A STUDY ON LED FLOODLIGHTING SYSTEM FOR OUTDOOR TENNIS COURT ILLUMINATION

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR DEGREE OF

MASTER OF ENGINEERING

IN

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SUBMITTED BY

SAGAR DAS

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UNDER THE SUPERVISION OF

Prof.(Dr.) Biswanath Roy

ELECTRICAL ENGINEERING DEPARTMENT

FACULTY OF ENGINEERING AND TECHNOLOGY

JADAVPUR UNIVERSITY
Kolkata - 700032

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JADAVPUR UNIVERSITY
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ELECTRICAL ENGINEERING DEPARTMENT

RECOMMENDATION CERTIFICATE

This is to certify that the thesis entitled "A STUDY ON LED FLOODLIGHTING SYSTEM FOR OUTDOOR TENNIS COURT ILLUMINATION " submitted by SAGAR DAS, (Examination Roll No.M2ILN21021, Registration No.154024 of 2020-2021) of this University in partial fulfilment of requirements for the award of degree of Master of Engineering in Illumination Engineering, Electrical Engineering Department, is a bonafide record of the work carried out by him under my guidance and supervision.

(Thesis supervisor)
Dr. Biswanath Roy
Professor
Electrical Engineering Department
Jadavpur University

Countersigned:

Prof.(Dr.) Saswati Mazumder
Head of the Department,
Electrical Engineering Department,
Jadavpur University

Prof.(Dr.) Bhaskar Gupta
Dean of the Faculty of Engg. and Tech.
Jadavpur University

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This foregoing thesis is hereby approved as a creditable study in the area of Illumination Engineering, carried out and presented by SAGAR DAS, in a manner of satisfactory warrant its acceptance as a pre-requisite to the degree for which it has been submitted. It is notified to be understood that by this approval, the undersigned do not necessarily endorse or approved the thesis only for the purpose for which it has been submitted.

FINAL EXAMINATION FOR EVALUATION OF THESIS

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DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of my Master of Engineering in Illumination Engineering studies.

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

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

NAME : SAGAR DAS
EXAMINATION ROLL NO. : M2ILN21021

THESIS TITLE : "A STUDY ON LED FLOODLIGHTING SYSTEM FOR OUTDOOR TENNIS COURT ILLUMINATION ".

SIGNATURE WITH DATE :

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SAGAR DAS

Place:Jadavpur

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1 Chapter1:Introduction

1.1 Literature Review

Among all type of lighting designs, Sports lighting design is the most challenging task a lighting designer ever encounters. It desires utmost excellence from a lighting designer. Unlike other type of lighting designs, sports lighting is something beyond just satisfying a set of standardized design criteria. Sports lighting involves infinite number of viewing perspectives of different users of the sports facility involved - players, match referee and/or umpires, other gaming and non-gaming staffs, spectators present in the live game and the cameras for televised gaming events.For the lighting of tannis courts it is essential that there should be complete freedom from glare and that the light should have a high speed of discrimination. In Philips Technical Review (Eindhoven) of August last, it is pointed out that both these requirements are exceptionally well fulfilled by a lighting system employing sodium lamps. Although no satisfactory method was found for making quantitative measurements of the disturbing effect produced with different types of light, experience has shown that the presence of a source of light in the field of vision is less disturbing with sodium lamps than with other lamp sources of equivalent total candle power. This is due to the comparatively low luminous intensity of sodium lamps. Several experimenters have also proved that the speed of discriminating objects is quicker with sodium light than with other types of light. Professional and collegiate sport venues consume huge electrical energy. Therefore, a smart management of their electric energy is essential for significant energy saving.

R. A. Hargroves, et. al proposed a method for Glare evaluation of tennis court floodlighting. CIE TC 5-04 'Glare in Outdoor Lighting' has proposed a formula which predicts the subjective impression of glare for a floodlighting scheme on a nine-point scale. This formula was initially developed from appraisals made on football pitches. The Formula is :

$$GF = 7.3 - 2.4log\frac{L_v}{L_{(ve)}0.9}$$

where GF is the glare control mark for floodlighting, related to the nine-point scale of subjective appraisals. At its meeting on 25 November 1985, CIE Technical Committee TC 5-04 adjusted the glare formula to change the scale and to rename 'Glare Control Mark, GF' as 'Glare Rating,GR'. This was done in order to express glare by a number between 0 and 100, with a higher figure denoting greater glare. The basic concept, philosophy and validity of the method are not affected by this adjustment.

The ultimate objective of sports lighting is providing good visibility for players and spectators , with adequate comfort and agreeable colour rendition . Visibility depends mainly on illuminance and contrast but can be seriously affected by disability and discomfort glare. Glare is, to a certain extent, dependent on floodlight characteristics and aiming, but mainly on their mounting height. Recommendations on glare in sports lighting are made by CIE TC-5.04. They are based on W.J.M. van Bommel et al's research which found that glare is determined by the empirical ratio :

$$Ratio = \frac{L_v}{L_(ve)^0.9} = 10 \sum(Eeye/\theta^2)/(0.035 * Eh * \rho/\pi)^{0.9}$$

TC-5 .04 further decided to convert this to a 'Glare Rating' :

$$GR = 27 + 24log(Ratio)$$

From the above two expressions we can write,

$$GR = 27 + 24log[572 \sum(Eeye/\theta^2/(Eh * \rho)^{0.9}\ )]$$

where, L_v =veiling luminance due to luminaires seen.

$L_(ve)$= equivalent veiling luminance of the environment.

$E_(eye)$= illuminance at the eye, on plane normal to line of sight.

$theta$= angle between glare incidence and LoS.

So, the basis of glare assessment is as proposed 0, by TC-5.04, the Van Bommel relation Lv /Lve or, derived from it, L_v/L_0, where L is the luminance of the task to be seen, which in the case of a large sports f ield is also a measure of the adaptation level. Van Bommel's research was based on a blend of disability glare and discomfort glare assessment. It is the most extensive investigation of glare on sports fields done and justifies its use as a basis of specifications for sports lighting, where both discomfort and disability glare play a role.

In another paper Alexis Polycarpou et. al showed that MH Lighting system luminosity is less than LED. Furthermore, the MH lighting system illuminates many parts of the playing area insufficiently. Whereas the LED system illuminates the field uniformly.

MH lamp has many qualities such as good color rendering, high lighting efficiency, stable luminance as well as long lifetime. Because the increment impendence of MH lamp is negative, the current through the lamp will tend to run away unless ballast is connected in series with the lamp. Conventionally, an inductor, called as electromagnetic fype ballast, is employed to nm the lamps. The electromagnetic type ballast has a few drawbacks, such as low efficiency, heavy weight, large size and low power factor. Dongyan Zhang et. al extensively explored the High power-High frequency resonant mode electronic ballast for metal balide lamp. In this paper, .a novel type of ballast has been developed for high power. The new ballast operates at high frequency-resonant mode. The operating frequency is about 100 kHz-500 ldIz in which range the acoustic resonance of the lamps can be avoided. The LCC resonant inverter has been employed to match the characteristic of the lamps. ZVS soil switching technique is utilized in this design to reduce the switching loss of power devices and to improve the efficiency of the ballast as well as to reduce EMI. Moreover, by using resonant mode, the output power can be easily adjusted by varying operating frequency. In additions, the over-voltage and over-current protections are provided to make sure that the ballast is always work safely. Operating MH lamps at high frequency permits the use of a relatively small inductor and capacitors in the resonant tank. This makes the ballasts small size, low cost, because only two power stages are needed at this type of ballast, compared with second generation ballast, containing PFC, DCiDC converter, DCiAC inverter and high voltage igniter. One-400W-prototype ballast was built and several hundreds of lamps had been tested. The experimental results showed that not all manufacturer's 400W MH lamps are stable in the range of 80 kHz- 250 Hz, however, the MH lamps from the manufactures, GE, Osram and k are stable in this operating frequency range.

Wei Han et. al proposed a high-order compensated wireless power transfer (WPT) system for dimmable metal halide (MH) lamps without using any ignitor or ballast. This is LCC-LC compensated WPT system for the dimmable MH lamp. The LCC-LC compensation network is identified to be more suitable than other compensation networks for the wireless MH lamp because of its higher ignition voltage and more constant current output. Meanwhile, the continuous dimming control can be achieved by adopting the phase-shift modulation. This proposed system can be extended to other types of HID lamps such as low-pressure and high-pressure sodium lamps.

Jane Preema Salis et. al did a case study on Lighting Design Of An Indoor Sports Facility. Their work aims at the quality analysis and energy effective design of a table tennis court. The design and analysis of the lighting system is done in accordance to Philips lighting standards. The newly designed system is able to give required lux levels without compromising the quality. By the reduction in number of luminaries the cost is also reduced. It was shown that the newly designed system has uniform illumination contours with lesser lux levels compared with the existing lighting system.

X-H Lee et. al designed a luminaire for tennis court illumination.In this paper, a user-friendly design of an LEDbased diffusive luminaire for illumination of a tennis court is presented. The proposed LED luminaire is composed of high-performance LED lighting modules, volume-scattering diffusers with higher than 70 percent one-shot transmittance and a reflecting cavity wih higher than 85 percent reflectivity.

