A THESIS REPORT ON

Studies On Energy Efficient Lighting Solution for Academic Building

A thesis submitted in partial fulfilment of the requirements for the award of the degree

Of

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in
Illumination Engineering

Submitted by

MOLLA MAHMADUL HASSAN
Examination Roll No: M4ILN24013
Registration No: 144822 of 2018-19

Under the Guidance of

MRS. SANGITA SAHANA
Assistant Professor

DEPARTMENT OF ELECTRICAL ENGINEERING
FACULTY OF ENGINEERING AND TECHNOLOGY
JADAVPUR UNIVERSITY
KOLKATA

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CERTIFICATE

This is to certify that **Mr. Molla Mahmadul Hassan (Examination Roll no-M4ILN24013 and Registration No: 144822 of 2018-2019)** is a student of M.E in Illumination Engineering at Jadavpur University, Kolkata– 700032, has been entitled a thesis work and directed to submit the final report for the partial fulfilment of the requirements for award degree of M.E in Illumination Engineering Examination at the Department of Electrical Engineering of Jadavpur University

During the period of final year, he has been carried out the thesis work on **"Studies on Energy Efficient Lighting solution for Academic Building"** under the guidance and supervision of Assistant Professor **Sangita Sahana** and the content of this thesis report have not been submitted earlier by any other Institute by any one for award of any degree.

…….…….
Supervisor
Prof. Sangita Sahana
Assistant Professor,
Department of Electrical Engineering
Jadavpur University,
Kolkata-700032

……..
Head of the Department
Dr. Biswanath Roy
Department of Electrical Engineering
Jadavpur University,
Kolkata-700032

……..
DEAN
Prof. Depak Laha
Faculty of Engineering and Technology
Jadavpur University,
Kolkata-700032

DECLARATION OF ORIGINALITY AND COMPLIANCE WITH ACADEMIC ETHICS

I hereby declare that the thesis "**Studies on Energy Efficient Lighting Solution for Academic Building**" contains literature survey and original research work that has been carried out by myself, as a part of my Master of Engineering Degree in Illumination Engineering during the academic year 2022-2024. All the information in this document has been obtained and presented in accordance with academic rules and ethical conduct. As per the rules and regulations I also declare that, I have fully cited all the reference materials and given due credit to their respective authors for any data or information that are not original to this work.

Name: Molla Mahmadul Hassan

Examination Roll Number: M4ILN24013

Registration No: 144822 of 2018-2019

Place: Kolkata ……

Signature of Candidate

Date:

CERTIFICATE OF APPROVAL

The foregoing thesis, entitled as "**Studies on Energy Efficient Lighting solution for Academic Building**" is hereby approved by the committee of final examination for evaluation of the thesis as a creditable study of an engineering subject and presented by Mr. Molla Mahmadul Hassan (Registration No: 144822 of 2018-2019) in a manner satisfactory to warrant its acceptance as a prerequisite to the degree M.E in Illumination Engineering for which it has been submitted. It is understood that by this approval, the undersigned do not necessarily endorse or approve any statement made, opinion expressed, or conclusion drawn therein, but only the thesis for which it is submitted.

Committee of final examination for the evaluation of the thesis –

…….

……

Signature of Examiners

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Abstract:

This thesis investigates the implementation of energy-efficient lighting systems in application areas of an academic building and corridor 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. Areas of an academic building and Corridor with their unique lighting requirements, stand to gain from advancements in lighting technology.

The study begins with an assessment of current lighting systems in application areas of an academic building and corridor, 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 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 the areas. The findings offer valuable recommendations for institutions considering similar upgrades and highlight areas for future research in energy- efficient lighting applications.

Chapter: 1

Introduction

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.

1.1 Literature Review:

Electric lighting consumes a considerable amount of energy. However, significant energy savings can be achieved by utilizing energy-efficient devices, implementing effective control systems, and employing thoughtful design. Reducing the use of electric lighting decreases heat accumulation, thereby lowering the demand for air conditioning and enhancing thermal comfort. It is crucial to balance this with the need for adequately lit spaces to support productivity, well-being, safety, and health. A well-lit environment must meet both the functional and aesthetic lighting needs of the

specific application and architectural design while ensuring energy is used efficiently. [1]
Light-emitting diode (LED) technology is advancing swiftly, opening new possibilities for various LED lighting applications in the industry. As new innovations emerge, lighting products are becoming more energy-efficient and environmentally friendly. In addition to energy conservation, factors such as illuminance, brightness, lamp spectrum, and color rendering index (CRI) must also meet user expectations. In office lighting settings, users tend to favor LEDs over traditional fluorescent lamps, such as Compact Fluorescent Lamps (CFLs). [2,3]

A smart lighting control system can lower energy consumption and costs while greatly enhancing comfort in the workplace, making it a crucial feature in contemporary commercial buildings. LED luminaires can be easily dimmed to conserve energy. Light sensors can track illumination levels, and this data can be used as feedback for a lighting controller to adjust the artificial light output, ensuring that the desired brightness levels are consistently maintained. [4,5]

In the workplace, glare poses a significant occupational hazard. It is crucial to anticipate and control glare effectively. Evaluating discomfort glare is challenging due to its subjective nature. The International Commission on Illumination (CIE) suggests the Unified Glare Rating (UGR) formula for predicting glare, which offers a standardized and technical method for measuring glare levels. UGR can also be gauged through subjective analysis, such as experiments involving 65 participants. Generally, the subjective glare rating tends to be slightly lower than the glare level predicted by the UGR formula. [6]

Occupancy sensors provide substantial energy savings in areas that are used infrequently or unpredictably, such as restrooms, stairwells, hallways, storage rooms, and mail sorting stations. The challenge lies in identifying the optimal placement for the sensors and selecting the appropriate type of sensor. The quantity of sensors should be optimized to improve accuracy and minimize time delays without significantly raising costs. [7]

Traditionally, lighting has prioritized visual performance, such as horizontal illuminance on work surfaces, before focusing on energy efficiency. Only recently has attention shifted toward the impact of light on human health. Light serves as the primary trigger for resetting the biological clock. Each morning, exposure to light realigns the sleep-wake cycle with the natural day-night rhythm. The specific qualities of light, including its intensity, spectral composition, timing, and duration, are key to this process. Light also has an immediate alerting effect on people, similar to the boost provided by caffeine. Research suggests that a Circadian Stimulus (CS) of at least 0.3 for a minimum of two hours during the day is beneficial for circadian regulation, increasing alertness and energy levels. Supplementing standard overhead lighting with a desk lamp that directs light toward the eyes of office workers can deliver higher levels of CS at a lower lighting power density (LPD) compared to overhead lights alone, which are designed to achieve the CS benchmark of 0.3. Exposure to blue light influences the body's production of melatonin, a key hormone in the circadian system. Meanwhile, red light can offer a similar alerting effect without reducing melatonin levels or disturbing circadian rhythms. [8]

1.2 Problem Identification:

- **Outdated Technology**: Current lighting fixtures may rely on fluorescent or other inefficient technologies, leading to high energy consumption.
- **Poor Light Quality**: Non-LED lighting often results in inconsistent brightness, glare, and poor color rendering, affecting the learning environment.
- **Energy Inefficiency**: Traditional fixtures consume more electricity and generate heat, increasing cooling loads and operational costs.
- **Maintenance Challenges**: Frequent bulb replacements and repairs are common with non-LED lighting, disrupting educational activities.
- **Lack of Uniformity**: Inadequate light distribution creates dark spots and shadows, impacting visibility and comfort in classrooms.
- **Environmental Impact**: Fluorescent tubes contain hazardous materials like mercury, posing disposal and environmental challenges.

1.3 Objectives

The major objective of this research paper identify the energy usage discusses the performance of different types of lighting installation. In order to complete this research few objectives are set, which are:

i. To identify the ideal number of luminaires needed in certain room.
ii. To determine the minimum required lamps in a specific place without reducing the quality of lighting.

iii. To identify the performance of different types of lighting installations used in Jadavpur University of Electrical Engineering Department and saving in energy consumption in the education building lighting application.

1.4 Methodology

Fundamentals of Lighting Design

When designing a lighting solution for indoor or outdoor settings, the following design considerations should generally be addressed:

- Whether the lighting is intended for a safe or hazardous environment.
- The necessary illumination level for the activities to be carried out in the space.
- The working plane where the desired level of illuminance should be met.
- The types of lamps and luminaires to be used, including their lumen output.
- The available mounting height.
- The consistency of illumination that needs to be achieved.
- The color rendering required for the tasks performed in the area.
- The total electrical energy consumption.
- Measures to limit light pollution.

Closed Vs. Open Areas

The level of protection needed for luminaires against elements like weather, corrosion, and dust or water ingress depends on whether the lighting is installed indoors or outdoors. Indoor luminaires are not suitable for areas with only a roof and no side walls. However, the reflectance properties of the luminaires can significantly impact the illuminance (lux) levels.

Working Plane Height

In areas such as reading rooms or assembly shops, the working plane is typically at desk level (750 to 900 mm above the floor). In contrast, for corridors or sports fields, the working plane is usually at floor level.

Mounting Height

The height at which lamps are mounted affects the illuminance on the working plane. Indoor lighting is influenced by the space above the mounting height (ceiling cavity), below the working plane, and the surrounding walls of the work area.

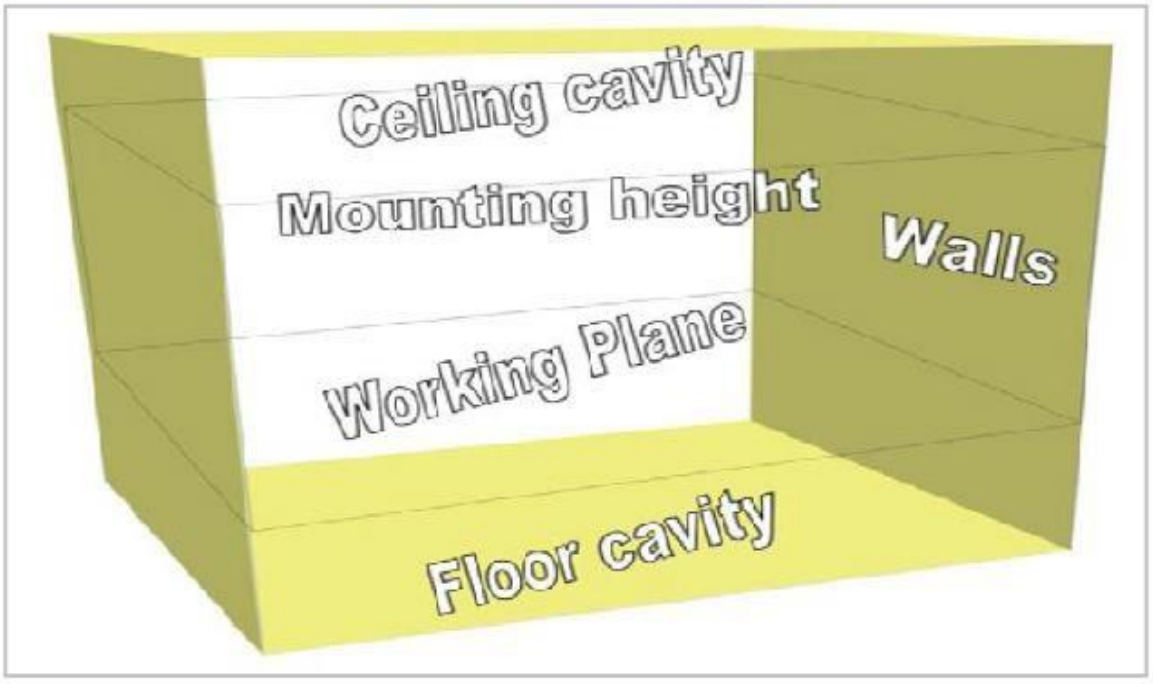


Fig-1: Working plane and Mounting Heights

Reflectance Factors

Reflectance can be classified into three types – Light, Medium and Dark. The average value of these factors for ceiling, walls and floor can be obtained from the following table1.1

Table 1: The average value of the reflectance for ceiling, wall and floor

Surface Reflectance	**Light**	**Med**	**Dark**
Celling cavity	0.70	0.50	0.30
Walls	0.50	0.30	0.10
Floor Activity	0.30	0.20	0.10

Coefficient of Utilisation

This represents the ratio of luminous flux that reaches the working plane compared to the total flux emitted by the installed lamps, taking into account floor and ceiling cavities and reflectance factors. In a closed room, the Coefficient of Utilisation (CoU) is determined by the room's dimensions (length, width, and luminaire mounting height) and is calculated using the formula:

Room Index = Length × Width / Mounting Height × (Length + Width)

CoU values are provided by luminaire manufacturers for various types of luminaires, depending on room indices and reflectance factors, and are used in lighting calculations to determine the number of luminaires needed.

Maintenance / Depreciation Factor

The luminaire depreciation factor accounts for the decrease in light output over time due to aging, dirt accumulation, and material degradation. Lamp output also gradually decreases with age due to factors like filament evaporation, known as the lamp depreciation factor. The maintenance factor (MF) compensates for reduced light output from luminaires or lamps. A typical MF of 0.7 to 0.8 is used in design calculations when specific information about maintenance plans or the type of luminaire or lamp is not available.

Lighting Design Parameters

Average Illuminance (Eavg)

Illuminance refers to the amount of light that falls on a unit area of a surface. For effective lighting, it is important to ensure that:

- There is a good balance between the horizontal illuminance in the task area (where activities such as reading and computer work take place) and the surrounding environment.
- Adequate vertical illuminance is provided to present a true and aesthetically pleasing appearance of the interiors and occupants.

Overall Uniformity
(U_0)

Best practice guidelines suggest that illuminance uniformity should be evaluated as the ratio of minimum illuminance to average illuminance across an area, which could be an entire interior or specific task zones.

Uniformity ($U_0 = E_{min} / E_{avg}$)

Uniformity is crucial for several reasons:

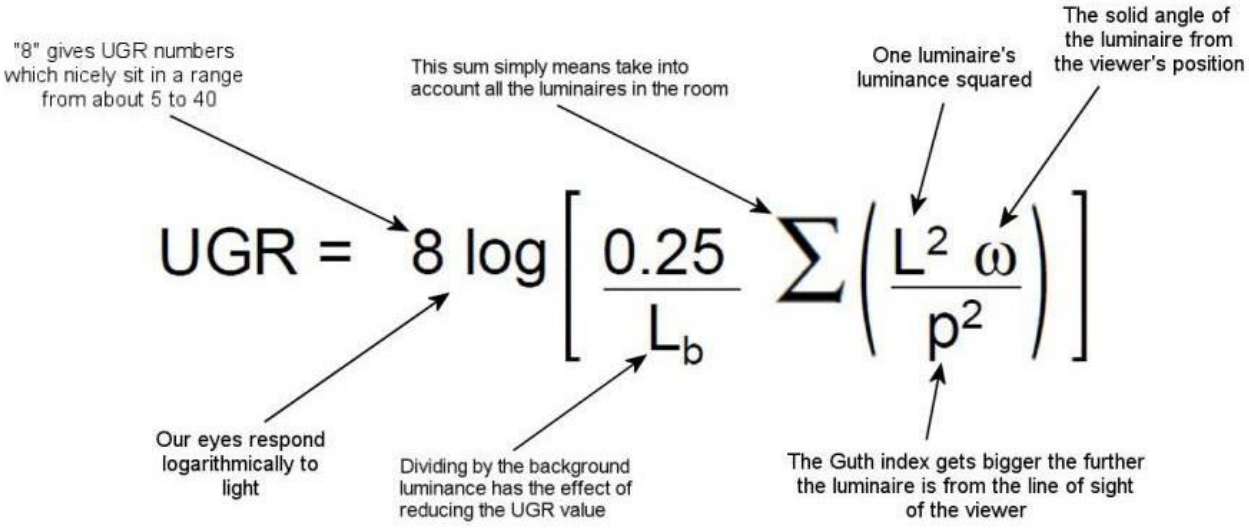
- High variations in illuminance can result in some areas receiving inadequate lighting.
- Frequent changes between brightly and poorly lit areas can cause significant eye strain, leading to stress and fatigue.

Unified Glare Rating (UGR)

Glare refers to a vision condition where discomfort or a decrease in the ability to see important objects occurs due to improper luminance distribution or extreme contrasts in space or time.

UGR (Unified Glare Rating) is a method for assessing glare caused by luminaires, light from windows, and other bright light sources. It helps determine the likelihood of a luminaire causing discomfort. The UGR scale ranges from 5 to 40, with lower values indicating less glare.

The formula to calculate UGR is given below



Average UGR value ranges from 10-13-16-19-22-25-28. The relationship between calculated UGR value and Hopkinson's discomfort glare criteria is shown in the following Table 1.2.

