and user preferences. Future research can explore the feasibility and effectiveness of these approaches in enhancing energy efficiency and user satisfaction.

V. **Cross-Disciplinary Collaboration:** Collaboration between lighting designers, architects, educators, museum curators, and sustainability experts will be crucial in advancing energy-efficient lighting solutions. Future studies can investigate interdisciplinary approaches to lighting design that prioritize both energy efficiency and user experience.

VI. **Policy and Standards Development:** Continued research is needed to inform policy development and establish industry standards for energy-efficient lighting in museums and classrooms. Future studies can contribute to the development of guidelines, regulations, and certification programs that promote the adoption of sustainable lighting practices.

Conclusion:

In conclusion, this thesis has examined the importance of energy-efficient lighting solutions in museums and classrooms, aiming to balance the dual objectives of conservation and illumination. Through a comprehensive review of literature, case studies, and practical analysis, several key findings have emerged:

- **Significance of Lighting:** Lighting plays a critical role in enhancing the aesthetic appeal, educational experience, and overall ambiance of both museums and classrooms. However, traditional lighting systems often consume significant energy and contribute to environmental degradation.

- **Benefits of Energy Efficiency:** The adoption of energy-efficient lighting solutions offers numerous benefits, including reduced energy consumption, lower operating costs, and decreased environmental impact. Moreover, energy-efficient lighting can improve visual comfort, productivity, and well-being for occupants.

- **Challenges and Considerations:** Implementing energy-efficient lighting solutions in museums and classrooms is not without challenges. Financial constraints, technical complexities, and stakeholder preferences pose significant barriers to adoption. However, through careful planning, stakeholder engagement, and innovative design strategies, these challenges can be overcome.

- **Recommendations:** Based on the findings of this research, several recommendations have been proposed for achieving optimal energy efficiency in museum and classroom lighting. These include:

    - Embracing LED technology for its energy efficiency, longevity, and versatility.
    - Designing lighting systems that are tailored to the specific needs and activities of each space.
    - Integrating daylighting strategies to maximize natural light while minimizing energy consumption.
    - Implementing advanced controls and sensors to optimize lighting performance and energy usage.

- Educating stakeholders about the benefits of energy-efficient lighting and fostering a culture of sustainability.

➢ In conclusion, energy-efficient lighting solutions hold tremendous promise for enhancing the sustainability and quality of lighting in museums and classrooms. By addressing the challenges and leveraging emerging technologies, educators, museum professionals, and lighting designers can collaborate to create environments that are both visually captivating and environmentally responsible. This thesis serves as a stepping stone towards achieving that vision and lays the groundwork for future research and innovation in the field of energy-efficient lighting.

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APPENDIX :

Luxmeter:

A lux meter, also known as a light meter, is a device used to measure the intensity of light in units called lux. Lux is the standard unit of measurement for illuminance, which refers to the amount of visible light falling on a surface.

Lux meters are commonly used in various applications, including photography, cinematography, architecture, industrial lighting, and environmental monitoring. They provide a quantitative measurement of light levels, helping users assess and control lighting conditions. Lux meters typically consist of a light sensor or photodiode that detects the incoming light and converts it into an electrical signal. The meter then displays the light intensity in lux on a digital or analog screen. Some advanced lux meters may also offer additional features such as data logging, multiple measurement ranges, and connectivity options for data transfer.

To use a lux meter, you simply place the sensor in the area where you want to measure the light intensity and read the value displayed on the meter. Lux meters are calibrated to provide accurate measurements based on the sensitivity of the sensor and the spectral response of human vision.When selecting a lux meter, consider the measurement range, accuracy, resolution, and any additional features you may need for your specific application. Lux meters are available in various models and price range

Fig 7.1 : Lux meter

Laser distance meter:

A laser distance meter, also known as a laser rangefinder or laser measuring device, is a tool used to measure distances using laser technology. It utilizes a laser beam to determine the distance between the device and a target object by calculating the time it takes for the laser pulse to reflect back to the device.

Here's how a typical laser distance meter works:

Targeting: The user aims the laser distance meter at the object they want to measure. The device usually has a built-in viewfinder or a laser pointer to assist with accurate targeting.

Emitting laser pulse: Upon pressing a button or triggering a measurement, the device emits a laser pulse towards the target object.

Reflection: The laser pulse hits the object and reflects back towards the device. The device's sensor detects the reflected pulse.

Time calculation: The device measures the time it takes for the laser pulse to travel to the object and return. It uses the speed of light to calculate the round-trip time.

Distance calculation: Using the measured time and the speed of light, the laser distance meter calculates the distance between the device and the target object. This distance is typically displayed on a screen or readout.

Laser distance meters are commonly used in various fields such as construction, architecture, real estate, forestry, and sports. They provide quick and accurate distance measurements, making them convenient for tasks like measuring room dimensions, determining distances between objects, assessing building heights, or calculating area and volume.

It's worth noting that laser distance meters have different measurement ranges and accuracies, so it's important to choose a device that suits your specific needs. Additionally, some advanced laser distance meters offer additional features like angle measurements, Pythagorean calculations, Bluetooth connectivity for data transfer, or even integration with smartphone apps.

Fig 7.2 : Laser Distance Meter