This is composed of two high-performance lighting modules, volume scattering diffusers and a reflecting cavity with high reflectivity. The design concept, an LED cavity with three projecting exit surfaces, is aimed to obtain enough illuminance across the playing field with reduced glare. The luminous flux emitted from the lighting modules is directed to the three volume scattering diffusers, which serve as the effective light sources of the luminaire. The function of the volume scattering diffuser is to produce a comfortable and soft lighting effect and to restrain the amount of glare by reducing the luminance of the LED luminaire. The reflecting cavity with high reflectivity plays a key role in enhancing the optical efficiency. Partially reflected light from the volume-scattering diffusers can be reused by a photon-recycling mechanism. This reflected luminous flux has an opportunity to exit out the luminaire again and that increases the optical efficiency of the whole luminaire system. Also, the luminous flux emitted at large angles and which is not directed to the diffusers could hit the high-reflectivity wall in the lighting cavity, and so have more chances to reach the three exit surfaces. Therefore, light from lighting modules can be all radiated and controlled by the three output surfaces of the proposed luminaire system to avoid the appearance of arbitrary lighting of the tennis court. To distribute the light to the whole field above each tennis court, we must adjust the tilt angle of the volume-scattering diffusers. Therefore, each large slanted surface of the luminaire faces a different part of the court. Compared with original traditional lighting in the tennis centre, the average illuminance on the floor was enhanced by about 300 percent and the uniformity was obviously improved. The LED luminaire, which uses the three-large-surfaces radiation method to reduce luminance, results in a comfortable and soft lighting effect and restrains the influence of direct glare. Besides, the switch-on speed of luminaire is greatly reduced from 5 to 10 minutes to 1 second.

M. Di Pede et. al has described the development of an innovative procedure, for the in situ measurements of vertical illuminance in fencing halls. Despite the technical standards provide qualitative and quantitative indications on the main lighting parameters, they do not provide sufficient information on the measurement procedures necessary for the in situ verification of the vertical illuminance and its uniformity. These evaluations are very important to ensure similar visual conditions for competitors, especially in the case of sports like fencing for which the recognition of the opponent's silhouette or part of it (the target) becomes fundamental. From the analysis conducted in this work it has been possible to highlight the need to have measurement procedures customized for each sport.

Safaa Alaa Eldeen Hamza et. al has discussed the use of Pulse Width Modulation "PWM" Technique in LED Lighting Systems.

LEDs require a device that can convert incoming AC power to the proper DC voltage, and regulate the current flowing through the LED during operation. The driver converts 120V (or other voltage) 60Hz AC power to low-voltage DC power required by the LEDs, and protects the LEDs from line-voltage fluctuations. PWM driving methods is used in LEDs driving circuits, as shown in Figure, the ideal LED current waveform based on this driving method, where the current is periodically switched between a constant level IOH and zero level at a period of Td. The duty cycle of the period output current, controlling the dimming level ,rang from zero to one. Since the output current changes with time, the current time function can be represented by equation :

D. Nath et. al proposed a rough set-based method for aiming angle tuning of luminaires for outdoor sports lighting. All the optical parameters are enhanced simultaneously by considering overall horizontal uniformity as the decisive optical parameter for design optimisation. The validation is done using a real-time dataset of the Yuvabharati football stadium.

Shady S. Refaat et.al proposed a novel embedded real-time, smart, and active energy management system to monitor and efficiently manage such huge and typically uncontrolled energy for minimizing energy consumption and cost per day while considering spectators preferences, comfort level in behavioural modification program, and health aspects. In addition, the proposed energy management system is equipped with embedded tools to collect and monitor energy information for each stadium's area. The data are processed and fed to the artificial neural network algorithm that is used for managing and controlling stadium loads. This strategy does not require any change in the conventional stadium electrical panel. The proposed online algorithm yields to improve the overall grid efficiency, reliability, and increase awareness of the importance of energy conservation. During the game days, the energy consumption in a typical stadium may reach 10 MW that us used to for lighting fixtures, water pumps, fans, air-conditioning, etc . Electrical energy management is one of the most important and effective way toward improving energy efficiency in different grid sectors. Active energy efficient system basically depends on two different categories; technological modification program and behavioral modification program . Both programs are required for energy efficient stadiums. Technological modification program includes a use of high efficiency appliances, eg. light emitting diode (LED), different smart sensors, control lighting, variable speed drives, temperature control, etc. In this paper they proposed active energy management system.

1.2 Problem Identification

• Design of illumination system for a typical outdoor tennis court for both televised and non-televised events following standards given in National Lighting Code (NLC) (SP 72: 2010) published by Bureau of Indian Standards (BIS).

1.3 Objectives

To illuminate a typical outdoor tennis court using 440W Energy efficient LED luminaire. To achieve different photometric parameters according to the standard values for both televised case and non-televised case separately as given in NLC 2010 (SP 72: 2010) published by BIS.

1.4 Steps of Execution

• Doing necessary theoretical and background study to get idea about the DIALux 4.13 software, different photometric parameters and their values standardized in Indian National Lighting Code 2010.
• Studying previous literatures to get an idea about the process of executing the design.
• Executing the design in DIALux 4.13 software for both televised and non-televised tennis game-play.
• Comparing the obtained photometric parameters with that of NLC 2010.

1.5 Thesis Organization

The thesis is divided into five chapters.
• In chapter1, an introduction to the thesis work has been given. It includes Literature Review, Problem Identification,Objective,Steps of Execution of thesis and the Organisation of the thesis.
• Chapter 2 includes the theoretical background 0f sports lighting, lighting design parameters,design aspect of tennis court.
• Chapter3 deals with tennis sports arena such as size of tennis court , types of tennis court.
• Chapter4 deals with lighting design performed in DIAlux 4.13 software by LED floodlight.
• At last, conclusion, bibliography and annexure.

2 Chapter2:Theoretical Background

2.1 Fundamental of Sports and Sports Lighting Design Parameters

In recent years, considering the modern lifestyle of the developed countries, sports is attaining a vital social role among grown ups and children.In the design of sports environment both indoor and outdoor, the lighting represents a very interesting topic.Good quality sports lighting is required to satisfy the need of Professional users i.e the players and umpires/officials,so that they can perform their best skills and abilities.The lighting ambiance should also ensure the spectators (recreational users) participation and satisfaction.
Apart from the spectators present at the stadium,there are millions of peoples who are watching the games live on their television sets sitting in the comfort of their drawing room or club, miles away from the actual playing arena.Therefore,it is essential to transmit good quality picture on the Television network so that the watchers sitting at home or club, should feel that they are actually part of real action happening in the playing arena.It is worthwhile to mention here that the games like soccer,cricket,hockey,tennis and badminton have become more popular due live television coverage.
In short we can say that Sports lighting should satisfy mainly the requirement of-
• Players and Officials/Umpires
• Spectators present in the gallery and
• TV and Media Crew.
Before discussing the lighting design parameters it is important to know about different types of sports-

1. TYPES OF SPORTS : The sports events can be divided into two groups depending on lighting requirement-
i. Aerial Sports and
ii. Ground level Sports.

i. Aerial Sports- In the Aerial sports the playing objects (such as a ball) may be in the ground as well as in the ground.
The major subcategories in Aerial lighting are as follows-
a. Multi-directional and

b. Uni-directional.

a. Multi-directional : Multi directional aerial sports are sports where players and spectators view the playing object from multiple position and viewing angles.
• These sports required vertical Illuminance over the height of the playing area and horizontal Illuminance on the ground level.
• Typical examples are Badminton, basketball, volleyball, tennis, soccer, and cricket.

b. Uni-directional : Uni-directional aerial sports are sports where playing object is viewed in the air from the fixed position on the ground.
• General horizontal Illuminance is required at a place from where the playing object is launched and vertical Illuminance is required where the playing object lands.
• Typical examples include trap shooting, golf and skeet shooting etc.

ii. Ground level Sports- In the Ground level sports the playing objects are in the ground or at small height from the ground.
The major subcategories are-
a. Multi-directional and
b. Uni-directional.

a. Multi-directional : Multi-directional ground level sports where the players and spectators view playing objects from multiple position normally,looking downward,horizontally, and occasionally upward.
• Here horizontal Illuminance plays an important role.
• Typical examples are Boxing, wrestling, weight lifting, Ice hockey,swimming etc.

b. Uni-directional : Uni-directional ground level sports where the playing object is aimed at a fixed target near ground level.
• Vertical Illuminance is critical at the target. Typical examples are bowling, skiing, archery etc.