Table 2: UGR Table

UGR	Discomfort Glare Criteria
10	Imperceptible
13	Just perceptible
16	Perceptible
19	Just acceptable
22	Unacceptable
25	Just uncomfortable
28	Uncomfortable

Lighting Power Density (LPD)

Lighting power density is a straightforward metric used to assess potential energy savings within a space. It is defined as the maximum amount of lighting power installed per unit area, based on the space's function or the building's classification. LPD can be determined in two ways:

- **Building Area Method** - This approach calculates the total watts per square meter for the entire building according to its type.
- **Space Function Method** - This method adjusts LPD based on the specific function of the space, tailored to the type of building.

Lighting Design Procedure

- **Step I:** The initial task for any designer is to engage in a formal discussion with the client or end user and other members of the design team. It is essential to determine whether the design is for a new construction or an existing building, understand the purpose of the space, and gather all necessary details about the project.
- **Step II:** For existing buildings, the design options are limited since luminaire positions are generally fixed. Energy savings can be achieved by retrofitting with equivalent LED solutions and incorporating some controls. For new construction projects, the AutoCAD files are thoroughly reviewed, room dimensions are analyzed, and any missing information is requested from the client.
- **Step III:** Relevant codes and guidelines are reviewed in detail.
- **Step IV:** Various types of lamps and luminaires are explored for the lighting design, considering options such as recessed, surface-mounted, suspended, direct, indirect, or a combination of both direct and indirect lighting.
- **Step V:** The AutoCAD file is imported into lighting design software, such as DIALux version 4.13. A 3D model of the rooms is created using the design software, and different lighting scenarios are simulated to identify the most efficient solution that meets relevant standards.
- **Step VI:** The type of sensor is selected based on its intended locations, and sensor positions are determined in the AutoCAD drawing to ensure optimal coverage and minimal overlap.
- **Step VII:** If the simulation does not meet the standards or if the client has specific requirements, the design is reviewed and revised until it complies with the standards and satisfies the client's needs.

1.5. Thesis Outline

In **chapter 1**, an introduction to the thesis work has been given. It also includes Literature survey, problem definition, objective, methodology and organisation of the thesis.

In **chapter 2,** Introduction of Computer Aided Lighting Design to the thesis work has been given, it also includes Introduction, Historical Background of Lighting Design, Lighting Design Software, DIALux: A Comprehensive tool of Lighting Design, DIALux 4.13: An Overview, DIALux Evo: An Overview and Comparison Between DIALux 4.13 & DIALux Evo.

In **chapter 3**, Concept about Lighting designed and standard

In **chapter 4,** Used instrument details and Survey on Existing Lighting Conditions of the Seminar-room, Classrooms & Corridor.

In **chapter 5**, Result, Discussion and analysis to the thesis work has been given, it also includes producing Lighting Design for Seminar-room, Classroom- E-2-1, Classroom- E-2-2 and K.C.ROY Hall & Corridor Using DIALux. Specifications of Producing Lighting, Comparison between Existing & Producing avg. illuminations, Comparison between existing & producing overall Uniformity, Comparison between Existing & Producing Lighting Power Density (LPD), Comparison between Existing & Producing Lighting Energy Consumption per year, Comparison between Existing & Producing Lighting Energy Cost per year.

In **chapter 6**, Conclusion of the thesis work is drawn and future scope of this work is highlighted.

At last, all the references have been given

Chapter: 2

Computer Aided Lighting Design

2.1 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 existing 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.

2.2 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.

2.3 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.

2.3.1 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 Seminar-room 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 Seminar-room 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.

2.4. 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.

Applications in Seminar-room:

In Seminar-room 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:**

Seminar-room 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 Seminar-room 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.

2.5 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.

2.6. DIA Lux 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.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.

- **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

2.7. 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.

Chapter: 3

Lighting Design and Standard

3.1. Conventional Light Sources

Traditional light sources, like incandescent bulbs or General Lighting Service (GLS) lamps such as tungsten filament and tungsten halogen, are very energy-inefficient. They have an efficacy of around 10-25 lumens per watt, with only about 5% of the electricity consumed being converted into visible light. These bulbs work by heating a filament until it glows, emitting a yellowish-white light. However, they have a short lifespan as the filament slowly evaporates over time.

With the development of low-pressure mercury discharge lamps, such as fluorescent lamps (FLs) and compact fluorescent lamps (CFLs), LEDs, GLS lamps have gradually been phased out, especially in office lighting, and are now almost entirely obsolete. The primary reasons for this are the higher efficiency (up to 100 lumens per watt) and longer lifespan of fluorescent lamps compared to GLS lamps.

The traditional lamps that are still used in office environments today are discussed below:

3.1.1. Fluorescent Tube Lamp (FTL)

Fluorescent lamps, also known as gaseous discharge lamps, produce light by passing an electric arc through a tube filled with low-pressure argon gas and mercury vapor. When electrons in the arc collide with electrons in mercury atoms, the mercury electrons are displaced and move to a higher energy level. They quickly return to their original state, releasing the absorbed energy. The primary emission is ultraviolet light, which is invisible to the human eye. This ultraviolet light then interacts with phosphor coatings on the inner surface of the lamp tube, converting the invisible light into useful white light.

Fig.-2: T5, T8 and T12 Fluorescent Tube Lamp

Classification

Fluorescent Tube Lamps come in different shapes and sizes. The letter "T" indicates a tubular shape, followed by a number representing the diameter in eighths of an inch.

T12 Fluorescent Tubes: These early fluorescent lamps have the largest diameter of 12/8 inches. They are less efficient compared to T5 and T8 lamps and last up to 8,000 hours.

T8 Fluorescent Tubes: These second-generation fluorescent lamps have a smaller diameter of 1 inch and are among the most widely used traditional lamps. They are more energy-efficient than T12 lamps, lasting up to 15,000 hours or longer. They are typically available in 4-foot lengths with 36W power, providing about 2,500 lumens of output.

T5 Fluorescent Tubes: These third-generation lamps have the smallest diameter of 5/8 inch and are the most efficient, usually lasting up to 20,000 hours. T5 lamps are the first linear lamps to be used exclusively with electronic ballasts. They have a high efficacy of around 90 to 100 lumens per watt. The Color Rendering Index (CRI) of T5 lamps can range from 70 to the mid-90s. Generally, 28W 4-foot tubes are available, producing approximately 2,500 lumens.

3.1.2. Types of Ballasts

There are two main types of ballasts used with fluorescent lamps: electromagnetic and electronic.

- **Electromagnetic Ballast**: Electromagnetic ballasts function as current-limiting transformers, as illustrated in Fig. 2.6. They consist of coils of enamel-coated copper wire wound around a core made of transformer-grade steel. These ballasts consume about 15 to 25 percent of the rated lamp power, which is released as heat. They also contribute to both the creation and control of harmonic currents.

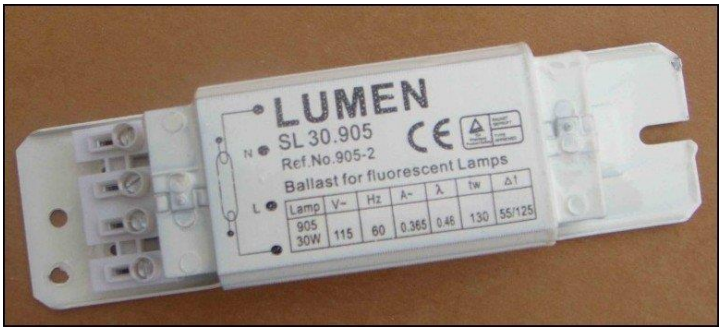


Fig-3: Electromagnetic Ballast

- **Electronic Ballast**: Electronic ballasts, shown in Fig. 2.7, use an oscillator circuit to produce frequencies between 20 and 40 kHz. Fluorescent lamps operate more efficiently at these high frequencies. Electronic ballasts have much lower internal power losses compared to electromagnetic ballasts.

Fig-4: Electromagnetic Ballast

3.2. LED Light Source

Light-Emitting Diodes (LEDs) generate light by using diodes that emit light when a circuit is completed. This process is a form of electroluminescence, where LEDs release a significant number of photons. An LED is composed of p-type and n-type regions with a junction between them, similar to a standard diode. When a sufficient voltage is applied to the semiconductor chip, electrons can easily move across the junction and are attracted to the positive forces in the p region. As an electron moves close to a positive charge in the p region, they combine, and the electric potential energy is converted to electromagnetic energy, resulting in the emission of a photon. The frequency of this photon is determined by the properties of the semiconductor material, which is usually made from a combination of gallium, arsenic, and phosphorus. Different semiconductor materials are used to produce LEDs that emit different colours.

3.2.1 White LEDs

LEDs do not naturally emit white light, but certain technologies allow them to produce it. There are two primary methods to create white LEDs:

- **Wavelength Conversion**: In this method, an LED that emits blue light is used to excite a yellow phosphor (Yttrium Aluminium Garnet), as illustrated in Fig. 2.8 and 2.9. This results in the emission of both yellow and blue light, which combine to appear as white light. This type of LED has higher efficacy than RGB LEDs but usually has a cooler color temperature.

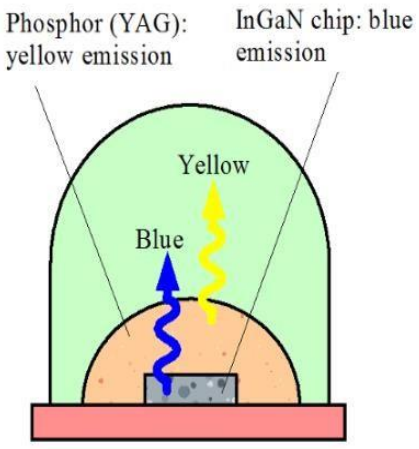


Fig-5: White LED using Wavelength

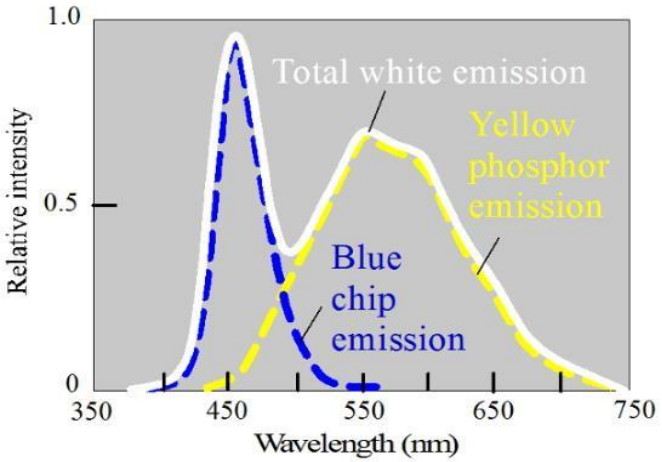


Fig.-6: SPD of phosphor coated Blue LED

- **Color Mixing**: This method involves combining LEDs that emit red, blue, and green light within a lamp. By adjusting the intensity of each LED, white light is produced, as shown in Fig. 2.10 and 2.11. This approach is versatile because it allows for easy tuning of the color temperature of the white light by mixing different colors.

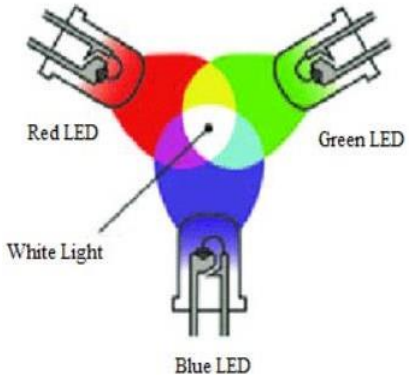


Fig-7: Mixing of RGB to Produce White Light.

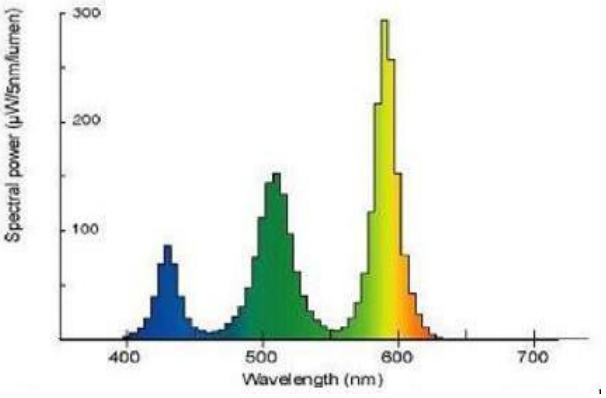


Fig-8: Spectral Power Distribution (SPD) white light of an RGB LED

3.3. Standards for design:

IS 3646-Part 1 (1992) [9] and IS 3646-Part 2 (1966) [10] and National Lighting Code (NLC) 2010[11] deals with the general illumination requirements and limitation of glare indices for working interiors.

The IS 3646 recommends illuminance and maximum glare limitation values for office interiors. The values are as shown in the following Table-3

Table- 3: Standard Values of Illuminance and Glare as per IS 3646

Areas	Illuminance (Lux)	Quality of Service Illuminance in Lux
Teaching Space General (classroom)	200-300-500	3
Lecture theatre	200-300-500	1
Demonstration bench	300-500-750	1
Seminar room	300-500-750	1
Corridors	70	-
Assembly Hall room	200-300-500	3

According to National Lighting Code 2010, recommended values of uniformity for the task area and background area are given below in Table 4.

Table 4: Standard Values of Uniformity as per National Lighting Code 2010

Area	**Uniformity value**
Task Area	≥0.7
Background Area	≥0.5

LPD Values for Educational Buildings (AS/NZS 3646.1:1992)

The AS/NZS 3646.1:1992 standard, titled Interior Lighting: Part 1 - General Principles and Recommendations, provides guidelines and recommendations for lighting levels and LPD values in various types of buildings. For educational buildings, the recommended LPD values using the Building Area Method are as follows:

Table-5: Standard vales of Lighting power density

Area	**LPD (W/m^2)**
Classrooms and Lecture Halls	15
Corridors, Lobbies, and Stairwells	6
Offices and Administrative Areas	12

For an office building interior lighting, the allowed LPD values using space function method are shown in Table 3.4, 3.5 and 3.6.

Chapter: 4

Survey on Existing Lighting System

4.1. Used Instrument Details for Survey:

4.1.1. SR 1130 Luxmeter:

Features:

- ✓ 3-1/2-digit LCD display, ax reading 1999
- ✓ Hand or Auto measuring range: 0 ~100,000 Lux
- ✓ Lux/fc unit selection
- ✓ Max and Min Reading Hold Function
- ✓ Storage 50 data's and delay logging function (1 to 60 selection)

Fig-9: 1SR 1130 Luxmeter

Table-6: Specifications of Luxmeter

Model	SR1130
LCD Display	1999
Measuring Range	2000/20000/100000 Lux, 200/2000/10000 Fc
Resolution	1Lux
Accuracy	±4% rdg ± 10dgts (<10,000 lux) ±5% rdg ± 10dgts (>10,000 lux) Total accuracy: for C.I.E standard illuminate A (2856K)
Repeatability	±2%
Sampling Rate	2 times/second
Range Selection	Automatic measurement / manual measurement
Data Hold	Display 'H'
MAX/MIN Record	Yes
LUX/FC Selection	Yes
Data Logging	Yes (50 data)
Low Battery Display	Yes
Working Temperature	0°C to 40°C (32°F to 104°F) <70% R.H.
Storage Temperature	-10°C to 55°C (14°F to 122°F) <70% R.H.
Power	Two AAA batteries
LCD size	35*32mm
Dimensions	128mm(L)*55mm(W)*30mm(H) SENNOR: 87mm(L)*55mm(W)*20mm(H)
Weight	Approx. 130g

4.1.2. Distance Meter: LDM100+

Function:

- Display Illumination [Backlight]
- Min / Max, Measurement / Continuous Measurement
- Addition / Subtraction
- Pythagoras Measurement
- Area / Volume Calculation
- Wall Area Measurement
- Triangular Area Measurement
- Stake out Measurement
- Front / Back Benchmark Measuring Datum Selection

Fig-10: Distance meter

Display Screen

- Laser Emission Indicator
- Reference Edge [Front]
- Reference Edge [Behind]
- Stored Data Indicator
- Stake out Function
- MAX / MIN Measurement
- Indirect measuring / Pythagoras
- Theorem Measurement
- Triangular Area
- Time
- Silence
- Area / Volume Function.
- Battery Indicator
- The third Display Line
- The Second Display Line
- The First Display Line
- Main Display Line (Result)

Table-7: Specifications of Distance meter

Range	0.05 – 100m
Measuring Accuracy:	±1.5mm
Measurement Time:	0.25 – 1s
Units:	m / in / ft / ft+in
Smallest Unit Displayed:	1mm
Laser Class:	Class II
Laser Type	630 – 670nm, <1mW
Auto Laser Switch Off	After 30 seconds
Automatic Switch Off:	After 3 minutes of inactivity
Timer (Self-Triggering):	Yes
Historical Storage	99
Storage Temperature:	-20°C – 60°C
Operating Temperature:	-10°C – 50°C
Power:	1.5V AAA x 2 Batteries
Battery Life	Up to 5000 Measurements
Rating (Dust Proof & Splash Proof):	IP40
Dimensions:	110 x 44 x 26mm (approx.)
Weight	70g (including batteries, approx.)
Accessories:	1.5V AAA x 2 Batteries (Installed), Drawstring Pouch, Instruction Manual, Wristlet

4.1.3. Measuring Tape:

- FREEMANS Leatherette 30m:13mm Fibreglass Measuring Tape - 30m/100ft
- Case Reinforced with Stainless Steel Band
- Durable Winding Mechanism Handle and Stainless-Steel Mouth with End Hook

Fig-11: Measuring Tape

About this item

- Fiberglass tape ribbon is non-conductive, non-creasing, weather resistant and durable against wear and tear.
- The FREEMANS Leatherette fibreglass tape blade is manufactured with 1mm graduations.
- Tough vinyl leatherette covered case to with stand difficult conditions.
- Quick winding handle ensures long trouble-free usage.
- Heat sealed markings on tape ribbon for prolonged life.
- CE (MID) and ISI (BIS) certified
-

4.2. Types of Lamps:

Here total no. of four types lamps are used in educational building.
Follows the light details are-

4.2.1. Type -1: 36 W FTL

Table-8: Specification of FTL

Manufacturer	Philips
Model Reference:	TL-D
Lamp Type:	Fluorescent
Bulb Shape	T8
Wattage:	36W/830
Dimensions:	2463 x 1197 pixels
Luminous Flux	3070 lm
Luminous Efficiency	85 lm/w
Correlated Color Temperature (CCT)	6500K
Color Rendering Index (CRI)	80
Voltage	103v

Fig-12: 36 W FTL

4.2.2. Type-2 LED Tube Light 34 W

Table-9: Specification of LED Tube Light 34 W

Manufacturer	Philips
Technology	LED Integrated
Tube Shape	T8
Wattage	34W
Luminous Efficacy (lm/W)	100
LED panel size	60x60cm
Luminous Flux (Lumen)	3600lm
Color Rendering Index(CRI)	80
Correlated Color Temperature (CCT)	6500K
Voltage	100-227V

.