2. SPORTS LIGHTING DESIGN PARAMETERS : Illuminance is not seen by the human eye, but luminance is. Ability to see is affected by the

amount of light delivered into the space and the reflection of the surfaces in the space. Illuminance measures the incident of light or the light illuminating a surface, while luminance measures what is reflected from the surface.The desired luminous environment is created by proper luminance ratio between objects and background.Luminance depends on the amount of light incident on it i.e the illuminance,surface finish and reflectance of the surface and the direction of view.In sports lighting ,the illuminated surface environment involves objects having wide variety of reflecting surfaces and it also involves an almost infinite range of viewing angles.Because of this,it is extremely difficult,if not impossible to calculate luminance values for sports lighting.Design and specifications in sports lighting,therefore,are generally based on average illuminance concept and illunance ratio rather than luminance concept.
The illuminance level is predominantly determined by the following factors-

a. The level of Sports activity taking place: Broadly,the activity in any sports arena can be classified based on the decreasing demands of lighting level.The level of competition and and lighting classifications according to the European standard for sports lighting, EN 12193:2008 are as follows-

i. Lighting Class-I - International and National level competition which generally involves large spectators capacity with long potential viewing distance comes under Lighting ClassI.This class has the requirement of high definition TV coverage.

ii. Lighting Class-II - National and Regional level competitions which involves medium size spectator capacities and medium viewing distance, with or without the requirement of TV coverage.

iii. Lighting Class-III - Recreational and practice level without the requirement of TV coverage.Lighting class-III generally do not involve spectators.
Categorizations of the Activity level by several sports regulating authorities may differ from the above.So,it is recommended to follow the guideline of respective sports regulating authorities.

b. Size of the object and camera shooting distance: The apparent size of an object dependent upon the actual size of the object and camera shooting distance.When the apparent size is small,it is difficult to see the object ,then higher lighting lighting level is required.To view the importance details of the players(e.g arm,leg etc movement) from a longer distance demands higher light level.

c. Speed of action: Sports can be classified into three groups A,B and C characterized mainly by speed of action occurring during camera shots as stated below.This is an important parameter in determining vertical illuminance.

i. Group A- In this group of sports,movement of playing object is along the the direction of view,so requires less illumination level as compared to Group B and C. Archery,athletics,billiards,bowling,darts,horse jumping,swimming etc.

ii. Group B- In this group of sports,although the players movement may not be faster ,but the direction of play changes frequently and rapidly,which calls for quick reaction on the part of the spectators and cameraman as well as the players.Badminton,baseball,basketball,hockey comes under this group.

iii. Group C- In this group of sports,the object of play is small and travels at high speed e.g Table tennis,squash or,where there is action involving split second judgement,such as slip catch or,boxing,these all involve high speed of movement and requires higher illumination level.

Table 1: Indian Standard for Lighting of Outdoor Tennis Court

class	Horizontal illuminance(lux)	U0(Min/Avg)	Ra	Glare
i)	750	.7	> 60	< 50
ii)	500	.7	> 60	< 50
iii)	300	.5	> 20	< 55

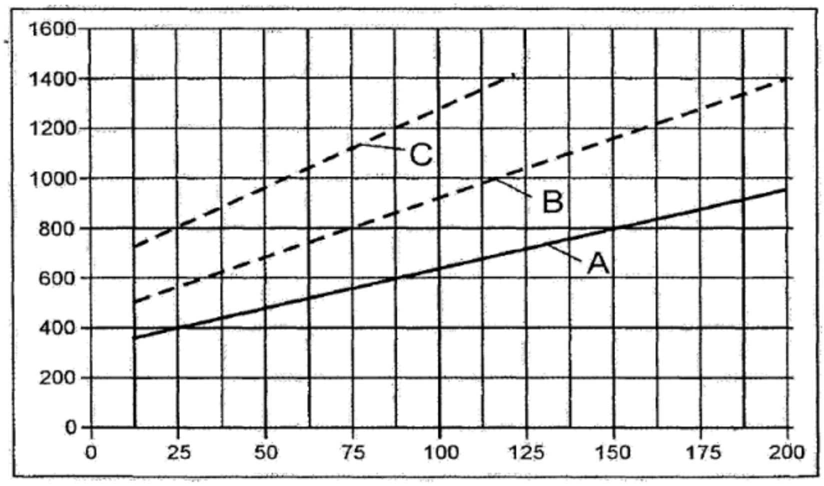


Figure 1: Recommended Vertical Illuminances Related to Camera Shooting Distance(NLC 2010)

•The lighting design parameters for stadium lighting are as follows-

a. Horizontal illuminance[Eh] : The illuminated playing surface takes up a major part of the field of view for anyone in a sporting venue, whether players, officials or spectators. Horizontal illuminance (Eh) represents the illuminance on this horizontal plane at ground level. It serves primarily to create a stable visual background against which the eye can discern players and objects.
Standard specifies the average horizontal values(Eh(avg)).

b. Vertical illuminance[Ev] : The athletes in any particular sporting event, as well as the ball they are using, can be understood as vertical surfaces. This means that we need to keep vertical illuminance (Ev) primarily in mind when we light them.
To guarantee an optimal view and make it possible for the human eye to identify players from every direction, we should generally measure Ev at a height of 1.5 meters, which corresponds approximately to the faces of the players.To ensure that the television picture has a well-balanced brightness, the ratio between the average vertical and horizontal illuminance should match as closely as possible, but shouldn't exceed a 0.5 to 2 ratio.Also for televised

sporting events, camera should be able capture close shots of players' faces, spectators, scoreboard and movement of bat, ball, shuttle etc. which will be possible iff proper vertical illuminance is achieved everywhere. The planes normal to the four principal directions of the playing field at a height are considered as shown in Figure 2 and 3.

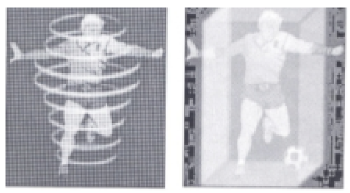


Figure 2: Vertical planes surroundings players

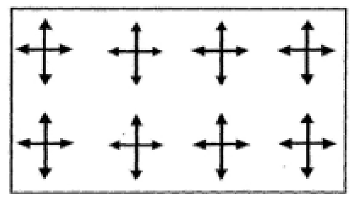


Figure 3: Vertical illuminance towards North-South-East-West

c. Vertical illuminance with respect to camera : It represents the illuminance at a point in vertical plane facing camera location,i.e.the vertical plane is normal to the line joining the point of measurement and the center of camera aperture.So in most of the cases the plane is inclined rather than perpendicular to the playing ground.

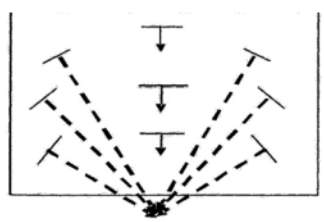


Figure 4: Vertical Illuminance with respect to Camera

The vertical illuminance required for players and spectators will usually be obtained if the requirements regarding the horizontal illuminance are fulfilled.Vertical illumnance at 1.5 mtr above ground level facing towards main/secondary camera forms the basis of the lighting requirement for CTV and Filming.Apart from recognition of players and spectators,the vertical illuminance also has be such as to ensure that ball flight above the playing field can be easily followed by the players,spectators and cameras.
Standard specifies the average vertical illuminance values with respect to camera direction(Ev_{avg}).

d. Uniformity of illuminance : Good illuminance uniformity in the horizontal and vertical planes is important in order to avoid adaptation problems for players and spectators, and adjustment problems for cameras, respectively, for different directions of view.ifthe uniformity is not good enough, there is a certain risk (especially with television cameras) that the ball or a player will not be seen clearly at certain positions on the field.
Uniformity is expressed as
- the ratio of the lowest to the highest illuminance ($U1 = E_{min}/E_{max}$).
- the ratio of the lowest to the average illuminance ($U2 = E_{min}/E_{avg}$).

e. Horizontal illuminance gradient : Illuminance gradient means change in iluminance over distance.It is important to focus that Horizontal illuminance level should not change rapidly during the lighting design process.
Too high rate of change of illuminance can cause sudden losses of picture brightness,for television and photographic system while panning the camera over the field.Not only that,if the illuminance uniformity gradient is very high,then the player may miss judge the actual speed of playing object and hence may lead to miss-fielding/miss-passing.

f. Uniformity on Vertical planes over four directions at grid a point : Vertical illuminance values in four directions (North-South-East-West) at a grid point should not differ too much from each other.
Fulfilment of this requirement will ensure,in the case of one or more main camera locations across the field,that the vertical planes facing individual camera locations will have sufficiently high illuminance.It also enables secondary cameras to make shots at arbitrary position within limited area around the field.Fulfilment of these requirement guarantees adequate modelling of the sportsman on the field.
It is recommended that the ratio between minimum values to maximum values of illuminance over four directions on a point should be better than 0.30.

g. Ratio between average horizontal and vertical Illuminance$[Eh_{avg}/Ev_{avg}]$ **:** The players and playing objects becomes comfortably visible against the background of illuminated playing ground when proper contrast is maintained between objects and their background.This contrast is depends on the ratio between average horizontal illuminanace and average vertical illuminance. To have comfortable viewing condition and good picture quality,it

is recommended that there should be a balance between horizontal illuminance to vertical illuminance.
The recommended value of the ratio is-

$$0.5 < [Eh_{avg}/Ev_{avg}] < 2.0$$

h. Glare restriction : Glare has a disturbing effect on the visual comfort of both players and spectators. Glare can be minimised by paying careful attention to the aiming of the floodlights relative to the main direction of view for the sport or sports that is considered.In sports lighting applications usually discomfort glare is evaluated by Glare rating for a number of significant observer locations looking towards each and every grid points of the field.

• The glare rating evaluation is dependent upon two lighting parameters-

i) the veiling luminance produced by the luminaires: Lvl; and
ii) the veiling luminance produced by the environment: Lve .

• The following interrelationship between these two parameters describes the degree of glare rating (GR) possessed by the installation for a certain observer position and viewing direction-

$$GR = 27 + 24log[Lvl/(Lve)^{0.9}]$$

Here GR stands for Glare Rating for Floodlighting. The lower the GR, the better the glare restriction.

• The assessment scale given below corresponds with the values of the glare rating GR,

GR	Interpretation
90	unbearable
80	
70	disturbing
60	
50	just admissible
40	
30	noticeable
20	
10	unnoticeable

• For sports lighting acceptable GR values lies within 50.

i. Modelling and shadows : Modelling refers to lighting's ability to reveal form and texture. Modelling ability is particularly important in providing a pleasant overall impression of the athletes and objects in the field of play, not to mention of the spectators in the stands.The effectiveness of modelling is dependent upon the direction from which the light comes and the number and type(Narrow beam/wide beam/indirect lighting) of light source used.Good quality television pictures demand good modelling from the lighting. An installation where light comes from only one direction will result in harsh shadows and poor modelling.

j. Colour properties : The color properties of luminaires have two important aspects-
(i)The colour appearance of the light. This is the colour impression of the total environment that the light source creates.
(ii)The colour rendering properties of the light source used, or the CIE Colour Rendering Index (CRI). This describes how faithfully a light source can reproduce a range of colours.
An indication of a lamp's color appearance can be obtained from its correlated colour temperature as measured in degrees Kelvin (K), which vary mainly between 2000 and 6500 K. The lower the color temperature, the "warmer" the color impression of the light is; the higher the color temperature, the "cooler" or more bluish the impression of the light is.
Sports lighting generally requires a color temperature of between 4000 and 6500 K.
The color rendering properties of a light source can be indicated by its Colour Rendering Index, expressed as a numerical value between 0-100. A light source with a CRI of 100 will represent scene colors faithfully, with daylight as the standard of comparison. Colour perception is highly relevant in most sports applications.While some of the color distortions that artificial lighting causes are acceptable for non-televised activities, TV broadcasting requires highly accurate color rendition.
he transition from conventional lighting to LED lighting gave rise to a discussion of whether CRI remains the correct color fidelity metric for television broadcasting. It was developed based on the human eye response curve and for a set of pastel colors, and is not necessarily appropriate for sports broadcast cameras that transmit images rich in saturated colors.
To ensure a lamp with good colour rendering index(viz. 80-90)was quite

acceptable a decade ago which were capable to reproduce the true colour of ball,dresses of the player quite well.But nowadays for colour matching(advertising hoarding)-colour rendering index of more than 90 is preferable.

k. Flicker : A particular problem for super slow-motion cameras is a 50 Hz flicker, due to the phasing of the light.Cameras perceive light level changes due to the uneven ratio between the camera scanning frequency and the alternating amplitude of artificial lights powered by mains frequency. This effect, which is visible only during slow-motion replay, is called the flicker effect.

• Sports federations have started to incorporate a so-called flicker factor into their lighting recommendations.To avoid any visible slow-motion image flicker, a flicker factor of less than 3 percent is recommended.

l. Lighting the spectator areas : Adequate horizontal illuminance is key to ensure spectators safety movement when they enter or leave the stands and other premises.

A stadium must be equipped with an emergency lighting system approved by relevant local authorities for use in the event of a general lighting failure in any part of the stadium to which the public or staff can access.

• European norm EN 12193 recommends a minimum value of 10 lux in the spectator area, to ensure spectator comfort.

m. Continuity of lighting : It is important for the sports federations or organizing committees to ensure that an event should continue even if a power failure occurs.

• Therefore,it is important for the professional competitions that a primary power supply disruption automatically trigger a secondary power supply in a way that creates no disruption to the lighting of the field of play.

The main points to consider are-

(i) The time delay involved in switching from one power source to another, taking into account luminaire's re-strike times.

(ii) The need to maintain a lighting level sufficient to maintain broadcasting continuity.

n. Controlling of spill light : Stray light from outdoor lighting installations can disturb people in the vicinity i.e. drivers on adjacent roads,inhabitants

of nearby houses etc.That is why Spill light outside the field boundary is also called light pollution.Lighting design should be such that it should fulfil the design criteria on the field and upto the spectator gallery and at the same time it should limit the spill light to a minimum.
To control the spill light,floodlight luminaires used for big stadium should have an internal mechanism to control the light spill-in the form of internal baffle.

2.2 Light source and Luminaire used in Sports Lighting

1.Light Source : Depending upon the level of competition and location of the event (i.e indoor or outdoor),following lamps are used in Sports sports lighting-
i. Tabular fluorescent lamp.
ii.High pressure Sodium Vapour Lamp(SON).
iii.Metal Halide(MH) Lamp.
iv. LED Lamp.
• The lamp selection parameter are mainly basd on Colour properties(i.e. CCT and CRI)of the lamp.For top level competition (Category-I)suitable for CTV transmission metal halide lamps should be used for indoor and outdoor events.Because of its good CCT and CRI,metal halide lamps give top quality white light, which is crucial for the illumination of both indoor and outdoor night games.
• For non televised Category-II and III,use of high pressure sodium vapour lamp offers better solution in perspective of energy and usage as luminous efficacy of SON is much higher than MH lamp.
• For Indoor venues club/recreational level lighting can be achieved by fluorescent lamps.The physical length of these lamps and its rather low luminous flux make it unsuitable for floodlighting.
• Incandescent(tungsten and tungsten halogen)lamps are used for providing emergency/anti panic lighting in stadiums because of its instantaneous start-up.
• Now a days,LED lamps are used in both indoor and outdoor sport.Both in Televised(Class-I) and Non-Televised(Class-II and Class-III) events,LED Lamps are used because of its own advantages.More energy efficiency,low maintenance costs,superior light quality,less environmental impact compared

to older lighting system such as halide or sodium-vapour lamps makes LED to use in any Sports event.

• The following table shows different lamp parameters-

Table 2: Lamp selection parameters

Lamp types	Rating(W)	Efficacy(lm/W)	CCT(K)	CRI	RUT	RST	Life(hr)
LED	300-600	120-150	5000-7000	G	Instant	Instant	50000
MH	400-2000	79-82	4000-6700	G to E	3-5 min	10 min	10000
SON	400-1000	90-100	2000	P	3-5 min	1-2 min	15000

In the above table-

• Rating is in Watt(W) and Efficacy is in lm/W.

• CCT-Co-related colour Temperature, CRI-Colour Rendering Index.

• In CRI column E,M,G and P indicates Excellent,Moderate,Good and Poor respectively.

• RUT and RST indicates Run-up time and Re-strike time respectively.

• Life(hr) means total burning hours of a lamp.

• In my thesis work,I used LED lamps for design,so the brief discussion about these lamp are only my consideration .

2.2.1 LED Lamp

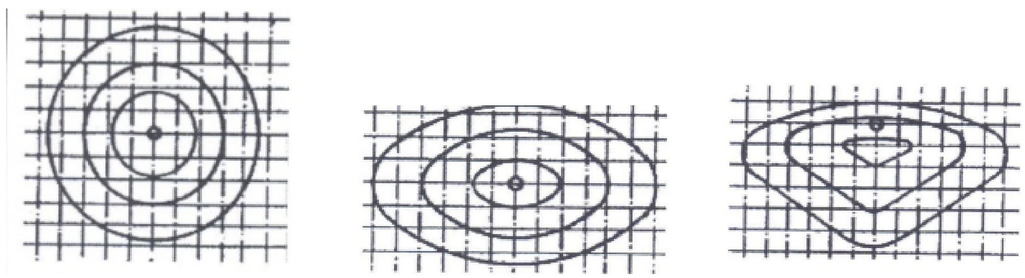
A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons (Energy packets). The color of the light (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the band gap of the semiconductor. White light is obtained by using multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device. An LED lamp or LED light bulb is an electric light that produces light using lightemitting diodes (LEDs). LED lamps are significantly more energy-efficient than equivalent incandescent lamps and can be significantly more efficient than most fluorescent lamps. The most efficient commercially available LED lamps have luminous efficacy of 200 lumen per watt (lm/W). Commercial LED lamps have a lifespan many times longer than incandescent lamps. LED lamps require an electronic LED driver circuit to operate from mains power lines, and losses from this circuit means that the efficiency of the lamp is lower than the efficiency of the LED chips it uses. The driver circuit may require special features to be compatible with lamp dimmers intended for use on incandescent lamps. Generally the current waveform contains some amount of distortion, depending on the luminaires' technology. LEDs come to full brightness immediately with no warm-up delay. Frequent switching on and off does not reduce life expectancy as with fluorescent lighting. Mixing red, green, and blue sources to produce white light needs electronic circuits to control the blending of the colors. Since LEDs have slightly different emission patterns, the color balance may change depending on the angle of view, even if the RGB sources are in a single package, so RGB diodes are seldom used to produce white lighting. Nonetheless, this method has many applications because of the flexibility of mixing different colors, and in principle, this mechanism also has higher quantum efficiency in producing white light. Electro-luminescence (The p–n junction in any direct band gap material emits light when electric current flows through it. This is electroluminescence. Electrons cross from the n-region and recombine with the holes existing in the p-region. Free electrons are in the conduction band of energy levels, while holes are in the valence energy band. Thus the energy level of the holes is lower than the energy levels of the electrons. Some portion of the energy must be dissipated to recombine the electrons and the holes. This energy is emitted in the form of heat and light. As indirect band gap materials the electrons dissipate energy in the form of heat within the crystalline silicon and germanium diodes, but in gallium arsenide phosphide (GaAsP) and gallium phosphide (GaP) semiconductors, the electrons dissipate energy by emitting photons. If the semiconductor is translucent, the junction becomes the source of light, thus becoming a light-emitting diode) as a phenomenon was discovered in 1907 by the English experimenter H. J. Round of Marconi Labs, using a crystal of silicon carbide and a cat's-whisker detector. Russian inventor Oleg Losev reported creation of the first LED in 1927. His research was distributed in Soviet, German and British scientific journals, but no practical use was made of the discovery for several decades. In September 1961, while working at Texas Instruments in Dallas, Texas, James R. Biard and Gary Pittman discovered near-infrared (900 nm) light emission from a tunnel diode they had constructed on a GaAs substrate. By October 1961, they had demonstrated efficient light emission and signal coupling between a GaAs p-n junction light emitter and an electrically isolated semiconductor photodetector. The first blue-violet LED using magnesium-doped gallium nitride was made at Stanford University in 1972 by Herb Maruska and Wally Rhines, doctoral students in materials science and engineering. Even though white light can be created using individual red, green and blue LEDs, this results in poor color rendering, since only three narrow bands of wavelengths of light are being emitted. The attainment of high efficiency blue LEDs was quickly followed by the development of the first white LED. LEDs work on the principle of Electroluminescence. On passing a current through the diode, minority charge carriers and majority charge carriers recombine at the junction. On recombination, energy is released in the form of photons. As the forward voltage increases, the intensity of the light increases and reaches a maximum. Like an ordinary diode, the LED diode works when it is forward biased. In this case, the n-type semiconductor is heavily doped than the p-type forming the p-n junction. When it is forward biased, the potential barrier gets reduced and the electrons and holes combine at the depletion layer (or active layer), light or photons are emitted or radiated in all directions. A typical figure below shows the light emission due to electron-hole pair combining on forward biasing. Mixing white LEDs with different color temperature will produce a bouquet of white light, and luminous flux of this mixed white light is the sum of white LEDs with different color temperatures. Spectral distribution curve of the mixed white light is the sum of spectral power distribution curve of different color temperature white LED, which determines the color temperature of mixed white light. By changing LED drive current, we can change their luminous, which also changes spectral power distribution curves of different LEDs. The new spectral power distribution generated by different color temperature LED results in dynamic tunable white light.