Fig-13: 34 W LED Tube

4.2.3. Type-3: 20W LED Tube light

Table-10: Specification of 20W LED Tube light

Manufacturer	Philips
Technology	LED Integrated
Tube Shape	T5
Wattage	20
Voltage	360 Volts
Color Temperature	6500K
Luminous Flux (Lumen)	2000 Lumen
Color Rendering Index(CRI)	80
Voltage	100-227V

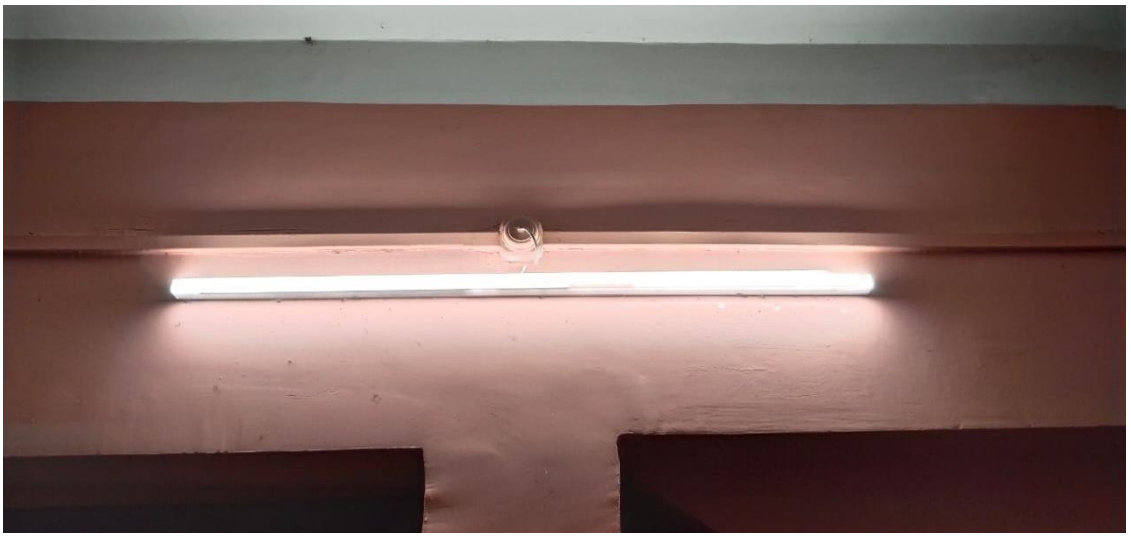


Fig-14: 20 W LED Tube light

4.2.4. Type-4: 28 W LED Recessed Light:

Table-11: Specifications 28 W LED Recessed Light

Manufacturer	Havells
Material	Aluminum
Light Colour	White
Wattage	28
Voltage	140 V to 270 V
Color Temperature	3000 K
Luminous Flux (Lumen)	840 Lm
Temperature:	10 °c to 45 °c
Power Factor	> 0.90

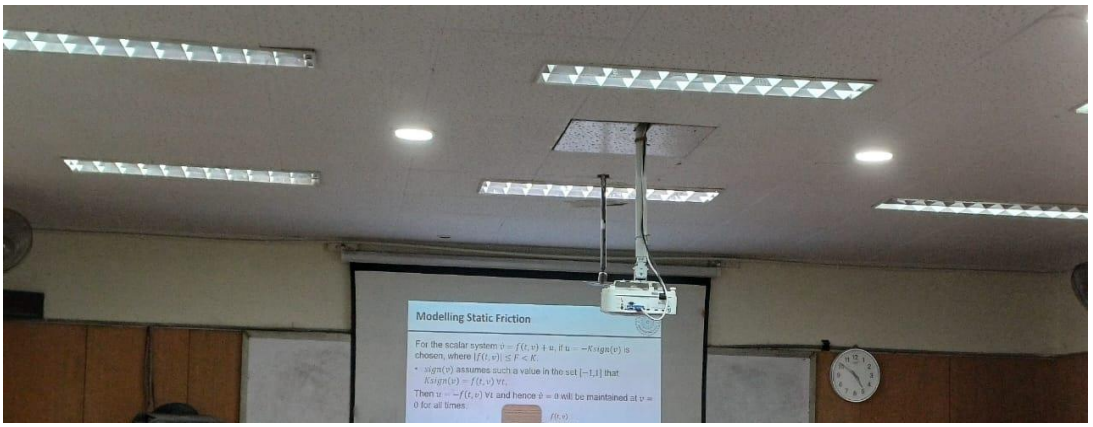


Fig-15: 28 W LED Recessed Light

4.3. Survey of Existing Lighting Design :

4.3.1.Seminar-room with Existing Lighting Systems:

Seminar-room Dimension:

- Length: 12.2 m
- Width(d): 6.8 m
- Floor to Ceiling Height: 3.1 m
- Area =12.2 m × 6.8 m= 82.96 m^2
- Distance between two grids= 0.2 × 5log d = 0.2 × 5log 6.8 = 0.83 m.

Luminaire Used in Existing Lighting Design:

- 15×2 FTL of 36 watts
- 8 Recessed Light of 28 watts

i) Font view room space

Fig-16(a): - Front view of the Seminar Room

ii) Back View Full Space:

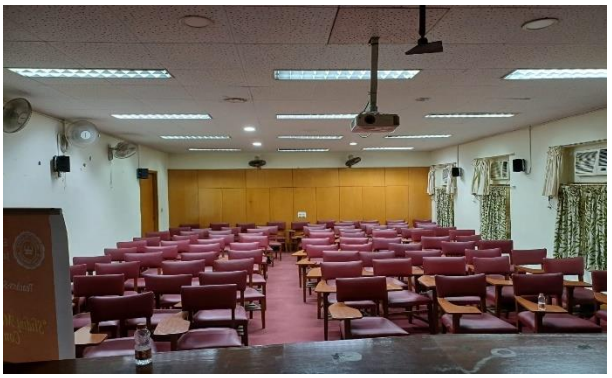


Fig-16(b): - Back view of the Seminar Room

- **Average Illuminance Value: 155.34 lx**

- **Minimum Illuminance value: 82.2 lx**

Calculated Uniformity: 0.52 (We can see the value is less than desired value i.e. 0.7)

Measure LPD & Energy Cost Per Year:

Total FTL Wattage = 30× 36 = 1080 watts
Total Recessed Light Wattage = 8 × 28 = 224 watts
Total Wattage = 1080 + 224 = 1304 watts
Lighting Power Density $(LPD) = \frac{Total\ Power}{Total\ Area} = \frac{1304w}{82.96m^2} = 15.71w/m^2$

Let suppose per day effective burning time 10 hrs.

So, per day wattage = 1304 × 10 = 13040 watts
Now FTL wattage in 30 Days = 13040 × 30 = 391200 watts = 391.2 kw

So Annual Energy Consumption = 391.2 × 12=4694.4 kw

Let suppose 1 BOT cost = 10 rupees

So annual cost = 4694.4 × 10 = 46944 rupees

Table-12: Seminar room details

Average Illuminance (Lux)	**Uniformity**	**LPD (w/m^2)**	**Types of lamps**	**No. of lamps**	**Energy consumption (**kw**)**	**Energy cost per year (rupees)**
155.34	0.52	15.71	2 (36 W, Phillips) (28W, Havells)	38	4694.4	46944

4.3.2. Existing Lighting Design for Classroom -E-2-1:

Room Dimension:

- Length: 8.2 m
- Width(d): 6.6 m
- Floor to Ceiling Height: 3.5 m
- Area =18.2m × 6.6 m= 54.12 m^2
- Distance between two grids= $0.2 \times 5\log d = 0.2 \times 5\log 6.6 = 0.544$ m.

Luminaire Used in existing lighting design:

- 12 FTL Light of 36 watts
- 8 LED Light of 20 watts

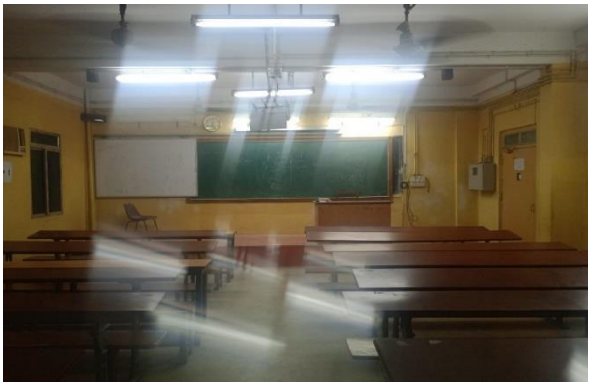


Fig-17: -Front view of the E-2-1 classroom

Fig-18: -Back view of the E-2-1 classroom

Average Illuminance Value: 257.6 lx

Minimum Illuminance Value: 110.2 lx

Calculated Uniformity: 0.4 (We can see the value is less than desired value i.e. 0.7)

Measure LPD & Energy Cost Per Year:-

Total FTL Light Wattage = 16 × 36 = 576 watts
Total LED Wattage = 6 × 34 = 204 watts
Total Wattage = 576 +204 = 780 watts
Lighting Power Density $(LPD) = \frac{Total\ Power}{Total\ Area} = \frac{780w}{54.12m^2} = 14.41w/m^2$

Let suppose per day effective burning time 10 hrs.

So, per day wattage = 780 × 10 = 7800 watts
Now FTL wattage in 30 Days = 7800 × 30 = 234000 watt = 234 kw
So, Annual Energy Consumption = 234× 12= 2808 kw

Let suppose 1 unit cost = 10 rupees

So annual cost = 2808 × 10 = 28080 rupees

Table-13: Classroom(E-2-1) details

Average Illuminance (Lux)	Uniformity	LPD (w/m^2)	Types of lamps	No. of lamps	Energy consumption (kw)	Energy cost per year (rupees)
257.6	0.42	14.41	2 (36 W, Phillips) (34W, Havells)	20	2808	28080

4.3.3. Existing Lighting Design for Classroom - E-2-2:

Room Dimension:

- Length: 9.35 m
- Width: 7.12 m
- Floor to Ceiling Height: 3.5 m
- Area = 9.35m × 7.12m = 66.572 m^2
- Distance between two grids= 0.2 × 5log d = 0.2 × 5log 7.12 = 0.85 m.

Luminaire Used in Existing Lighting design:

- 16 FTL of 36 watts
- 8 LED Tube Light of 34 watts

Fig-19: -Front view of the E-2-2 classroom

Fig-20: -Front view of the E-2-2 classroom

- **Average Illuminance Value: 269.48 lx**
- **Minimum Illuminance value: 127 lx**

Calculated Uniformity: 0.471 [We can see the value is less than desired value i.e. 0.6)

Measure LPD & Energy Cost Per Year:

Total FTL Light Wattage = 16 × 36 = 576 watts
Total LED wattage = 8 × 34 = 272 watts
Total Wattage = 576 + 272 = 848 watts
Lighting Power Density $(LPD) = \frac{Total\ Power}{Total\ Area} = \frac{848w}{66.572m^2} = 12.73\ w/m^2$

Let suppose per day effective burning time 10 hrs.
So, per day wattage = 848 × 10 = 8480 watts
Now FTL wattage in 30 Days = 8480 × 30 = 254400 watts = 254.4 kw
So Annual Energy Consumption = 254.4 × 12 = 3052.8 kw

Let suppose 1 unit cost = 10 rupees

So annual cost = 3052.8 × 10 = 30528 rupees

Table-14: Classroom(E-2-2) details

Average Illuminance (Lux)	Uniformity	LPD (w/m^2)	Types of lamps	No. of lamps	Energy consumption (kw)	Energy cost per year (rupees)
269.48	0.471	12.73	2 (36 W, Phillips) (34W, Havells)	24	3052.8	30528

4.3.4. Existing Lighting Design for Corridor:

Room Dimension:

- Length: 20 m
- Width(d): 3.2 m
- Floor to Ceiling Height: 4.5 m
- Area =20m × $3.2m = 64m^2$
- Distance between two grids= 0.2 × 5log d = 0.2 × 5log 3.2 = 0.653 m.

Luminaire Used in Existing Lighting Design:

- 4 Wall mounted LED of 20 watts
- 16 FTL Light of 36 watts

Fig-21: -Front view of the Corridor

Fig-22: Back view of the Corridor

- **Average Illuminance Value: 118.2 lx**
- **Minimum Illuminance value: 56.1 lx**

Calculated Uniformity: 0.39 [We can see the value is less than desired value i.e. 0.6)

Measure LPD & Energy Cost Per Year:

Total FTL Light Wattage = 16 × 36 = 576 watts
Total LED wattage = 4 × 20 = 80 watts
Total wattage = 576 + 80 =656 watts
Lighting Power Density $(LPD) = \frac{Total\ Power}{Total\ Area} = \frac{656w}{64m^2} = 9\ w/m^2$
Let suppose per day effective burning time 10 hrs .
So, per day wattage = 656 × 10 = 6560 watts
Now FTL wattage in 30 Days = 6560 × 30 = 196800 watt = 196.8 kw
So Annual Energy Consumption = 196.8 × 12 = 2361.6 kw

Let suppose 1 unit cost = 10 rupees

So annual cost = 2361.6 × 10 = 23616 rupees

Table-15: Corridor details

Average Illuminance (Lux)	**Uniformity**	**LPD (w/m^2)**	**Types of lamps**	**No. of lamps**	**Energy consumption (**kw**)**	**Energy cost per year (rupees)**
118.2	0.47	9	2 (36 W, FTL, Phillips) (20 W, LED Phillips)	20	2361.6	23616

4.3.5. Existing Lighting Design for KC Roy Hall:

Room Dimension:

- Length: 15.2 m
- Width(d): 10.5 m
- Floor to Ceiling Height: 4.2 m
- Area = 15.2 × 10.5 =159.6 m^2
- Distance between two grids= 0.2 × 5log d = 0.2 × 5log 10.5 = 1.021 m.