2.2.2 Luminaires

Proper luminaire selection and their mounting are the of the vital issues to achieve the desired quality lighting over the sports arena.Luminaire mounting includes both their layout on the head frame and aiming towards the playing ground.Selection of proper luminaire is based on Indoor or outdoor event.Luminaire photometry,layout of high mast with respect to playing ground,Electrical safety,cost etc.Out of these luminaire photometry is most important.

Luminaire Photometry- Mainly three types of light distribution in space,are used in indoor as well as outdoor lighting applications.
a. Symmetric-Circular shaped luminaires with discharge tube(DT)at focus

of the reflector.
b. Asymmetric-rectangular shaped with DT at central line of reflector.
c.Double asymmetric-rectangular shaped with DT at off-central line of reflector.The typical isocandela diagram for the above three luminaire are as follows-

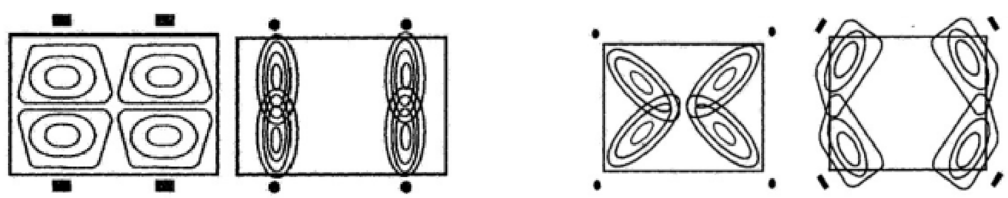


(a) Axially symmetric (b) Asymmetric (c) Double Asymmetric

Figure 5: Iso-candela diagram of luminaires used in sports lighting

- To ensure efficient floodlight,beam shape plays a important role-

a. The rectangular floodlight offers the advantages over the circular unit when mounted closely spaced along the sides of a playing field. .
b. The circular floodlight however is more efficient than the rectangular unit when used in the four corner.



(a) Side Mounted Luminaire (b) Corner Mounted Luminaire

Figure 6: Side and Corner Mounted Luminaire photometry(NLC 2010)

2.3 Dimming

Dimming means reducing the output of a lamp on lighting fixture. As a lamp or fixture is dimmed its lumen output decreases.All conventional light sources can not be dimmed but all LED can be dimmed though it is not always simple.The dimming of a LED lamp or a lighting fixture depends on the driver that is been used to control it.The main function of a driver is to run the LEDs at the correct voltage and current,converting the mains AC supply(in India 240 volt,50 Hz)to usually 12-24 volt DC.This is necessary because LEDs don't operate on mains.LEDs work at low voltages on DC.

The driver can be separated from the LED or integrated with the LEDs.

Dimming driver- It acts as a driver as well as a dimmer.As a driver it converts mains AC supply to low voltage DC and as a dimmer it raises and lowers the amount of electrical energy flowing out to the LEDs.Now a days mainly Pulse Width Modulation(PWM) or Amplitude Modulation(AM)are being used to carry out this function.

Sealed in Drivers- With most LED lamps the driver is sealed inside.So,there is no means of delivering any dimming control signal to the driver.Therefore,if dimming is required,it must be done by fitting an external dimmer.

There are several ways to control a driver or instruct it what to do.The most common methods of controlling a driver are Digital Addressable Lighting Interface(DALI),Digital Multiplex(DMX),1-10 V analog control etc.DALI is the most wide spread communications protocol for commercial lighting control.A DALI signal is delivered to the LED driver via two wires that are in addition to the wires delivering the mains supply.On the other hand 1-10 V analog control is an analog communication protocol.Like DALI,it is delivered to the driver on two wires that are in addition to the main wires.DMX512 is a standard for digital communication networks that are commonly used to control lighting and effects.It is widely used for colour changing applications such as facade lighting.In recent years there are several wireless technologies available for communicating with LED drivers including Zigbee and bluetooth.

2.3.1 Methods of Dimming Control:

Drivers may use either of two techniques to reduce the amount of energy flowing to the LEDs-

i. PWM- An LED driver that dims by using PWM is switching the power to the LED s on and off.The longer the on pulses the brighter the LEDs will appear to be and vice-versa,provided this takes place at a frequency greater than about 200 Hz any flickering will not be visible to the human eye and the brain will average the perceived level of brightness.

ii. AM- Here the driver simply increase or decreases the output currents to the LEDs.The risk of flicker is eliminated,but some LEDs change colours slightly if their current is altered,especially at low level.
Some LED driver manufacturer use a combination of PWM and AM to achieve an optimal performance.

2.3.2 Types of LED dimmer:

The most common LED dimmers are phase-cutting dimmers.The two types of this is given below-

i.Leading Edge phase cutting dimmer/Triac dimmer : These work by switching the current off at the zero crossing point and on again later in the same main cycle.The amount of energy flowing to the LEDs depends on the duration of the off period.The longer the off period the dimmer the LEDs will appear to be.

ii. Trailing Edge Phase cutting Dimmer : These work by switching the current at the zero crossing point and off later in the mains cycle.Usually this is done using Isolated Gate Bipolar Transistor(IGBT).The amount of energy flowing to the LEDs depends on the duration of the off period.The longer the off period the dimmer the LEDs will appear to be.

3 Chapter 3: Discussion about Tennis Court arena

3.1 History of Tennis Court

There are many theories as to the origins of tennis but many believe that the early form of tennis can be dated back to the 11th century when monks used to play hand ball around the cloisters of monasteries. The game gradually evolved to the game of Real Tennis, the precursor of the modern game, and became very popular with the French and British nobility. Henry VIII was a keen player and had the original Real Tennis court built at his Palace at Hampton Court (see below) but Charles II later re-modelled the court in the 17th century to the court that exists today which is the oldest in Britain.There are many theories as to the origins of tennis but many believe that the early form of tennis can be dated back to the 11th century when monks used to play hand ball around the cloisters of monasteries. The game gradually evolved to the game of Real Tennis, the precursor of the modern game, and became very popular with the French and British nobility. Henry VIII was a keen player and had the original Real Tennis court built at his Palace at Hampton Court (see below) but Charles II later re-modelled the court in the 17th century to the court that exists today which is the oldest in Britain.Tennis has been a popular sport in India since around the 1880s when the British Army and Civilian Officers brought the game to India. Soon after regular tournaments like the 'Punjab Lawn tennis Championship' at Lahore (Now in Pakistan) (1885); 'Bengal Lawn Tennis Championship' at Calcutta (now Kolkata) (1887) and the 'All India Tennis Championships' at Allahabad (1910) were organised. In the history of major tournaments, India has already beaten among others France, Romania, Holland, Belgium, Spain and Greece in Davis Cup ties (1921 to 1929)

3.2 Size of the Tennis Court

The tennis court is a rectangular field. There are two standard sizes of tennis courtsi Singles' tennis court- Its standard size is 23.77 meters in length and 8.23 meters in width . ii Doubles' tennis court- Its standard size is 23.77 meters in length and 10.97 meters in width . There is a leave room behind each end line and side line. The end line free space is not less than 6.40

meters and the side line free space is not less than 3.66 meters. The middle is separated by a ball net.