Luminaire Used in Existing Lighting designed:

- 33 FTL of 36 watts

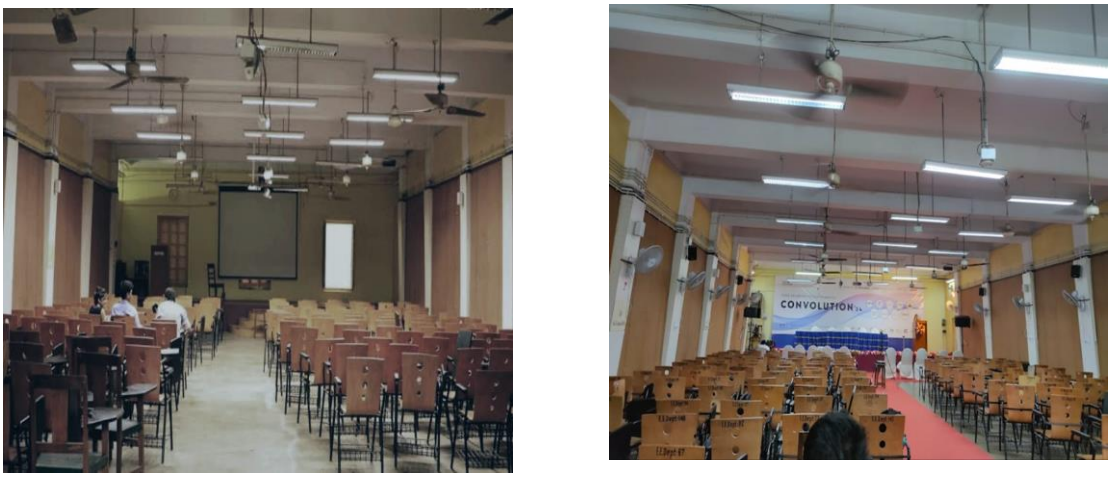


Fig-23: -Front view of K.C. Roy Hall with FTL Lighting

- **Average Illuminance Value: 130.2 lx**
- **Minimum Illuminance value: 68.7lx**

Calculated Uniformity: 0.52 [We can see the value is less than desired value i.e. 0.)

- **Measure LPD & Energy Cost Per Year:**

Total FTL Wattage = 33 × 36 = 1188 watts
Lighting Power Density (LPD)= $\frac{1188\text{w}}{159.6\text{m}^2}$=7.44w/$m^2$

Let suppose per day effective burning time 10 hrs.
So, per day wattage = 1188 × 10 = 11880 watts
Now FTL wattage in 30 Days = 11880 × 30 = 356400 watts = 356.4 kw
So Annual Energy Consumption = 356.4 × 12= 4276.8 kw

Let suppose 1 unit cost = 10 rupees

So annual cost = 4276.8× 10 = 42768 rupees

Table-16: K C Roy Hall details

Average Illuminance (Lux)	Uniformity	LPD (w/m^2)	Types of lamps	No. of lamps	Energy consumption (kw)	Energy cost per year (rupees)
130.21	0.52	7.44	1 (36 W, FTL, Phillips)	33	4276.8	42768

Table-17: Summary of Existing Lighting design of Education Building:

Location	Average Illuminance (Lux)	Uniformity	LPD (w/m^2)	Types of lamps	No. of lamps	Energy consumption (kw)	Energy cost per year (rupees)
Seminar room	155.34	0.52	15.71	2 (36 W, Phillips) (28W,Havells)	38	4694.4	46944
Classroom (E-2-1)	257.6	0.42	14.41	2 (36 W, Phillips) (34W,Havells)	20	2808	28080
Classroom (E-2-2)	269.48	0.471	12.73	2 (36 W, Phillips) (34W,Havells)	24	3052.8	30528
Corridor	118.2	0.47	9	2 (36 W, FTL, Phillips) (20 W, LED Phillips)	20	2361.6	23616
KC Roy Hall	130.21	0.52	7.44	1 (36 W, FTL, Phillips)	33	4276.8	42768

Chapter: 5

Result and Discussion

5. Case study of a new Lighting Design in using DIALux EVo

5.1. Seminar-room with Producing LED Lighting Design :

Room Dimension:

- Length: 12.2 m
- Width: 6.8 m
- Floor to Ceiling Height: 3.1 m
- Area =12.2 m × 6.8 m= 82.96 m^2
- Total no. of grid = 50
- Distance between two grids= 0.2 × 5log d = 0.2 × 5log 6.8 = 0.83 m.

Luminaire Used in Producing Lighting designed:

- **27 LED Tube Lights of 21 watts**

DIALux Designed Producing Department Seminar-room:

Fig-24: Front view

Fig-25: Back view

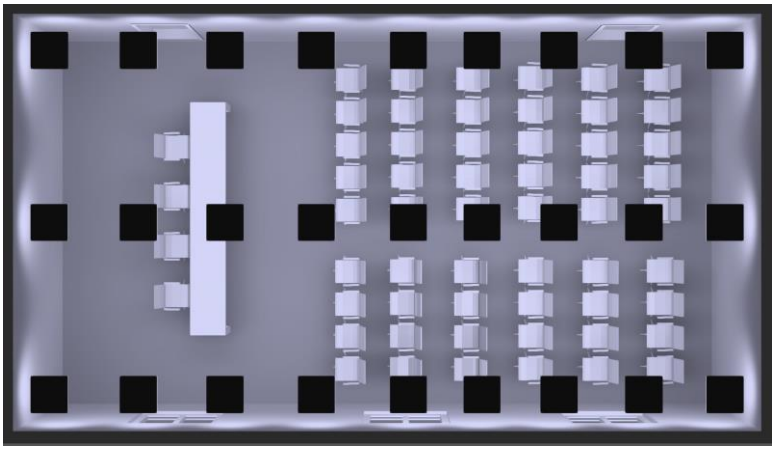
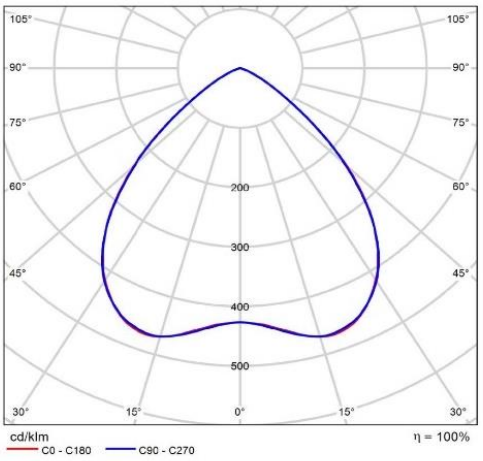


Fig-26: Top view

Product data sheet

3F Filippi S.p.A. - 3F Diagon FCH 19W/840 599x599

Article No.	23795
P	21.0 W
Φ_{Lamp}	3354 lm
$\Phi_{Luminaire}$	3354 lm
η	100.00 %
Luminous efficacy	159.7 lm/W
CCT	4000 K
CRI	80



Polar LDC

Glare evaluation according to UGR

ρ Ceiling		70	70	50	50	30	70	70	50	50	30
ρ Walls		50	30	50	30	30	50	30	50	30	30
ρ Floor		20	20	20	20	20	20	20	20	20	20
Room size X	Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H	2H	16.7	17.8	17.0	18.0	18.2	16.7	17.8	17.0	18.0	18.2
	3H	16.6	17.6	16.9	17.9	18.1	16.6	17.6	16.9	17.8	18.1
	4H	16.6	17.5	16.9	17.8	18.0	16.6	17.5	16.9	17.7	18.0
	6H	16.5	17.3	16.8	17.6	17.9	16.5	17.3	16.8	17.6	17.9
	8H	16.5	17.3	16.8	17.6	17.9	16.4	17.3	16.8	17.6	17.9
	12H	16.4	17.2	16.8	17.5	17.8	16.4	17.2	16.8	17.5	17.8
4H	2H	16.7	17.6	17.0	17.8	18.1	16.7	17.6	17.0	17.8	18.1
	3H	16.6	17.4	17.0	17.7	18.0	16.6	17.4	17.0	17.7	18.0
	4H	16.6	17.3	17.0	17.6	18.0	16.6	17.2	16.9	17.6	17.9
	6H	16.5	17.1	16.9	17.5	17.9	16.5	17.1	16.9	17.5	17.8
	8H	16.5	17.0	16.9	17.4	17.8	16.4	17.0	16.9	17.4	17.8
	12H	16.4	16.9	16.9	17.3	17.8	16.4	16.9	16.8	17.3	17.7
8H	4H	16.5	17.0	16.9	17.4	17.8	16.5	17.0	16.9	17.4	17.8
	6H	16.4	16.8	16.9	17.3	17.7	16.4	16.8	16.8	17.2	17.7
	8H	16.4	16.7	16.8	17.2	17.7	16.3	16.7	16.8	17.2	17.7
	12H	16.3	16.7	16.8	17.1	17.6	16.3	16.6	16.8	17.1	17.6
12H	4H	16.4	16.9	16.9	17.3	17.8	16.4	16.9	16.8	17.3	17.7
	6H	16.4	16.7	16.8	17.2	17.7	16.3	16.7	16.8	17.2	17.7
	8H	16.3	16.7	16.8	17.1	17.6	16.3	16.6	16.8	17.1	17.6
Variation of the observer position for the luminaire distances S											
S = 1.0H		+1.5 / -2.6					+1.6 / -2.6				
S = 1.5H		+2.6 / -6.1					+2.6 / -6.1				
S = 2.0H		+4.2 / -9.2					+4.2 / -9.1				
Standard table		BK00					BK00				
Correction summand		-1.7					-1.7				
Corrected glare indices referring to 3354lm Total luminous flux											

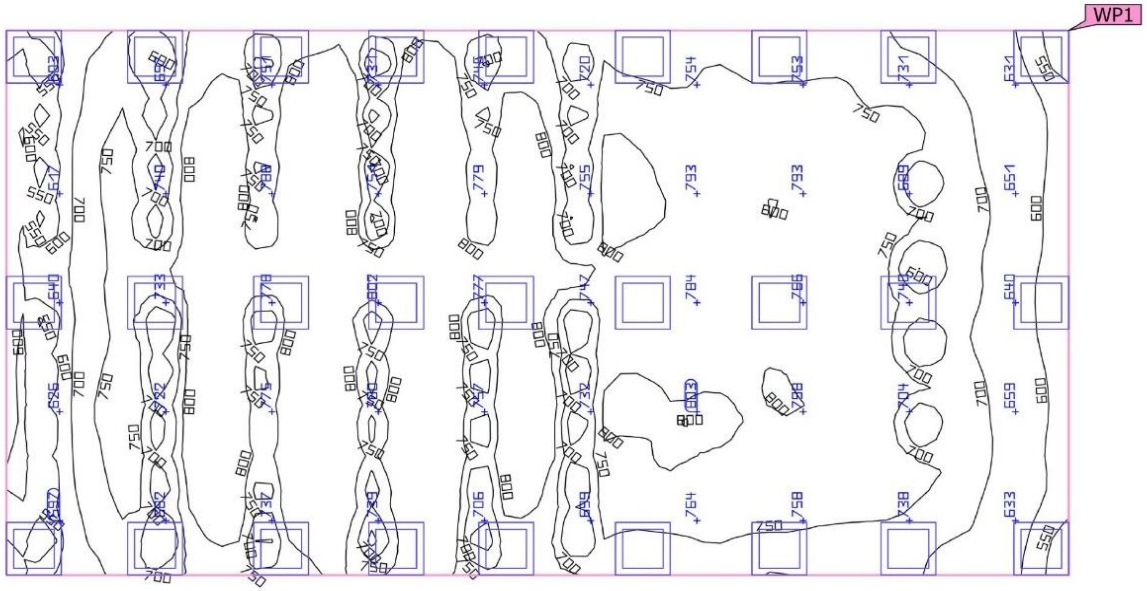
UGR diagram (SHR: 0.25)

ILLUMINOTECHNICAL
Luminous efficiency 100% (DLOR 100%, ULOR 0%).
Initial luminous flux of the luminaire 3354 lm.
Direct symmetric distribution.
Installation Interdistance Transv.D = 1.39 x hu - Long.D = 1.39 x hu.
Average luminance <1000 cd/m² for radial angles >65°.
Tabular UGR (CIE 117 - 4H-8H; S=0.25H; 70/50/20): RUG 16.5 - 16.5.
Beam angle: 93° - 92°.
Luminous efficacy 160 lm/W.
Lifetime (L95/B10): 30000 h. (tq+25°C)
Lifetime (L90/B10): 50000 h. (tq+25°C)
Lifetime (L80/B10): 80000 h. (tq+25°C)
Lifetime (L75/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
Squared LED module 19W/840.
Energy efficiency class (UE 2019/2020 - UE 2019/2015): C.

Building 1 · Storey 1 · SEMINAR ROOM (Light scene 1)

Working plane (SEMINAR ROOM)



Properties	Ē (Target)	E_{min}	E_{max}	U_o (g_1) (Target)	g_2	Index
Working plane (SEMINAR ROOM) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.300 m	754 lx (≥ 750 lx) ✓	526 lx	883 lx	0.70 (≥ 0.70) ✓	0.60	WP1

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

- **Average Illuminance Value:** 754 lx
- **Minimum Illuminance Value:** 526 lx
- **Overall Uniformity:** 0.70 (The value is less than desired value i.e. 0.70)

Energy Cost with the Producing Designed System for Seminar-room:

Total LED Wattage = 27 × 21 = 567 watts

Let suppose per day effective burning time 10 hrs.

So, per day wattage = 567 × 10 = 5670 watts

Lighting Power Density $(LPD) = \frac{Total\ Power}{Total\ Area} = \frac{567w}{82.96m^2} = 6.83\ w/m^2$

Now, FTL wattage in 30 Days = 5670 × 30 = 170100 watts = 170.1 kw

So Annual Energy Consumption = 170.1 × 12 = 2041.2 kw

Let suppose 1 BOT cost = 10 rupees

So annual cost = 2041.2 × 10 = 20412 rupees

Table-18: Producing Designed System for Seminar-room

Average Illuminance	**Uniformity**	**LPD (w/m^2)**	**Types of lamps**	**No. of lamps**	**Energy consumption (**kw**)**	**Energy cost per year (rupees)**
754	0.52	6.83	1 (21 W, 3 F Fillipi S.p.A)	27	2041.2	20412

5.2. Class-room(E-2-1) with Producing LED Lighting Design:

Room Dimension:

- Length: 8.2 m
- Width: 6.6 m
- Floor to Ceiling Height: 3.5 m
- Area =18.2m × 6.6 m= 54.12 m^2
- Total no. of Grid = 63
- Distance between two grids= 0.2 × 5log d = 0.2 × 5log 6.6 = 0.544 m.

Luminaire Used in Producing Lighting Designed:

- 14 LED Recessed Lights of 21 watts
- 12 LED Tube Lights 24 watts

DIALux Designed Editing Department Classroom-E-2-1:

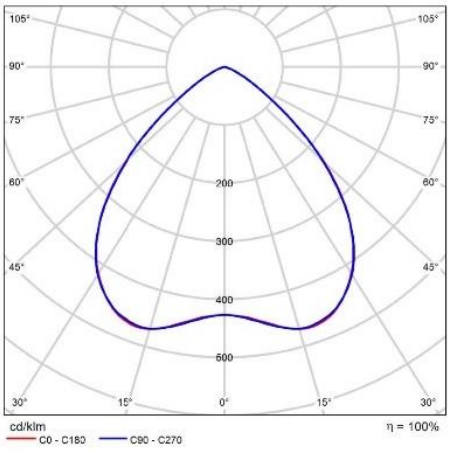
Fig-27: Top view

Fig-28: Down to Up view

Product data sheet

3F Filippi S.p.A. - 3F Diagon FCH 19W/840 599x599

Article No.	23795
P	21.0 W
Φ_{Lamp}	3354 lm
$\Phi_{Luminaire}$	3354 lm
η	100.00 %
Luminous efficacy	159.7 lm/W
CCT	4000 K
CRI	80



Polar LDC

Glare evaluation according to UGR										
ρ Ceiling	70	70	50	50	30	70	70	50	50	30
ρ Walls	50	30	50	30	30	50	30	50	30	30
ρ Floor	20	20	20	20	20	20	20	20	20	20
Room size X Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H 2H	16.7	17.8	17.0	18.0	18.2	16.7	17.8	17.0	18.0	18.2
3H	16.6	17.6	16.9	17.9	18.1	16.6	17.6	16.9	17.8	18.1
4H	16.6	17.5	16.9	17.8	18.0	16.6	17.5	16.9	17.7	18.0
6H	16.5	17.5	16.8	17.6	17.9	16.5	17.3	16.8	17.6	17.9
8H	16.5	17.3	16.8	17.6	17.9	16.4	17.3	16.8	17.6	17.9
12H	16.4	17.2	16.8	17.5	17.8	16.4	17.2	16.8	17.5	17.8
4H 2H	16.7	17.6	17.0	17.8	18.1	16.7	17.6	17.0	17.8	18.1
3H	16.6	17.4	17.0	17.7	18.0	16.6	17.4	17.0	17.7	18.0
4H	16.6	17.3	17.0	17.6	18.0	16.6	17.2	16.9	17.6	17.9
6H	16.5	17.1	16.9	17.5	17.9	16.5	17.1	16.9	17.5	17.8
8H	16.5	17.0	16.9	17.4	17.8	16.4	17.0	16.9	17.4	17.8
12H	16.4	16.9	16.9	17.3	17.8	16.4	16.9	16.8	17.3	17.7
8H 4H	16.5	17.0	16.9	17.4	17.8	16.5	17.0	16.9	17.4	17.8
6H	16.4	16.8	16.9	17.3	17.7	16.4	16.8	16.8	17.2	17.7
8H	16.4	16.7	16.8	17.2	17.7	16.3	16.7	16.8	17.2	17.7
12H	16.3	16.7	16.8	17.1	17.6	16.3	16.6	16.8	17.1	17.6
12H 4H	16.4	16.9	16.9	17.3	17.8	16.4	16.9	16.8	17.3	17.7
6H	16.4	16.7	16.8	17.2	17.7	16.3	16.7	16.8	17.2	17.7
8H	16.3	16.7	16.8	17.1	17.6	16.3	16.6	16.8	17.1	17.6
Variation of the observer position for the luminaire distances S										
S = 1.0H	+1.5 / -2.6					+1.6 / -2.6				
S = 1.5H	+2.6 / -6.1					+2.6 / -6.1				
S = 2.0H	+4.2 / -9.2					+4.2 / -9.1				
Standard table	BK00					BK00				
Correction summand	1.7					1.7				
Corrected glare indices referring to 3354lm Total luminous flux										

UGR diagram (SHR: 0.25)

ILLUMINOTECHNICAL
Luminous efficiency 100% (DLOR 100%, ULOR 0%).
Initial luminous flux of the luminaire 3354 lm.
Direct symmetric distribution.
Installation Interdistance Transv.D = 1.39 x hu - Long.D = 1.39 x hu.
Average luminance <1000 cd/m² for radial angles >65°.
Tabular UGR (CIE 117 - 4H-8H; S=0.25H; 70/50/20): RUG 16.5 - 16.5.
Beam angle: 93° - 92°.
Luminous efficacy 160 lm/W.
Lifetime (L95/B10): 30000 h. (tq+25°C)
Lifetime (L90/B10): 50000 h. (tq+25°C)
Lifetime (L80/B10): 80000 h. (tq+25°C)
Lifetime (L75/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.

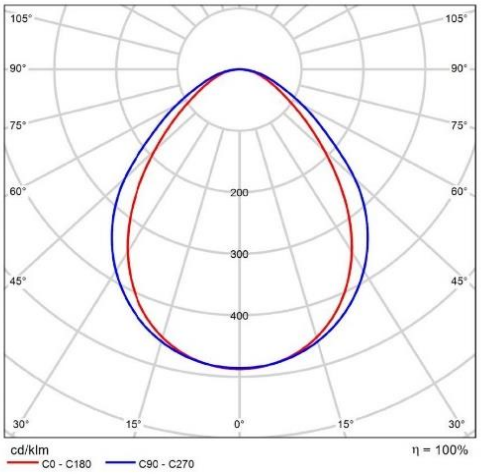
SOURCE
Squared LED module 19W/840.
Energy efficiency class (UE 2019/2020 - UE 2019/2015): C.

Product data sheet

AIRAM - Vario 1140 24W/840 ACMP DA2 WH

Article No.	4146888
P	24.0 W
Φ_{Lamp}	3100 lm
$\Phi_{Luminaire}$	3102 lm
η	100.07 %
Luminous efficacy	129.3 lm/W
CCT	4000 K
CRI	80

Developed and manufactured in Finland, Vario is a surface-mounted aluminium profile luminaire. The material used in the body is 100% recycled aluminum. Thanks to the variety of housing lengths and a wide range of corner pieces, you can create a customised lighting solution that meets your needs. Typical applications include offices, lobbies, educational institutions and corridors. With this luminaire, you can create a seamless line of light of up to 4,500 mm. The 100% Finnish Vario luminaires are designed and manufactured at Airam's factory in Lahti.



Polar LDC

Glare evaluation according to UGR

ρ Ceiling		70	70	50	50	30	70	70	50	50	30
ρ Walls		50	30	50	30	30	50	30	50	30	30
ρ Floor		20	20	20	20	20	20	20	20	20	20
Room size X	Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H	2H	20.1	21.3	20.4	21.6	21.8	21.7	22.9	22.0	23.1	23.3
	3H	20.9	22.0	21.2	22.2	22.5	22.5	23.6	22.8	23.9	24.1
	4H	21.2	22.2	21.6	22.5	22.8	22.9	23.9	23.2	24.2	24.5
	6H	21.5	22.5	21.9	22.8	23.1	23.2	24.1	23.5	24.4	24.7
	8H	21.6	22.6	22.0	22.9	23.2	23.3	24.2	23.7	24.5	24.8
	12H	21.7	22.6	22.1	22.9	23.2	23.4	24.3	23.8	24.6	24.9
4H	2H	20.6	21.6	21.0	21.9	22.2	21.9	22.9	22.2	23.2	23.5
	3H	21.6	22.4	21.9	22.8	23.1	23.0	23.8	23.3	24.1	24.5
	4H	22.0	22.8	22.4	23.2	23.5	23.4	24.2	23.8	24.6	24.9
	6H	22.5	23.1	22.9	23.5	23.9	23.9	24.6	24.3	24.9	25.3
	8H	22.6	23.3	23.1	23.7	24.1	24.1	24.7	24.5	25.1	25.5
	12H	22.7	23.3	23.2	23.7	24.2	24.2	24.8	24.6	25.2	25.6
8H	4H	22.3	22.9	22.7	23.3	23.7	23.6	24.2	24.0	24.6	25.0
	6H	22.9	23.4	23.3	23.8	24.3	24.1	24.6	24.6	25.1	25.5
	8H	23.1	23.6	23.6	24.0	24.5	24.4	24.8	24.8	25.3	25.7
	12H	23.3	23.7	23.8	24.2	24.7	24.6	25.0	25.1	25.4	25.9
12H	4H	22.3	22.9	22.7	23.3	23.7	23.6	24.1	24.0	24.5	25.0
	6H	22.9	23.4	23.4	23.8	24.3	24.1	24.6	24.6	25.1	25.5
	8H	23.2	23.6	23.7	24.1	24.6	24.4	24.8	24.9	25.3	25.8

Variation of the observer position for the luminaire distances S

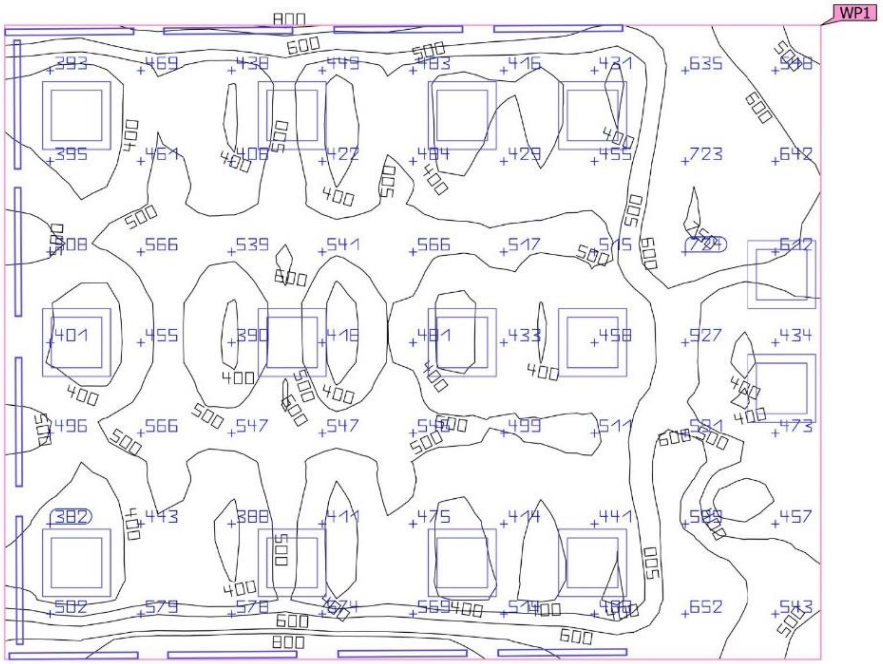
S = 1.0H	+0.3 / -0.4	+0.2 / -0.3
S = 1.5H	+0.6 / -0.9	+0.5 / -0.8
S = 2.0H	+1.1 / -1.4	+1.2 / -1.3
Standard table	BK04	BK04
Correction summand	5.3	6.8

Corrected glare indices referring to 3100lm Total luminous flux

UGR diagram (SHR: 0.25)

Building 1 · Storey 1 · E-2-1 (Light scene 1)

Working plane (E-2-1)



Properties	Ē (Target)	E_{min}	E_{max}	U_o (g_1) (Target)	g_2	Index
Working plane (E-2-1) Perpendicular illuminance (adaptive) Height: 0.000 m, Wall zone: 0.500 m	503 lx (≥ 500 lx) ✓	353 lx	882 lx	0.70 (≥ 0.70) ✓	0.40	WP1

Utilisation profile: Educational premises - Educational buildings (44.19 Circulation areas, corridors)

- **Average Illuminance Value:** 503 lx
- **Minimum Illuminance Value:** 353 lx
- **Overall Uniformity:** 0.70 (The value is less than desired value i.e. 0.70)

Energy Cost with the Producing Designed System for Classroom E-2-1:

Total Recessed LED Wattage = 21 × 14 = 294 watts
Total LED Tube Wattage = 24 × 12 = 288
Total LED Wattage = 294 + 288 = 582 watts
Lighting Power Density $(LPD) = \frac{Total\ Power}{Total\ Area} = \frac{582w}{54.12m^2} = 10.75\ w/m^2$

Let suppose per day effective burning time 10 hrs.
So per day wattage = 582 × 10 = 5280 watts
Now FTL wattage in 30 Days = 5280 × 30 = 158400 watt = 158.4 kw

So Annual Energy Consumption = 158.4 × 12 = 1900.8 kw

Let suppose 1 BOT cost = 10 rupees

So annual cost = 1900.8 × 10 = 19008 rupees

Table-19: Producing Designed System for Classroom E-2-1

Average Illuminance (Lux)	**Uniformity**	**LPD (w/m^2)**	**Types of lamps**	**No. of lamps**	**Energy consumption (**kw**)**	**Energy cost per year (rupees)**
503	0.7	10.75	2(21 W, 3 F Fillipi S.p.A) (24W, AIRAM Vario1140)	26	1900.8	19008

5.3. Class-room(E-2-2) with Producing LED Lighting Design :

Room Dimension:

- Length: 9.35 m
- Width: 7.12 m
- Floor to Ceiling Height: 3.5 m
- Area = 9.35m × 7.12m = 66.572 m^2
- Total no. of grid = 63
- Distance between two grids= $0.2 \times 5\log d = 0.2 \times 5\log 7.12 = 0.85$ m.

Luminaire Used:

- 16 LED Recessed Lights of 21 watts
- 9 LED Tube Lights of 24 watts

DIALux Designed Editing Department Classroom-E-2-2:

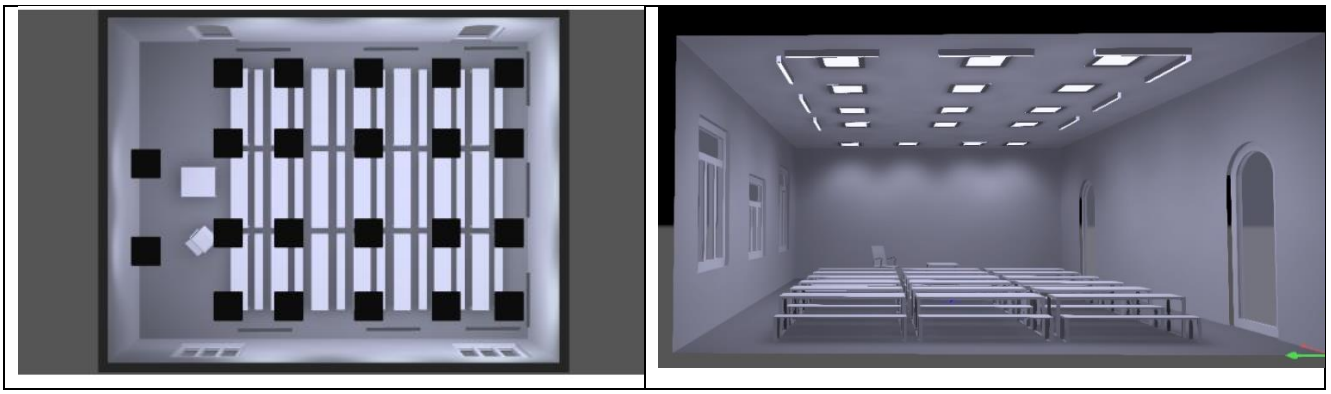


Fig-29: Top view

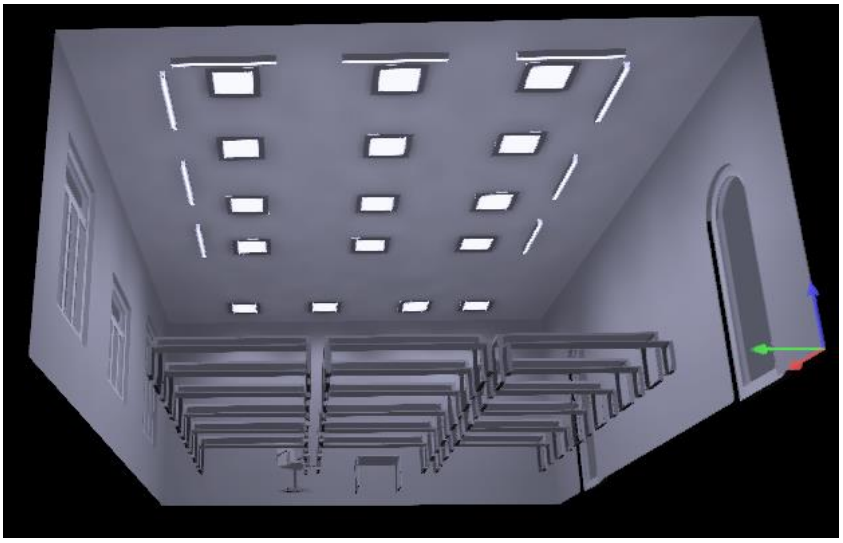
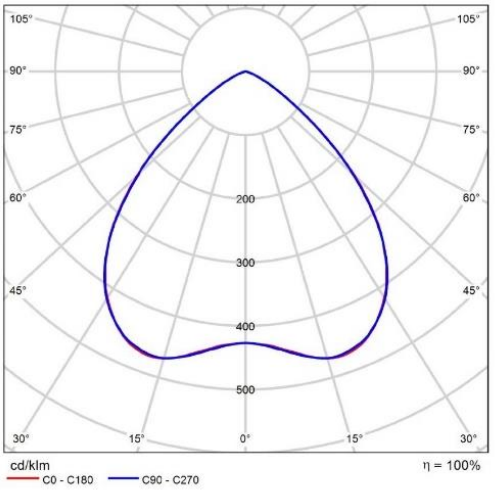


Fig-30: Down to up view

Product data sheet

3F Filippi S.p.A. - 3F Diagon FCH 19W/840 599x599

Article No.	23795
P	21.0 W
Φ_{Lamp}	3354 lm
$\Phi_{Luminaire}$	3354 lm
η	100.00 %
Luminous efficacy	159.7 lm/W
CCT	4000 K
CRI	80



Polar LDC

Glare evaluation according to UGR

ρ Ceiling		70	70	50	50	30	70	70	50	50	30
ρ Walls		50	30	50	30	30	50	30	50	30	30
ρ Floor		20	20	20	20	20	20	20	20	20	20
Room size X	Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H	2H	16.7	17.8	17.0	18.0	18.2	16.7	17.8	17.0	18.0	18.2
	3H	16.6	17.6	16.9	17.9	18.1	16.6	17.6	16.9	17.8	18.1
	4H	16.6	17.5	16.9	17.8	18.0	16.6	17.5	16.9	17.7	18.0
	6H	16.5	17.3	16.8	17.6	17.9	16.5	17.3	16.8	17.6	17.9
	8H	16.5	17.3	16.8	17.6	17.9	16.4	17.3	16.8	17.6	17.9
	12H	16.4	17.2	16.8	17.5	17.8	16.4	17.2	16.8	17.5	17.8
4H	2H	16.7	17.6	17.0	17.8	18.1	16.7	17.6	17.0	17.8	18.1
	3H	16.6	17.4	17.0	17.7	18.0	16.6	17.4	17.0	17.7	18.0
	4H	16.6	17.3	17.0	17.6	18.0	16.6	17.2	16.9	17.6	17.9
	6H	16.5	17.1	16.9	17.5	17.9	16.5	17.1	16.9	17.5	17.8
	8H	16.5	17.0	16.9	17.4	17.8	16.4	17.0	16.9	17.4	17.8
	12H	16.4	16.9	16.9	17.3	17.8	16.4	16.9	16.8	17.3	17.7
8H	4H	16.5	17.0	16.9	17.4	17.8	16.5	17.0	16.9	17.4	17.8
	6H	16.4	16.8	16.9	17.3	17.7	16.4	16.8	16.8	17.2	17.7
	8H	16.4	16.7	16.8	17.2	17.7	16.3	16.7	16.8	17.2	17.7
	12H	16.3	16.7	16.8	17.1	17.6	16.3	16.6	16.8	17.1	17.6
12H	4H	16.4	16.9	16.9	17.3	17.8	16.4	16.9	16.8	17.3	17.7
	6H	16.4	16.7	16.8	17.2	17.7	16.3	16.7	16.8	17.2	17.7
	8H	16.3	16.7	16.8	17.1	17.6	16.3	16.6	16.8	17.1	17.6
Variation of the observer position for the luminaire distances S											
S = 1.0H		+1.5 / -2.6					+1.6 / -2.6				
S = 1.5H		+2.6 / -6.1					+2.6 / -6.1				
S = 2.0H		+4.2 / -9.2					+4.2 / -9.1				
Standard table		BK00					BK00				
Correction summand		-1.7					-1.7				
Corrected glare indices referring to 3354lm Total luminous flux											

UGR diagram (SHR: 0.25)

ILLUMINOTECHNICAL
Luminous efficiency 100% (DLOR 100%, ULOR 0%).
Initial luminous flux of the luminaire 3354 lm.
Direct symmetric distribution.
Installation Interdistance Transv.D = 1.39 x hu - Long.D = 1.39 x hu.
Average luminance <1000 cd/m² for radial angles >65°.
Tabular UGR (CIE 117 - 4H-8H; S=0.25H; 70/50/20): RUG 16.5 - 16.5.
Beam angle: 93° - 92°.
Luminous efficacy 160 lm/W.
Lifetime (L95/B10): 30000 h. (tq+25°C)
Lifetime (L90/B10): 50000 h. (tq+25°C)
Lifetime (L80/B10): 80000 h. (tq+25°C)
Lifetime (L75/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.