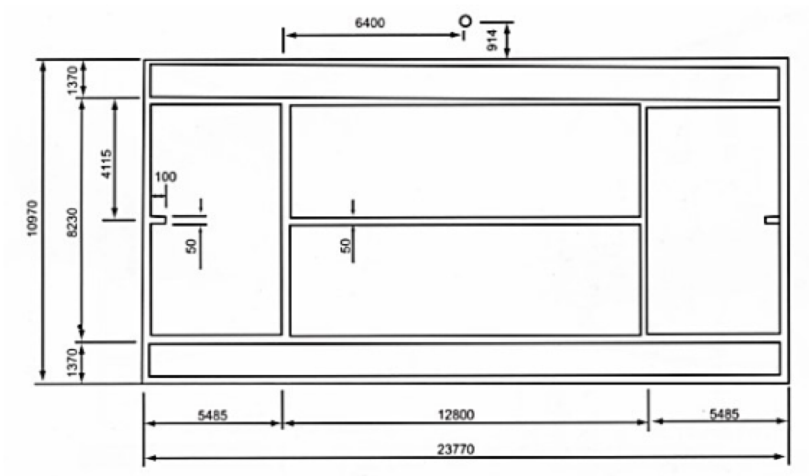


Figure 7: A standard size Tennis Court

3.3 Tennis court flooring types

The design of mainstream Tennis court ground focuses mostly on the safety and prevention of injuries of the players, regardless of the material of the floor.Tennis courts can be divided into two categories-Indoor and Outdoor.There are various types of court surfaces. Economy is the key factor which determines the selection of courts. For instance, lawn tennis is the most basic outdoor court, but it istoo expensive in terms of establishment and maintenance costs. Artificial courts have come into the picture as a replacement which are cheaper and easier to maintain.

1. Hard court : The hardcourt is made of uniformed, rigid, concrete or asphalt, and the acrylic layer surface. It is very consistent other than the outdoor hard surface, all-around playing experience. Also, it is faster than clay court but not to grass court, bounces relatively fast from grass court.

In order to the dynamic game, a player can practice applying all different kinds of spin and strokes. As a whole, the game becomes easier to control on hard courts because the bounce of the ball is predictable.

2. Clay court : The clay tennis court is most popular in Latin America than in North America, South Africa, and Europe. Clay courts are cheaper to construct than other types of tennis courts, which are made of crushed shale, stone, or brick. The red clay court is made of crushed brick and green clay which is made be metabasalt.

On this court, bounce can be slower and higher. A player gets more advantage over strong baseline players who play with a lot of topspin. Thus, This surface takes away many of the great advantages of several of tennis. In early history, Grand slam clay courts have been used at The French Open since 1891 and the US Open from 1975 to 1977.

3.Grass court- these courts are considered so elegant, they took such a decline in popularity. The answer is because grass courts require a lot of maintenance. Hard courts and clay courts require much less maintenance and, therefore, are often preferred.

They make natural grass courts by layering a thick layer that is made of a mixture of sand, silt, and clay. That layer is covered by natural grass. Some grass courts feature pipes in their foundation layers that are helpful for drainage. By adding drainage pipes, the grass court won't suffer from the accumulation of water.

Since grass courts offer a bit of slide on the ball, grass courts provide a fast court speed. Players also find that grass courts provide a low play where the balls remain closer to the ground than clay and hard courts. Therefore, players with topspin shots or flat shots love playing on grass courts. Grass courts have seen the longest tennis matches in history because the surface can make breaking your opponent's serves very tricky.

4. Carpet field - As the name suggests, this is a "portable" roll-up tennis court. Its surface is a plastic surface layer, nylon woven surface layer, etc. It is usually bonded to a certain strength and hardness of asphalt, cement, and concrete bases with special glue. On the ground. The speed of the ball is dependent on the flatness of the field surface and the roughness of the carpet surface. The maintenance of this kind of site is also very simple, as long as the ground is kept clean, free from damage and no accumulation of water.

The tennis world is vibrant and trendy, so it is no surprise that the court surfaces continue to improve and expand. As a result, players can enjoy a great variety of gameplay by trying their hands on different court surfaces, or they can stick to their favorite court surface. With so many different court surfaces available, players will never have a d ull game.

3.4 Famous International Tennis Tournaments

There are many famous Tennis tournaments happening all over the world in different countries. These Tennis tournaments attract good numbers of spectators every time. Among the many international tennis tournaments six famous grand-slams are-

1. Wimbledon : Among all the tennis tournaments, it is widely regarded as the oldest and most prestigious. It was first held in 1877 and is the only tennis event played on outdoor grass courts at the All England Club, Wimbledon, London.

Every year, it starts in late June and early July for 14 days. It consists of five main events, four junior events, and seven invitation events.

Wimbledon is quite known for its traditions. Tennis players must adhere to the all-white or nearly all-white dress code. Quite interestingly, strawberries and cream are usually eaten at the tournament.

2. US Open : The US Open is the most popular professional hardcourt US tennis tournament. It was first held in August 1881 as the US National Championship, and only men competed. Six years after, the first women's tournament was held in September 1887.

The tournament consists of five major events: men's and women's singles, men's and women's doubles, and mixed doubles. The tournament also includes events for seniors, juniors, and wheelchairs.

Each year, the US Open is played in late August and early September for over two weeks. Since 1978, all final tournaments have been hosted in Queens, New York. Check out the US Open prize money here.

3.French Open : It's the only major tennis tournament that is played on an outdoor clay court. It was formerly known as the French Championships and was first established in 1891. It is usually held in late May to early June at the State Roland Garros in Paris, France. Here's a breakdown of the French Open prize.

The most notable athlete in this event is Rafael Nadal, who has won the most in this event, with 13 titles. The tournament also features exciting elements, including the terrific view of Paris, its marvelous culture, upscale shopping centers, and superb restaurants and hotels.

4.Australian Open : This is the first Grand Slam of the year. It was first held in 1905. It has been played on a hard court surface since 1988. It is often referred to as the "Grand Slam of Asia/Pacific."

The tournament starts every fortnight of January at Melbourne Park, Melbourne. It consists of men's and women's tournaments, junior's tournaments; and wheelchair, legends, and exhibition events.

In recent years, Novak Djokovic has been dominating this tournament. In 2020, it made history by having the highest number of spectators among all the biggest tennis tournaments in the world. Here are the most popular tennis matches in history.

5.ATP Finals: The ATP Finals is popularly known as the "fifth grand slam". This was first held in 1970. It is played annually every November at O2 Stadium in London. In 2021, it will take place at the Pala Alpitour in Turin, Italy.

Like the WTA, eight single players are divided into two round-robin groups and eight doubles teams as a group-stage or round-robin format, followed by the semi-finals and finals.

ATP Finals has a different format than the major tournaments (Australian Open, French Open, Wimbledon Open, and US Open) because it uses a knock-out or bracket system. Here are the best men's tennis forums today.

6. WTA Finals : It's a tournament of the Women's Tennis Association played annually at the end of the season for the top tennis players. It consists of eight single players divided into two round-robin groups and eight doubles teams as a group-stage or round-robin format, followed by the semi-finals and finals.

The WTA Finals is scheduled to take place in Shenzhen, China, until 2028. In 2019.

3.5 Importance of sports lighting:

Sports lighting is a category of Area Floodlighting design, having both Indoor and Outdoor aspects of it. Although, in the NLC 2010 Sports lighting has been discussed as a part of Exterior Illumination, this too contains recommended values for Indoor Sports. Optimized lighting of a sports facility covers several aspects. It is beyond just placing some lights and making the venue available for a gameplay. A sports involves three types of human interaction. First and foremost are the Players, second are the referees or umpires or both depending on the game and the third are the spectators of the game. Now if the gameplay is being broadcast in television, then the people watching the game in the television are also involved with the sports lighting. The lighting designer must keep in mind the viewing perspective of all these human categories. According to the dimension of the sports area, it is divided in to parts Principal Playing Area (PPA) and Total Playing Area (TPA). PPA is the boundary area Within which the game is being played. TPA includes some extra space outside the PPA. A proper sports lighting design must enable the players to clearly see what all is going on the PPA so that they can deliver their best performance. Eventually, this will enhance the efficiency of the players and in turn quality of the game. The jurisdiction persons of the game must be able to view the game properly so that proper judgement can be done and the gameplay results to be fair one consequently. If optimum illumination is not available the referee or umpire may overlook some movements of the players, ball, shuttle or any equipment that involves scoring and that could lead an undesirable result of the game. The spectators who are present in the stadium must be able to follow the performances of the players and the continuation of the game in a enjoyable and comfortable environment. Again, if the game is being broadcast in television or streamed in the internet, proper illumination is highly required for good picture quality, accurate visibility of the game, the scores and every other part the camera captures. Also some sports involve continuous playing in the daylight as well as artificial light. For those cases, the transition between daylight and artificial light must be as smooth as possible so that the players' performance and the spectators' experiences are not disturbed.

3.6 Challenges of sports lighting:

Unlike lighting design of other areas, while design a sports facility lighting there are so many factors which stand as the odds. There are specified standard values of different photo-metric parameters for different sports. The simultaneous achievement of those values in the simulation of the design as well as in practical worksite is of utmost necessity. Along with offering proper and comfortable visual environment of the game, a sports facility must enable the spectators to see their surroundings and other nearby spectators also. Along with these, safe entry, exit and movement of the every person in the sports arena is also important. Along with these, there must be provision for safety lighting and power backup when the main illumination and supply system fails. Availability of power supply back up is a major consideration in sports lighting. There might be scenarios where part of or main power supply fails and consequently, a transient disruption in illumination level is encountered. In such cases, proper switching should be present which would isolate the failed system from the healthy system and trigger automatically the back up power supply to drive the lights considering the re-striking time of the floodlights. This scheme has to ensure that broadcasting of televised events are not hampered. Another challenging task in sports lighting design is the control of spill light and reducing light pollution as much as possible. In sports lighting design, to attend vertical illumination, there is a possibility that a huge amount of light goes above horizontal plane passing through the luminaire centre. This incident often disturbs the environment and people around the vicinity of the stadium. Also, there might be designs where the standard values of the parameters have been achieved but utilizing unnecessary amount of lights. These unoptimized designs not only consumes undesirable amount of energy but creates light pollution as well. Thus it is the duty of the designer to ensure an optimized design which will neither create spill light not cause light pollution.

3.7 Design aspect of tennis court:

Sports facilities can be divided according to the following characteristics- • Outdoor or Indoor Stadiums • Type of Sports being played • Level of Sports being played • Televised or Non-televised event The issues which are related to sports lighting design and installation aspects- • Type of Luminaire arrangement • Lighting parameter calculation • Switching Arrangements

• Aiming and Commissioning Before starting designs , it is essential to verify that whether it is feasible to do so. If such possibilities are not there then masts are needed to be installed. Lighting adds such many other elements, like switchgears, cables, catwalks, distribution boards for power supply, lifts and hoists etc. All these require additional spaces within the province of the stadium. Position of the masts are important factors in terms of installation aspect. There can be Corner Mounted or Side Mounted mast arrangements. Even sometimes mixed arrangements of masts and roof mounted luminaires are incorporated depending on the lighting needs and architectural perspectives.

4 Chapter4:Lighting design using LED flood-light

This thesis task is entirely simulation based, and hence this does not involve any physical site visit, data collection such as measurement of dimension, lux audit etc. The design has been performed in DIALux 4.13 software. DIALux 4.13 is a very popular and widely used lighting design software. Performance of both Indoor and Outdoor type of designs is very feasible in this software. In this chapter, the methodology for designing a lighting system of a Tennis court, both for non-televised and televised event using this software has been performed. In the later part, the analytical comparison of the results achieved after simulating the design with the values prescribed in NLC 2010 has been carried out.

4.1 Methodology

In this section,the lighting design for three different Non-televised class and Televised lighting has been discussed in step by step.

4.1.1 Design for Non-Televised Event

First of all,according to the required illuminance level in Class
1) To perform the design of an Tennis court, a “ New Exterior Project” has been incorporated at the very beginning and the project name has been given.
2) The luminaire Light Loss Factor which is Maintenance Factor for DIAlux has been taken as 0.7.
3) A typical model of Tennis court has been inserted into the Ground Element from the available sports sites.Any sports site is divided into two parts-Total Playing Area (TPA) and Principal Playing Area (PPA).PPA is the amount of area where the game-play happens.In most of the sports sites, this area is separately marked.TPA includes an additional safety area along with the playing area.According to NLC 2010,the required parameter has to achieve in Total Playing Area(TPA).
4) The dimension of the ”Tennis Court” is kept as the default values and dimension of the ground element is adjusted accordingly.
5) The Centre point of the ”Tennis Court” and Ground Element is placed at

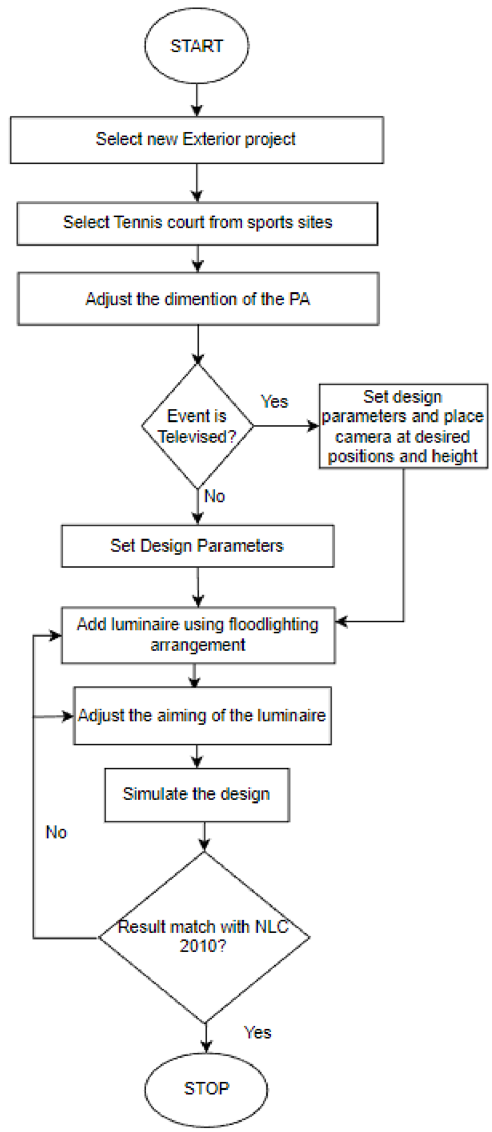


Figure 8: Flow Chart of the Design Methdology

same point.
6) According to the required illuminance for Class-I lighting,the number of luminaire is calculated from the Lumen formula.The Lumen formula for average illuminance is-

$$E_{avg} = \frac{N*\phi*COU*MF}{A}$$

Where,

N=Number of luminaires
$\phi = Lumenpackage$
COU=Coefficient of utilization
MF=Maintenance Factor
A=Playing Area

By using the the above formula,the no of luminaire required for Class-I Non-Televised Event can be calculated from the available data.Once,the luminaire required for Class-I lighting is obtained,then luminaire required for Class-II and Class-III lighting can be calculated mathematically according to their required illuminance level.
7) In the Luminaire arrangement tab,"Floodlight Arrangement" has been selected and the particular luminaire is selected.During the placement of Luminaire it is important to focus on Luminare photometry either the luminaire is suitable for Corner mounting or Side mounting which is discussed in Light and source and Luminaire used in sports lighting section of Chapter2.
8)According to the required no of luminaire,1/4 th value of the number has been given in Floodlight Arrangement and mirrored them horizontally and vertically to create a 4 pole structure having same number of luminaire in each pole.
9) Split the Floodlight Arrangement and placed each Floodlight in (C0,γ0)plane.Then add each floodlight arrangement into different Control group.In each control group,four luminaires are there with mirrored horizontal and vertical position with each other with respect to centre point of the playing Arena.Once the control group are formed,add all these control group into a Light scene to control ON/OFF or Dimming of the luminaire.
10) The aiming points or Beam Angles are adjusted for each of the luminaire for getting uniform illuminance into the playing ground.
11) Calculation Grid for the Total Playing Area (TPA) and Principle Playing Area (PPA) are already created by DIALux software automatically.The

"Display Values" option is selected,so that the illuminance at each grid point can be seen along with average illuminance and uniformity.For small playing area grid size 1 m*1 m or 2 m* 2m can be considered.
12) The aiming points are adjusted until the required illuminance level and uniformity is achieved.During Beam Angle adjustment, first adjust the Beam Angle of particular luminaires required for Class-III.This is followed by class-II and class-I.
13) To Check the Glare Rating,GR observer are placed at different different position of the playing ground.
14) After designing,simulated result is obtained which attached in Annexure I.A.
• The luminaires aiming for three different Class non-televised events are as follow-

4.1.2 Design for Televised Event :

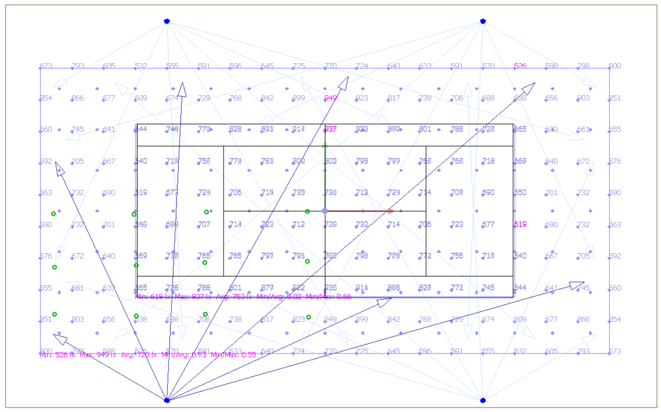
For the Televised case of design a cameras has been utilized for the simulation of camera vertical illuminance. This primary camera is placed at a height of 8.00 m.