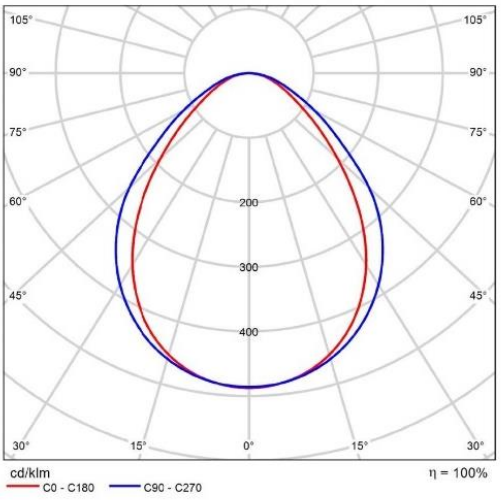
SOURCE
Squared LED module 19W/840.
Energy efficiency class (UE 2019/2020 - UE 2019/2015): C.

Product data sheet

AIRAM - Vario 1140 24W/840 ACMP DA2 WH

Article No.	4146888
P	24.0 W
Φ_{Lamp}	3100 lm
$\Phi_{Luminaire}$	3102 lm
η	100.07 %
Luminous efficacy	129.3 lm/W
CCT	4000 K
CRI	80

Developed and manufactured in Finland, Vario is a surface-mounted aluminium profile luminaire. The material used in the body is 100% recycled aluminum. Thanks to the variety of housing lengths and a wide range of corner pieces, you can create a customised lighting solution that meets your needs. Typical applications include offices, lobbies, educational institutions and corridors. With this luminaire, you can create a seamless line of light of up to 4,500 mm. The 100% Finnish Vario luminaires are designed and manufactured at Airam's factory in Lahti.



Polar LDC

Glare evaluation according to UGR

ρ: Ceiling		70	70	50	50	30	70	70	50	50	30
ρ: Walls		50	30	50	30	30	50	30	50	30	30
ρ: Floor		20	20	20	20	20	20	20	20	20	20
Room size X	Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H	2H	20.1	21.3	20.4	21.6	21.8	21.7	22.9	22.0	23.1	23.3
	3H	20.9	22.0	21.2	22.2	22.5	22.5	23.6	22.8	23.9	24.1
	4H	21.2	22.2	21.6	22.5	22.8	22.9	23.9	23.2	24.2	24.5
	6H	21.5	22.5	21.9	22.8	23.1	23.2	24.1	23.5	24.4	24.7
	8H	21.6	22.6	22.0	22.9	23.2	23.3	24.2	23.7	24.5	24.8
	12H	21.7	22.6	22.1	22.9	23.2	23.4	24.3	23.8	24.6	24.9
4H	2H	20.6	21.6	21.0	21.9	22.2	21.9	22.9	22.2	23.2	23.5
	3H	21.6	22.4	21.9	22.8	23.1	23.0	23.8	23.3	24.1	24.5
	4H	22.0	22.8	22.4	23.2	23.5	23.4	24.2	23.8	24.6	24.9
	6H	22.5	23.1	22.9	23.5	23.9	23.9	24.6	24.3	24.9	25.3
	8H	22.6	23.3	23.1	23.7	24.1	24.1	24.7	24.5	25.1	25.5
	12H	22.7	23.3	23.2	23.7	24.2	24.2	24.8	24.6	25.2	25.6
8H	4H	22.3	22.9	22.7	23.3	23.7	23.6	24.2	24.0	24.6	25.0
	6H	22.9	23.4	23.3	23.8	24.3	24.1	24.6	24.6	25.1	25.5
	8H	23.1	23.6	23.6	24.0	24.5	24.4	24.8	24.8	25.3	25.7
	12H	23.3	23.7	23.8	24.2	24.7	24.6	25.0	25.1	25.4	25.9
12H	4H	22.3	22.9	22.7	23.3	23.7	23.6	24.1	24.0	24.5	25.0
	6H	22.9	23.4	23.4	23.8	24.3	24.1	24.6	24.6	25.1	25.5
	8H	23.2	23.6	23.7	24.1	24.6	24.4	24.8	24.9	25.3	25.8

Variation of the observer position for the luminaire distances S

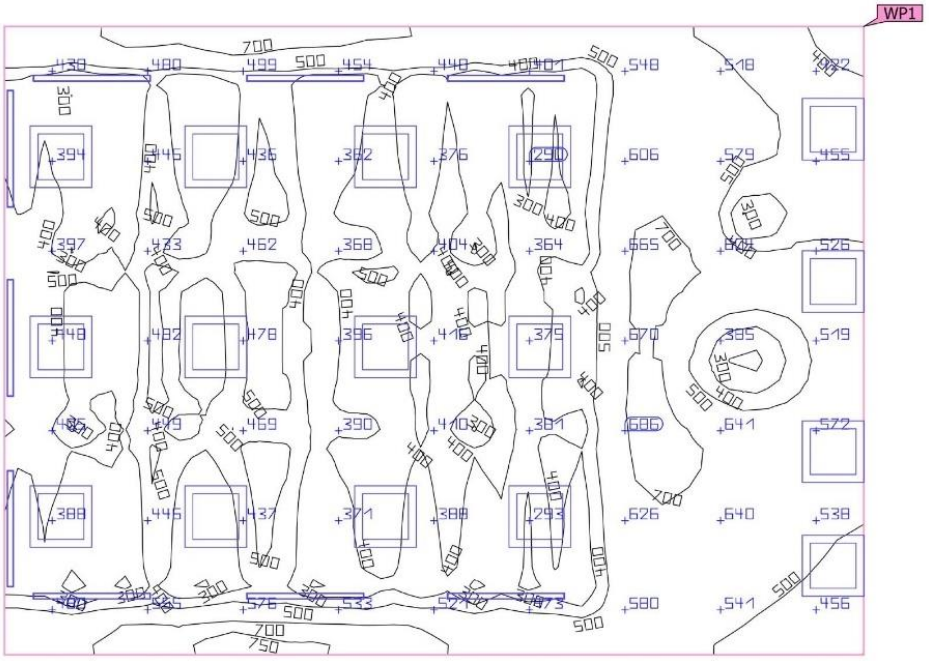
S = 1.0H	+0.3 / -0.4	+0.2 / -0.3
S = 1.5H	+0.6 / -0.9	+0.5 / -0.8
S = 2.0H	+1.1 / -1.4	+1.2 / -1.3
Standard table	BK04	BK04
Correction summand	5.3	6.8

Corrected glare indices referring to 3100lm Total luminous flux

UGR diagram (SHR: 0.25)

Building 1 · Storey 1 · E-2-2 (Light scene 1)

Working plane (E-2-2)



Properties	Ē (Target)	E_{min}	E_{max}	U_o (g_1) (Target)	g_2	Index
Working plane (E-2-2) Perpendicular illuminance (adaptive) Height: 0.000 m, Wall zone: 0.500 m	521 lx (≥ 500 lx) ✓	353 lx	794 lx	0.70 (≥ 0.70) ✓	0.44	WP1

Utilisation profile: Educational premises - Educational buildings (44.19 Circulation areas, corridors)

- **Average Illuminance Value:** 521 lx
- **Minimum Illuminance Value:** 353 lx
- **Overall Uniformity:** 0.70 (The value is less than desired value i.e. 0.70)

Energy Cost with the Producing Designed System for Classroom E-2-2:

Total LED Recessed Wattage = 16 × 21 = 336 watts
Total LED Tube Wattage = 9 × 24 = 216 watts
Total LED Wattage = 420 + 216 = 552 watts
Lighting Power Density $(LPD) = \frac{Total\ Power}{Total\ Area} = \frac{552w}{66.572m^2} = 8.29\ w/m^2$

Let suppose per day effective burning time 10 hrs .

So, per day wattage = 552 × 10 = 5520 watts
Now FTL wattage in 30 Days = 5520 × 30 = 16560 watt = 165.6 kw

So Annual Energy Consumption = 165.6 × 12 = 1987.2 kw

Let suppose 1 BOT cost = 10 rupees

So annual cost = 1987.2 × 10 = 19872 rupees

Table-20: Producing Designed System for Classroom E-2-2

Average Illuminance (Lux)	**Uniformity**	**LPD (w/m^2)**	**Types of lamps**	**No. of lamps**	**Energy consumption (**kw**)**	**Energy cost per year (rupees)**
521	0.7	12.73	2(21 W, 3 F Fillipi S.p.A) (24W, AIRAM Vario1140)	25	1987.2	19872

5.4. Corridor with Producing LED Lighting Design:

Room Dimension:

- Length: 20 m
- Width(d): 3.2 m
- Floor to Ceiling Height: 4.5 m
- Area =20m × $3.2m = 64m^2$
- Total no. of grid = 300
- Distance between two grids= $0.2 \times 5\log d = 0.2 \times 5\log 3.2 = 0.653$ m.

Luminaire Used:

- 10 LED Tube Lights of 16 watts
- LED Tube Lights of 33 watts

DIALux Designed Corridor

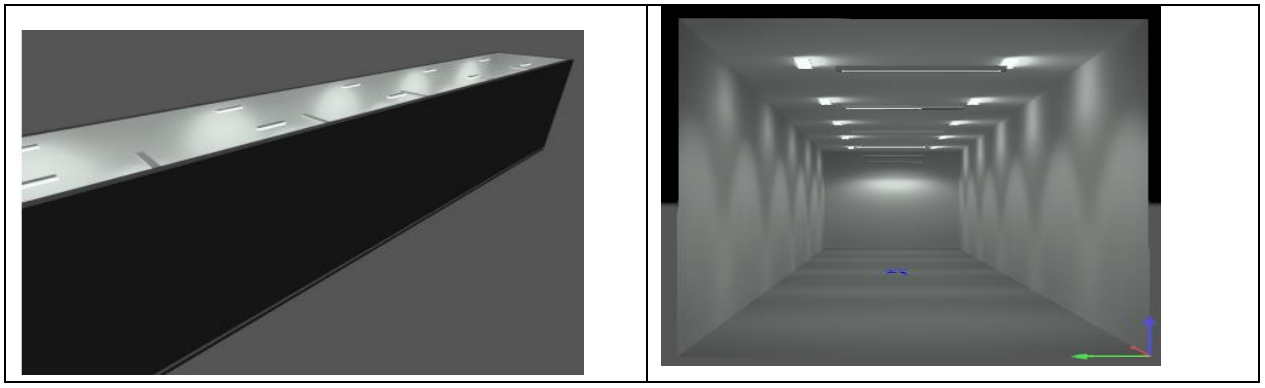


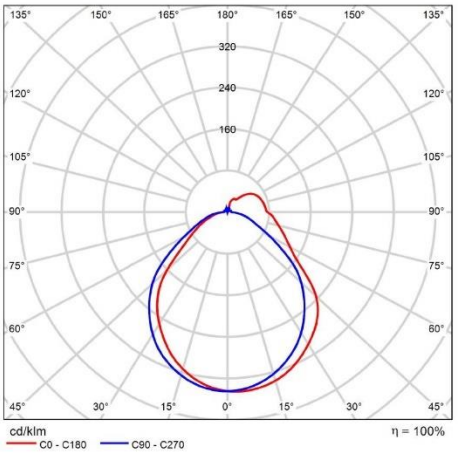
Fig-31: Top view of the corridor

Fig-32: Down to Up of the corridor

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.

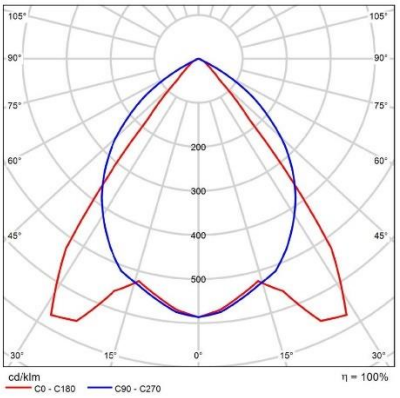
SOURCE
Linear LED module 14W/830.
Energy efficiency class (UE 2019/2020 - UE 2019/2015): D.
CIE 13.3 Colour rendering index: CRI >80 (R9 <50%).
IES TM-30 Fidelity Index: Rf = 84 Rg = 95.

Product data sheet

AIRAM - Office P 1245 33W/830 CA AL MA

Article No.	A1OFBA-CA
P	33.0 W
Φ_{Lamp}	4000 lm
$\Phi_{Luminaire}$	4014 lm
η	100.35 %
Luminous efficacy	121.6 lm/W
CCT	3000 K
CRI	80

The suspension-mounted Office P is an energy-efficient office luminaire range with a downlight. This extensive range offers numerous customisation options. Its optics features include an aluminium parabolic louvre and integrated opal shield, which eliminate glare from the LEDs and achieve a low Unified Glare Rating l/value (UGR <19). The luminaire is delivered with a 2-metre cable. Typical applications include schools, offices and other spaces where computers are used.



Polar LDC

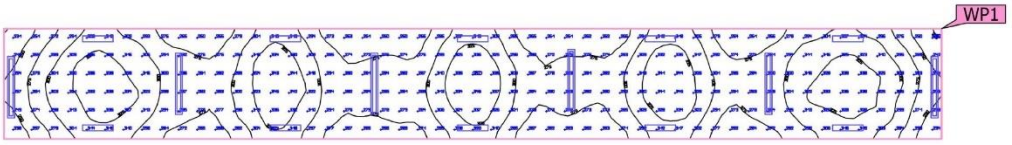
Glare evaluation according to UGR

ρ Ceiling		70	70	50	50	30	70	70	50	50	30
ρ Walls		50	30	50	30	30	50	30	50	30	30
ρ Floor		20	20	20	20	20	20	20	20	20	20
Room size X	Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H	2H	17.9	18.9	18.1	19.1	19.3	20.6	21.6	20.9	21.8	22.0
	3H	17.8	18.7	18.1	18.9	19.2	20.5	21.3	20.8	21.6	21.8
	4H	17.7	18.6	18.0	18.8	19.1	20.4	21.2	20.7	21.5	21.8
	6H	17.7	18.4	18.0	18.7	19.0	20.3	21.1	20.6	21.4	21.7
	8H	17.6	18.4	18.0	18.7	19.0	20.3	21.0	20.6	21.3	21.6
	12H	17.6	18.3	17.9	18.6	18.9	20.2	20.9	20.6	21.3	21.6
4H	2H	17.8	18.7	18.2	19.0	19.2	20.4	21.2	20.7	21.5	21.8
	3H	17.8	18.5	18.1	18.8	19.1	20.3	21.0	20.6	21.3	21.6
	4H	17.7	18.3	18.1	18.7	19.0	20.2	20.8	20.6	21.2	21.5
	6H	17.7	18.2	18.1	18.6	19.0	20.1	20.7	20.5	21.0	21.4
	8H	17.6	18.1	18.1	18.5	18.9	20.1	20.6	20.5	21.0	21.4
	12H	17.6	18.1	18.0	18.5	18.9	20.0	20.5	20.5	20.9	21.3
8H	4H	17.6	18.1	18.0	18.5	18.9	20.1	20.6	20.5	21.0	21.4
	6H	17.5	18.0	18.0	18.4	18.8	20.0	20.4	20.5	20.8	21.3
	8H	17.5	17.9	18.0	18.3	18.8	20.0	20.3	20.4	20.8	21.2
	12H	17.5	17.8	18.0	18.3	18.8	19.9	20.2	20.4	20.7	21.2
12H	4H	17.8	18.0	18.0	18.4	18.8	20.0	20.5	20.5	20.9	21.3
	6H	17.5	17.9	18.0	18.3	18.8	20.0	20.3	20.4	20.8	21.2
	8H	17.5	17.8	18.0	18.2	18.7	19.9	20.2	20.4	20.7	21.2
Variation of the observer position for the luminaire distances S											
S = 1.0H		+3.6 / -6.7					+1.4 / -1.7				
S = 1.5H		+5.3 / -9.1					+2.3 / -8.5				
S = 2.0H		+7.2 / -10.3					+4.2 / -17.2				
Standard table		BK00					BK00				
Correction summand		-0.5					2.0				
Corrected glare indices referring to 4000lm Total luminous flux											

UGR diagram (SHR: 0.25)

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

Working plane (CORRIDOR)



Properties	Ē (Target)	E_{min}	E_{max}	U_o (g_1) (Target)	g_2	Index
Working plane (CORRIDOR) Perpendicular illuminance (adaptive) Height: 0.000 m, Wall zone: 0.480 m	295 lx (≥ 250 lx) ✓	223 lx	349 lx	0.76 (≥ 0.70) ✓	0.64	WP1

Utilisation profile: Educational premises - Educational buildings (44.19 Circulation areas, corridors)

- **Average Illuminance Value:** 295 lx
- **Minimum Illuminance Value:** 223 lx
- **Overall Uniformity:** 0.70 (The value is less than desired value i.e. 0.70)

Energy Cost with the Producing Designed System for Corridor:

Total LED Tube Light Wattage = 10 × 16 = 160 watts
Total LED Tube Light Wattage = 6 × 33 = 198 watts
Total LED Tube Light Wattage = 160 + 198 = 358 watts
Lighting Power Density $(LPD) = \frac{Total\ Power}{Total\ Area} = \frac{358w}{64m^2} = 5.59\ w/m^2$

Let suppose per day effective burning time 10 hrs .

So per day wattage = 358 × 10 = 3580 watts
Now FTL wattage in 30 Days = 3580 × 30 = 107400 watt = 107.4 kw

So Annual Energy Consumption = 107.4 × 12 = 1288.8 kw

Let suppose 1 BOT cost = 10 rupees

So annual cost = 1288.8 × 10 = 12888 rupees

Table-21: Producing Designed System for Corridor

Average Illuminance (Lux)	Uniformity	LPD (w/m^2)	Types of lamps	No. of lamps	Energy consumption (kw)	Energy cost per year (rupees)
295	0.76	5.59	2(16 W, 3 F Fillipi S.p.A) (33W, AIRAM Office)	16	1288.8	12888

5.5. K C Roy Hall with Producing LED Lighting Designed:

Room Dimension:

- Length: 15.2 m
- Width(d): 10.5 m
- Floor to Ceiling Height: 4.2 m
- Area = 15.2 × 10.5 =159.6 m^2
- Total no. of grid = 77
- Distance between two grids= 0.2 × 5log d = 0.2 × 5log 10.5 = 1.021 m.

Luminaire Used:

- 7×5 LED Recessed Lights of 21 watts
- 1 LED LED Recessed Lights of 12 watts

DIALux Designed K.C.ROY Hall:

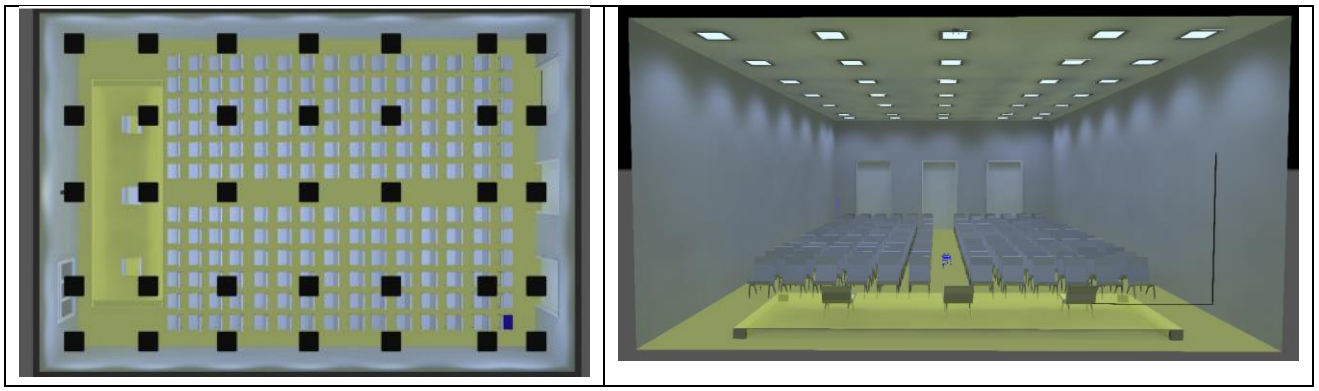


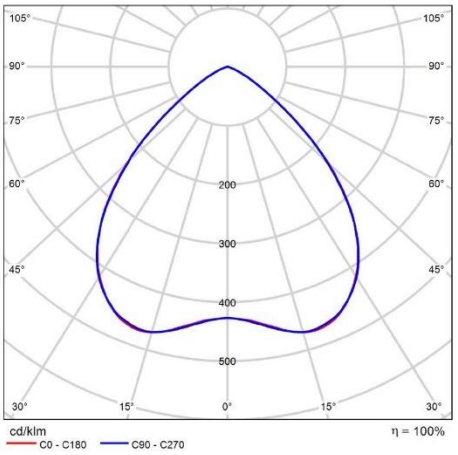
Fig-33: Top view of the KC Roy Hall

Fig-34: Down to Up View of the KC Roy Hall

Product data sheet

3F Filippi S.p.A. - 3F Diagon FCH 19W/840 599x599

Article No.	23795
P	21.0 W
Φ_{Lamp}	3354 lm
$\Phi_{Luminaire}$	3354 lm
η	100.00 %
Luminous efficacy	159.7 lm/W
CCT	4000 K
CRI	80



Polar LDC

ILLUMINOTECHNICAL
Luminous efficiency 100% (DLOR 100%, ULOR 0%).
Initial luminous flux of the luminaire 3354 lm.
Direct symmetric distribution.
Installation Interdistance Transv.D = 1.39 x hu - Long.D = 1.39 x hu.
Average luminance <1000 cd/m² for radial angles >65°.
Tabular UGR (CIE 117 - 4H-8H; S=0.25H; 70/50/20): RUG 16.5 - 16.5.
Beam angle: 93° - 92°.
Luminous efficacy 160 lm/W.
Lifetime (L95/B10): 30000 h. (tq+25°C)
Lifetime (L90/B10): 50000 h. (tq+25°C)
Lifetime (L80/B10): 80000 h. (tq+25°C)
Lifetime (L75/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
Squared LED module 19W/840.
Energy efficiency class (UE 2019/2020 - UE 2019/2015): C.

Glare evaluation according to UGR

ρ Ceiling		70	70	50	50	30	70	70	50	50	30
ρ Walls		50	30	50	30	30	50	30	50	30	30
ρ Floor		20	20	20	20	20	20	20	20	20	20
Room size X	Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H	2H	16.7	17.8	17.0	18.0	18.2	16.7	17.8	17.0	18.0	18.2
	3H	16.6	17.6	16.9	17.9	18.1	16.6	17.6	16.9	17.8	18.1
	4H	16.6	17.5	16.9	17.8	18.0	16.6	17.5	16.9	17.7	18.0
	6H	16.5	17.3	16.8	17.6	17.9	16.5	17.3	16.8	17.6	17.9
	8H	16.5	17.3	16.8	17.6	17.9	16.4	17.3	16.8	17.6	17.9
	12H	16.4	17.2	16.8	17.5	17.8	16.4	17.2	16.8	17.5	17.8
4H	2H	16.7	17.6	17.0	17.8	18.1	16.7	17.6	17.0	17.8	18.1
	3H	16.6	17.4	17.0	17.7	18.0	16.6	17.4	17.0	17.7	18.0
	4H	16.6	17.3	17.0	17.6	18.0	16.6	17.2	16.9	17.6	17.9
	6H	16.5	17.1	16.9	17.5	17.9	16.5	17.1	16.9	17.5	17.8
	8H	16.5	17.0	16.9	17.4	17.8	16.4	17.0	16.9	17.4	17.8
	12H	16.4	16.9	16.9	17.3	17.8	16.4	16.9	16.8	17.3	17.7
8H	4H	16.5	17.0	16.9	17.4	17.8	16.5	17.0	16.9	17.4	17.8
	6H	16.4	16.8	16.9	17.3	17.7	16.4	16.8	16.8	17.2	17.7
	8H	16.4	16.7	16.8	17.2	17.7	16.3	16.7	16.8	17.2	17.7
	12H	16.3	16.7	16.8	17.1	17.6	16.3	16.6	16.8	17.1	17.6
12H	4H	16.4	16.9	16.9	17.3	17.8	16.4	16.9	16.8	17.3	17.7
	6H	16.4	16.7	16.8	17.2	17.7	16.3	16.7	16.8	17.2	17.7
	8H	16.3	16.7	16.8	17.1	17.6	16.3	16.6	16.8	17.1	17.6
Variation of the observer position for the luminaire distances S											
S = 1.0H		+1.5 / -2.6					+1.6 / -2.6				
S = 1.5H		+2.6 / -6.1					+2.6 / -6.1				
S = 2.0H		+4.2 / -9.2					+4.2 / -9.1				
Standard table		BK00					BK00				
Correction summand		-1.7					-1.7				
Corrected glare indices referring to 3354lm Total luminous flux											

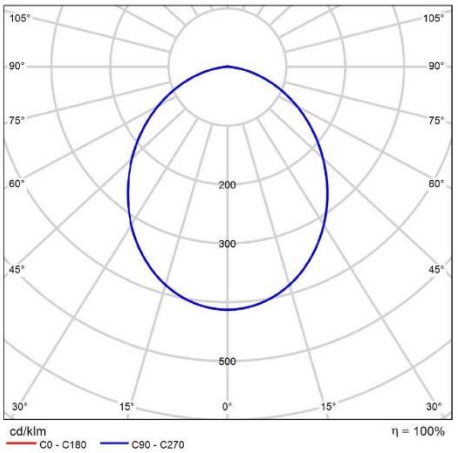
UGR diagram (SHR: 0.25)

Product data sheet

ARCLUCE S.p.A. - AURUM - 12W - 1450lm - Ultra Wide Flood 98°

Article No.	0208030A-930
P	12.0 W
Φ_{Lamp}	1450 lm
$\Phi_{Luminaire}$	1450 lm
η	100.00 %
Luminous efficacy	120.8 lm/W
CCT	3000 K
CRI	90

IP DEGREE : IP20
ELECTRICAL INSULATION CLASS: I
LUMINAIRE
Extruded aluminium body.
Polyester powder paint resistant to UV rays.
Screen made of opal plastic material.
Long LED life time > 50000h.
It complies with standards EN 60598-1 and EN 60598-2-1.
INSTALLATION
Ceiling installation.
Grommet for single cable entry.
Base plate made of painted steel.



Polar LDC

Glare evaluation according to UGR

ρ Ceiling		70	70	50	50	30	70	70	50	50	30
ρ Walls		50	30	50	30	30	50	30	50	30	30
ρ Floor		20	20	20	20	20	20	20	20	20	20
Room size X	Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H	2H	27.0	28.3	27.3	28.6	28.8	27.0	28.3	27.3	28.6	28.8
	3H	28.3	29.5	28.7	29.8	30.1	28.3	29.5	28.7	29.8	30.1
	4H	28.8	29.9	29.2	30.2	30.5	28.8	29.9	29.2	30.2	30.5
	6H	29.1	30.2	29.5	30.5	30.8	29.1	30.2	29.5	30.5	30.8
	8H	29.2	30.2	29.5	30.5	30.8	29.2	30.2	29.5	30.5	30.8
	12H	29.2	30.2	29.6	30.5	30.8	29.2	30.2	29.6	30.5	30.8
4H	2H	27.6	28.7	28.0	29.0	29.3	27.6	28.7	28.0	29.0	29.3
	3H	29.1	30.1	29.5	30.4	30.7	29.1	30.1	29.5	30.4	30.7
	4H	29.7	30.6	30.1	30.9	31.3	29.7	30.6	30.1	30.9	31.3
	6H	30.1	30.8	30.5	31.2	31.6	30.1	30.8	30.5	31.2	31.6
	8H	30.2	30.9	30.6	31.3	31.7	30.2	30.9	30.6	31.3	31.7
	12H	30.2	30.9	30.7	31.3	31.7	30.2	30.9	30.7	31.3	31.7
8H	4H	29.9	30.6	30.4	31.0	31.4	29.9	30.6	30.4	31.0	31.4
	6H	30.4	31.0	30.9	31.4	31.9	30.4	31.0	30.9	31.4	31.9
	8H	30.6	31.1	31.1	31.5	32.0	30.6	31.1	31.1	31.5	32.0
	12H	30.7	31.1	31.2	31.6	32.1	30.7	31.1	31.2	31.6	32.1
12H	4H	29.9	30.6	30.4	31.0	31.4	29.9	30.6	30.4	31.0	31.4
	6H	30.5	31.0	30.9	31.4	31.9	30.5	31.0	30.9	31.4	31.9
	8H	30.6	31.1	31.1	31.5	32.0	30.6	31.1	31.1	31.5	32.0

Variation of the observer position for the luminaire distances S

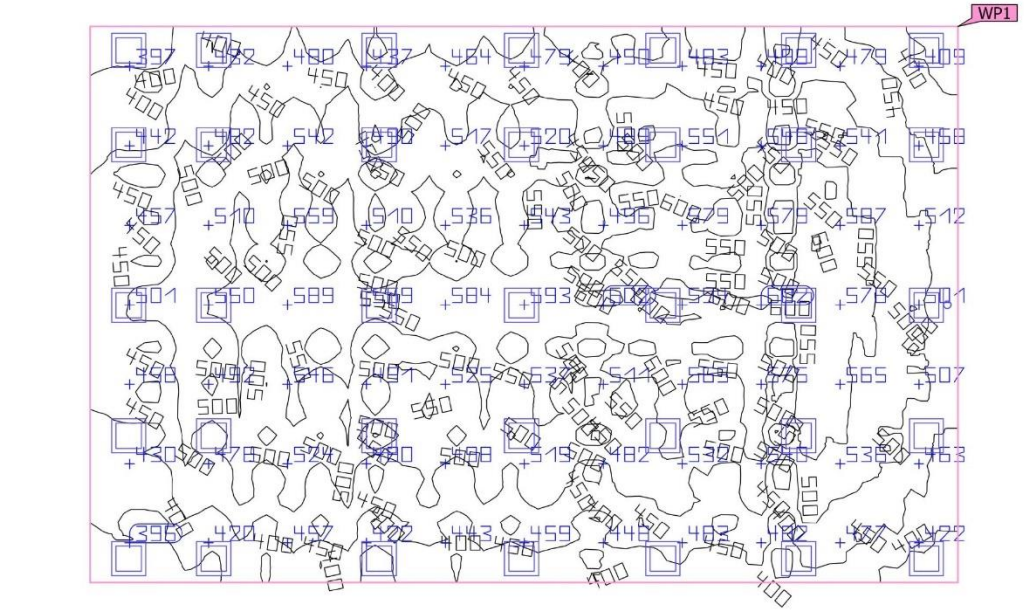
S = 1.0H	+0.1 / -0.2	+0.1 / -0.2
S = 1.5H	+0.3 / -0.5	+0.3 / -0.5
S = 2.0H	+0.5 / -0.9	+0.5 / -0.9
Standard table	BK05	BK05
Correction summand	13.3	13.3

Corrected glare indices referring to 1450lm Total luminous flux

UGR diagram (SHR: 0.25)

Building 1 · Storey 1 · K.C.ROY HALL (Light scene 1)

Working plane (K.C.ROY HALL)



Properties	Ē (Target)	E_{min}	E_{max}	U_o (g_1) (Target)	g_2	Index
Working plane (K.C.ROY HALL) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.500 m	500 lx (≥ 500 lx) ✓	353 lx	607 lx	0.71 (≥ 0.70) ✓	0.58	WP1

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

- **Average Illuminance Value:** 500 lx
- **Minimum Illuminance Value:** 353 lx
- **Overall Uniformity:** 0.71 (The value is less than desired value i.e. 0.70)

Energy Cost with the Producing Designed System for K.C. Roy Hall:

Total LED Wattage = 35 × 21 = 735 watts
Total LED Wattage = 1 × 12 = 12 watts
Total LED Wattage = 735 + 12 = 747 watts
Lighting Power Density $(LPD) = \frac{Total\ Power}{Total\ Area} = \frac{747w}{159.6m^2} = 4.68\ w/m^2$

Let suppose per day effective burning time 10 hrs.

So, per day wattage = 747×10 = 7470 watts
Now FTL wattage in 30 Days = 7470 × 30 = 22410 watts = 224.1 kw
So, Annual Energy Consumption = 224.1 × 12= 2689.2 kw
Let suppose 1 BOT cost = 10 rupees

So annual cost = 2689.2 × 10 = 26892 rupees

Table-22: Producing Lighting Designed Systems

Average Illuminance (Lux)	**Uniformity**	**LPD (w/m^2)**	**Types of lamps**	**No. of lamps**	**Energy consumption (**kw**)**	**Energy cost per year (rupees)**
500	0.71	4.68	2(12W, ARCLUDE S.p.A) (21 W, 3 F Fillipi S.p.A)	36	2689.2	26892

23. Summary of Existing Lighting design of Education Building:

Location	**Average Illuminance (Lux)**	**Uniformity**	**LPD (w/m^2)**	**No. of lamps**	**Types of lamps**	**Energy consumption (**kw**)**	**Energy cost per year (rupees)**
Seminar room	754	0.52	6.83	27	1 (21 W, 3 F Fillipi S.p.A)	2041.2	20412
Classroom (E-2-1)	503	0.7	10.75	26	2(21 W, 3 F Fillipi S.p.A) (24W, AIRAM Vario1140)	1900.8	19008
Classroom (E-2-2)	521	0.7	12.73	25	2(21 W, 3 F Fillipi S.p.A) (24W, AIRAM Vario1140)	1987.2	19872
Corridor	295	0.76	5.59	16	2(16 W, 3 F Fillipi S.p.A) (33W, AIRAM Office)	1288.8	12888
KC Roy Hall	500	0.71	4.68	36	2(12W, ARCLUD E S.p.A) (21 W, 3 F Fillipi S.p.A)	2689.2	26892

5.7. Analysis:

5.7.1. Comparison between Existing & Producing verage Illuminance

Table -24: Comparison of existing and producing average illuminance

Room	Existing avg. illuminance (Lux)	Producing avg. illuminance (Lux)
Seminar room	155.34	754
Class room E-2-1	257.6	510
Class room E-2-2	269.48	521
Corridor	118.2	295
K.C. Roy Hall	130.2	500

- Seminar Room: The existing average illuminance in the Seminar Room is 155.34 Lux, which increases significantly to 754 Lux under producing conditions. This increase indicates a substantial improvement in lighting, which could enhance visibility and comfort for occupants.

- Classroom E-2-1: For Classroom E-2-1, the existing average illuminance is 257.6 Lux, and it increases to 510 Lux under producing conditions. The increase in illumination by 252.4 Lux suggests enhanced lighting quality, likely contributing to a better learning environment.

- Classroom E-2-2: The average illuminance in Classroom E-2-2 rises from 269.48 Lux to 521 Lux. The increase of 251.52 Lux reflects a significant improvement in lighting conditions, potentially aiding in creating a more conducive environment for educational activities.

- Corridor: The corridor shows an increase in average illuminance from 118.2 Lux to 295 Lux. The increase of 176.8 Lux suggests that the lighting in the corridor has been significantly enhanced, improving visibility and safety in this shared space.

- K C Roy Hall: In K C Roy Hall, the existing average illuminance is 130.2 Lux, which increases to 500 Lux under producing conditions. The increase of 369.8 Lux represents a considerable enhancement in lighting, likely improving the overall ambiance and usability of the hall.

  Overall, all rooms and areas exhibit a notable increase in average illuminance levels under producing conditions. These improvements indicate efforts to enhance lighting quality, which can improve comfort, safety, and functionality in various spaces.

5.7.2. Comparison between Existing & Producing overall uniformity:

Table-25: Comparison between Existing & Producing overall uniformity

Room	Existing overall uniformity	Producing overall uniformity
Seminar room	0.52	0.7
Class room E-2-1	0.42	0.70
Class room E-2-2	0.47	0.70
Corridor	0.47	0.76
K.C. Roy Hall	0.52	0.7

- Seminar Room: The existing uniformity is 0.52, and the producing uniformity increases significantly to 0.7. This indicates a notable improvement in uniformity, suggesting better distribution of lighting or other relevant factors.

- Classroom E-2-1: The existing uniformity is lower at 0.42, but it also improves to 0.70 with the new measures. This jump suggests the previous uniformity was suboptimal, and the new approach has successfully addressed the inconsistency.

- Classroom E-2-2: Similarly, this room shows an increase from 0.47 to 0.70, indicating that the improvements have brought the uniformity in line with desired standards, likely enhancing the environment for occupants.

- Corridor: The corridor shows an increase from 0.47 to 0.76, which is the highest improvement among all areas. This suggests that the corridor may have initially had poor uniformity, which was significantly improved.

- K.C. Roy Hall: The uniformity in this hall was already at a moderate level (0.52) and has been improved to 0.7, aligning it with other rooms.

  Overall, the data indicates that the new measures have been effective in enhancing the uniformity across all analyzed spaces.

5.7.3. Comparison between Existing & Producing Lighting Power Density (LPD):

Table 26: Comparison between Existing & Producing Lighting Power Density

Room	Existing LPD (w/m^2)	Producing LPD (w/m^2)
Seminar room	15.71	6.83
Class room E-2-1	70.41	8.29
Class room E-2-2	12.73	10.75
Corridor	9	5.59
K C Roy Hall	7.44	4.68

- Seminar Room: The existing LPD is 15.71 W/m², which is significantly reduced to 6.83 W/m² in the producing LPD. This reduction indicates a more energy-efficient lighting system has been implemented without compromising the lighting quality.

- Classroom E-2-1: This room has an exceptionally high existing LPD of 70.41 W/m², which drops drastically to 8.29 W/m². Such a large reduction suggests that the original lighting was likely excessive or inefficient, and the new setup is far more sustainable.

- Classroom E-2-2: The existing LPD is 12.73 W/m², reduced to 10.75 W/m² in the producing state. Although the reduction is smaller compared to other rooms, it still reflects an improvement in energy efficiency.

- Corridor: The corridor shows a decrease in LPD from 9 W/m² to 5.59 W/m². This indicates a more efficient use of lighting in an area that typically requires less intense illumination.

- K.C. Roy Hall: The LPD drops from 7.44 W/m² to 4.68 W/m², suggesting a balanced approach to energy conservation while maintaining appropriate lighting levels.

Overall, the significant reductions in LPD across all areas indicate a successful transition to more energy-efficient lighting systems, contributing to lower energy consumption and cost savings.

5.7.4. Comparison between Existing & Producing Energy consumption per year

Table-27: Comparison between Existing & Producing Energy consumption per year

Room	Existing Energy consumption per year (kw)	Producing Energy consumption per year (kw)
Seminar room	4694.4	2041.2
Class room E-2-1	2808.0	1900.8
Class room E-2-2	3052.8	1987.2
Corridor	2361.6	1288.8
K C Roy Hall	4276.8	2689.2

- Seminar Room: The existing energy consumption is 4694.4 kW per year, while the producing energy consumption is 2041.2 kW per year. This indicates a significant reduction of 2653.2 kW, showcasing improved energy efficiency or better energy management in this room.

- Classroom E-2-1: The existing energy consumption for Classroom E-2-1 is 2808.0 kW per year. Under producing conditions, the energy consumption drops to 1900.8 kW per year. This reduction of 907.2 kW reflects enhanced energy-saving measures or technological upgrades.

- Classroom E-2-2: For Classroom E-2-2, there is a decrease from 3052.8 kW to 1987.2 kW per year. The reduction of 1065.6 kW suggests significant improvements in energy efficiency, similar to Classroom E-2-1.

- Corridor: The corridor shows a decrease in energy consumption from 2361.6 kW to 1288.8 kW per year. The saving of 1072.8 kW highlights effective strategies implemented in common areas to reduce energy use.

- K C Roy Hall: The largest area, K C Roy Hall, sees a reduction from 4276.8 kW to 2689.2 kW per year. This decrease of 1587.6 kW indicates a substantial improvement in energy efficiency.

  Overall, all areas show a notable reduction in energy consumption, suggesting successful implementation of energy-saving measures or more efficient technologies.

5.7.5. Comparison between Existing & Producing Energy cost per year

Table-28: Comparison between Existing & Producing Energy cost per year

Room	Existing Energy cost per year *(₹)*	Producing Energy Energy cost per *(₹)*
Seminar room	46944	20412
Class room E-2-1	28080	19008
Class room E-2-2	30528	19872
Corridor	23616	12888
K C Roy Hall	42768	26892

- Seminar Room: The existing energy cost for the Seminar Room is ₹46,944 per year, which decreases to ₹20,412 per year under producing conditions. This reduction of ₹26,532 indicates significant cost savings, likely due to improved energy efficiency or better energy management practices.

- Classroom E-2-1: The cost of energy for Classroom E-2-1 is reduced from ₹28,080 per year to ₹19,008 per year, resulting in savings of ₹9,072. This suggests that the implementation of energy-saving measures has effectively lowered operating costs.

- Classroom E-2-2: In Classroom E-2-2, the existing energy cost is ₹30,528 per year, while the producing energy cost is ₹19,872 per year. The reduction of ₹10,656 demonstrates effective strategies or technologies that have led to decreased energy expenses.

- Corridor: The corridor shows a cost reduction from ₹23,616 to ₹12,888 per year, resulting in a saving of ₹10,728. This significant decrease reflects efficient energy management in common areas.

- K C Roy Hall: The existing energy cost for K C Roy Hall is ₹42,768 per year, which decreases to ₹26,892 per year. This reduction of ₹15,876 indicates a substantial improvement in energy efficiency, contributing to significant cost savings.

  Overall, all rooms and areas experience a notable decrease in energy costs, highlighting the benefits of implementing energy-efficient practices or upgrading technologies. This reduction not only lowers operational expenses but also contributes to more sustainable energy use.

Chapter: 6

Conclusion & Future Scope

Conclusion:

To sum up, this thesis has explored the critical role of energy-efficient lighting solutions in Seminar-room, Classrooms, Corridor and K.C.ROY Hall with the goal of balancing the dual priorities of preservation and effective illumination. Through an in-depth review of literature, analysis of case studies, and practical evaluation, several key insights have been identified. Lighting is essential for enhancing the visual appeal, learning experience, and overall atmosphere in both museums and classrooms. However, conventional lighting systems tend to consume a large amount of energy and contribute to environmental challenges. The use of energy-efficient lighting provides numerous advantages, including reduced energy consumption, lower operating expenses, and a smaller environmental footprint. Additionally, energy-efficient lighting enhances visual comfort, productivity, and occupant well-being. Implementing energy-efficient lighting solutions in museums and classrooms is not without obstacles. Financial limitations, technical difficulties, and differing stakeholder preferences can hinder progress. Nevertheless, through thoughtful planning, active collaboration with stakeholders, and innovative design solutions, these challenges can be effectively addressed.

Drawing from the research, several key suggestions are made for achieving greater energy efficiency in museum and classroom lighting:

• Adopting LED technology for its energy efficiency, durability, and adaptability.

• Creating lighting systems specifically designed for the unique functions and activities of each space.

• Incorporating daylighting techniques to maximize the use of natural light and minimize energy use.

• Utilizing advanced controls and sensor technology to optimize lighting performance and manage energy consumption.

• Educating stakeholders on the advantages of energy-efficient lighting and promoting a culture of sustainability.

Energy-efficient lighting holds great potential for improving the sustainability and quality of lighting in both museums and classrooms. By overcoming challenges and embracing innovative technologies, educators, museum staff, and lighting designers can collaborate to create visually appealing and environmentally conscious environments. This thesis represents a step toward realizing that goal and paves the way for further research and advancements in energy-efficient lighting solutions.

Future Prospects:

I. **Technological Progress:** With ongoing advancements in technology, future developments in energy-efficient lighting solutions are expected. Research can focus on integrating emerging technologies like smart lighting systems, IoT-enabled sensors, and sophisticated control mechanisms to further improve energy conservation and lighting quality in museums and educational environments.

II. **Sustainability Efforts:** As sustainability becomes a global priority, future research can explore how energy-efficient lighting aligns with larger sustainability efforts in schools and cultural

institutions. This includes evaluating the environmental impacts of lighting systems, conducting life cycle assessments, and incorporating renewable energy sources into these systems.

III. **Human-Focused Lighting:** Research can further investigate human-focused lighting, which aims to enhance lighting conditions for improved human health, well-being, and productivity. Future work can examine the effects of dynamic, circadian, and personalized lighting solutions on occupants in museum and classroom settings.

IV. **Data-Driven Strategies:** The potential for data-driven methods, such as machine learning algorithms and occupancy sensors, can be explored to optimize lighting strategies based on real-time usage patterns and user preferences. Future studies can assess the practicality and efficiency of these techniques in improving energy conservation and user comfort.

V. **Interdisciplinary Collaboration:** Progress in energy-efficient lighting solutions will require collaboration between lighting designers, architects, educators, museum professionals, and sustainability experts. Future research can explore cross-disciplinary approaches to lighting design that emphasize both energy efficiency and the user experience.

VI. **Policy and Standards Advancement:** Ongoing research is needed to guide policy-making and establish industry standards for energy-efficient lighting in museums and classrooms. Future studies can contribute to the formulation of guidelines, regulations, and certification programs aimed at encouraging the use of sustainable lighting practices.

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APPENDIX:

Luxmeter: A lux meter, often referred to as a light meter, is an instrument used to quantify light intensity in units called lux. Lux measures illuminance, which indicates how much visible light falls onto a surface.

Lux meters are widely used across several fields such as photography, filmmaking, architectural design, industrial lighting setups, and environmental assessments. These meters offer precise measurements of light levels, enabling users to evaluate and adjust lighting conditions accordingly. Typically, a lux meter consists of a light sensor, usually a photodiode, which detects light and converts it into an electrical signal. The device then displays the light intensity in lux on either a digital or analog display. Some advanced models may include features such as data logging, adjustable measurement ranges, and options for data connectivity and transfer.

To operate a lux meter, you position the sensor in the area where light intensity needs to be measured and simply read the value shown on the display. Lux meters are calibrated to ensure accuracy, factoring in the sensor's sensitivity and the way human vision perceives different light wavelengths. When choosing a lux meter, it’s important to consider the measurement range, precision, resolution, and any additional functionalities that might be relevant to your specific needs. Lux meters come in a range of models and price points, catering to diverse applications.

Fig-35: Lux meter

Laser Distance Meter:

A laser distance meter, also called a laser rangefinder or laser measuring tool, is a device that uses laser technology to measure distances. It operates by emitting a laser beam towards a target object and calculating the distance based on the time taken for the laser pulse to reflect back to the device.

Here's how a standard laser distance meter functions:

Targeting: The user points the laser distance meter at the object whose distance they want to measure. Most devices feature a built-in laser pointer or viewfinder to help with precise aiming.

Emitting Laser Pulse: When the user activates the device by pressing a button, the meter sends a laser pulse towards the target.

Reflection: The laser beam strikes the object and bounces back to the meter, where a sensor detects the returning pulse.

Time Calculation: The device measures the time it takes for the laser pulse to travel to the object and return. This round-trip time, combined with the speed of light, allows the meter to compute the distance.

Distance Measurement: Based on the time it recorded, the device calculates the distance from the object and displays the result on its screen.

Laser distance meters are widely used in areas such as construction, architecture, real estate, forestry, and sports. They are prized for providing fast, precise distance measurements, making them useful for tasks like gauging room sizes, measuring distances between objects, estimating building heights, or calculating areas and volumes.

These meters come with varying levels of range and accuracy, so it's essential to select one that fits your needs. More advanced models may offer features like angle measurements, Pythagorean theorem calculations, Bluetooth connectivity for data transfer, or integration with smartphone applications.

Fig -36: Laser Distance Meter