4.1.3 Details of the Luminaire-

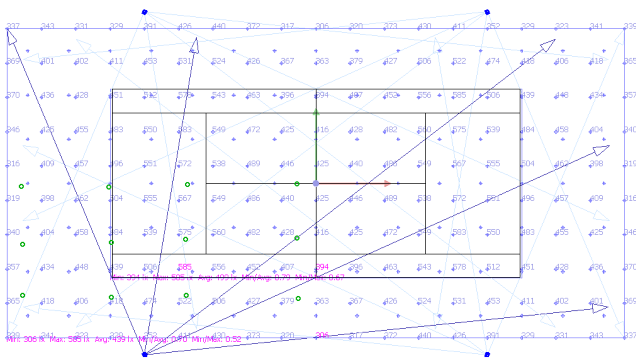
INTEGRATED POWER FL FLA400BL5KN01/ 440W,INTEGRATED POWER FL FLA400BL5KN03/440W
Luminous flux (Luminaire): 51115 lm, 53838lm
Luminaire Wattage: 440 W Luminaire classification according to CIE: 100
CIE flux code: 69 92 99 100 75
(Correction Factor 1.000).
LDC(Linear) of luminaires are given in annexure part.

4.1.4 Switching between Non-Televised and Televised Lighting Designs-

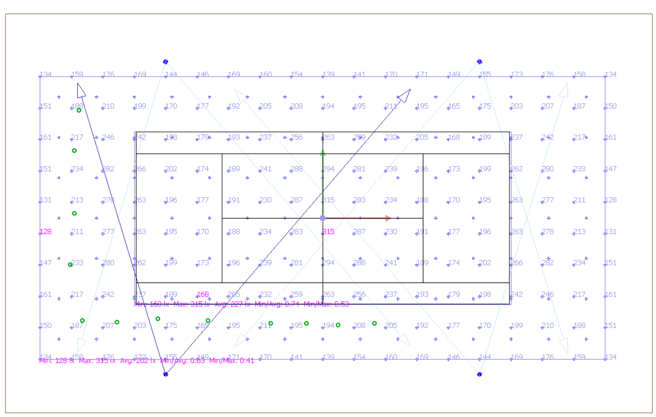
It is often hard to arrange separate sporting arenas for televised and non-televised games, due to availability if spaces, funds , manpower etc. So There might be cases where a single venue is used for both televised and non-televised events. For example,before happening of a televised game, the players play practice matches or warm up games in the same venue. Quite necessarily and obviously those sessions will not be broadcast by TV camera



(a) Luminaire Aiming of Class-I



(b) Luminaire Aiming of Class-II



(c) Luminaire Aiming of Class-III

Figure 9: Luminaire Aiming of three Non-Televised Event using LED

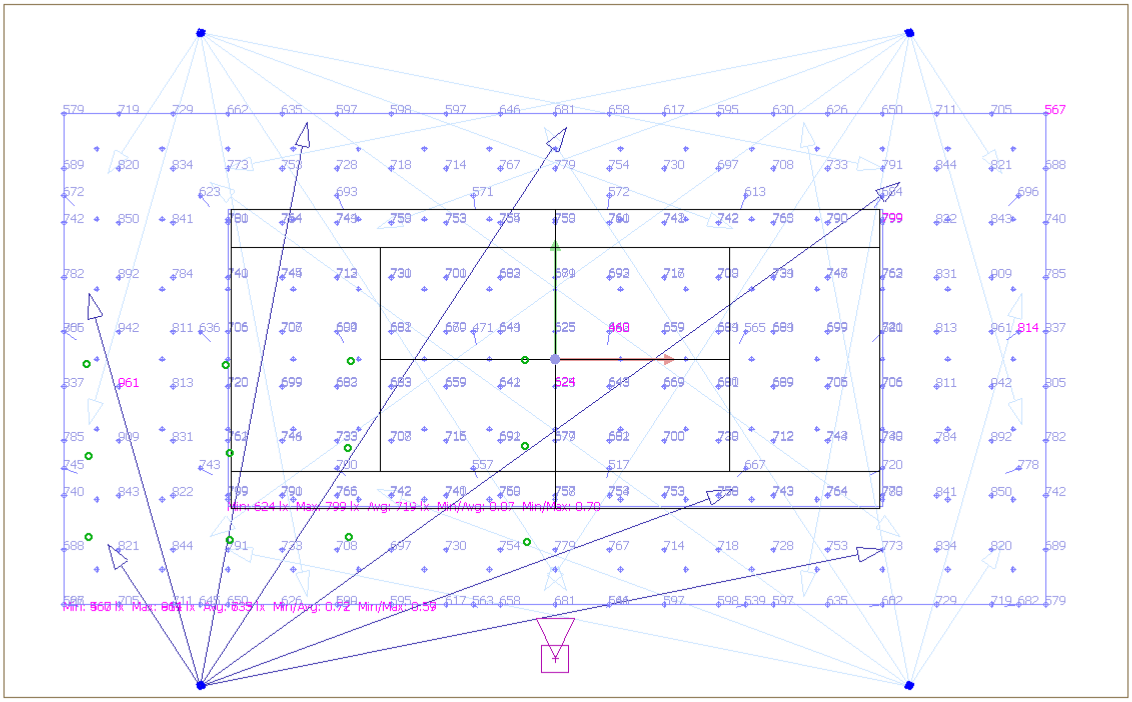


Figure 10: Luminaire Aiming of Televised Tennis Court using LED

but requirement of artificial lights may still be there.Although the amount of light required will obviously be lesser compared to that of Televised event but it must comply with the values in NLC 2010.Hence proper control scheme must be there to illuminate the field as per requirement.

Similar idea has been incorporated here in this design too. With the use of dimming method in the televised event court design, the horizontal average illuminance value has been reduced to match with the Non-televised event standard of NLC 2010. This method has been applied to achieve the Class I values of Illumination for Non-televised events from the televised one.

4.2 Technical Data for Selected Luminaires :

The lighting design has been performed here using Side Arrangement of Poles or luminaires instead of Corner Arrangement because the selected luminaire is double asymmetric which is explained properly in Chapter-2. Both the televised and non-televised designs have been performed using a LED having two beam angles.The beam angles are 20 degree and 80 degree,one in C0-C180 plane and the other one in C180- C270 plane.These beams are comes under wide beam.For Tennis Court,the playing area is no so small as compared to other playing ground,so narrow beam is used.In other sports Medium beam,Narrow beam or combination of two or three can be used. The type of game-play and corresponding luminaires used has been tabulated below

Type of game-play	No of luminaires used
Non-televised Class I	28
Non-televised Class II	20
Non-televised Class III	12
Televised Event	28

4.3 Result Analysis

Non-Televised Class-I Event- The required lighting design parameters for Class-I Non-Televised lighting design are as follows-

$$\text{Average Illuminance, } E_(avg) >= 700lx;$$
$$\text{Uniformity } (\frac{E_(min)}{E_(avg)}),\ U_0 >= 0.7;$$
$$\text{Glare Rating, } GR < 50.$$

The DIALux simulated result using LED lamp for Class-I Non-Televised Event is given below in Tabulated form.

Table 3: DIALux simulated result of Clas-I lighting

Area	E_{avg} (lx)	E_{min}(lx)	E_{max}(lx)	U2	U1	Glare (Maximum)
TPA	720	526	949	0.73	0.55	38
PPA	753	620	937	0.86	0.66	38

In the above table,Eavg,Emin and Emax are Average,Minimum and Maximum horizontal illuminance. All These parameters are in Lux(lx) here.
$U1 = E_{min}/E_{max}$,is also called transverse uniformity.

According to NLC 2010 guideline,the required parameter has to achieve in Total Playing Area(TPA).Once the parameter are obae obtained in TPA region,the the parameters are automatically obtained in PPA region.
The isoline line diagram for TPA(TA in DIALux) after DIALux simulation is-

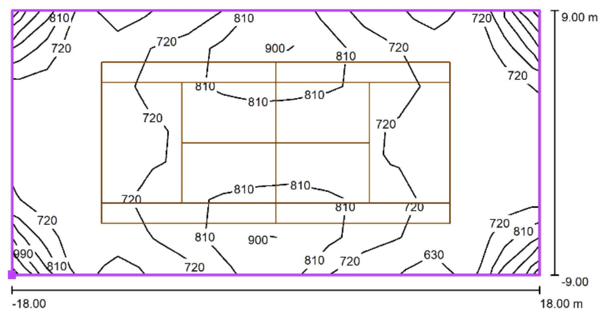


Figure 11: Isoline Diagram for Class I

Non-Televised Class-II Event- The required lighting design parameters for Class-II Non-Televised lighting are as follows-

$$\text{Average Illuminance, } E_(avg) >= 500lx;$$
$$\text{Uniformity } (\frac{E_(min)}{E_(avg)}),\ U_0 >= 0.7;$$
$$\text{Glare Rating, } GR < 50.$$

The DIALux simulated result result for Class-II Non-televised lighting is given in Table 6.

Table 4: DIALux simulated result of Class-II lighting

Area	E_{avg} (lx)	E_{min}(lx)	E_{max} (lx)	U2	U1	Glare (Maximum)
TPA	439	306	585	0.70	0.52	46
PPA	499	394	585	0.79	0.67	46

The Isoline diagram of TPA for Class-II lighting after DIALux simulation is as follows-

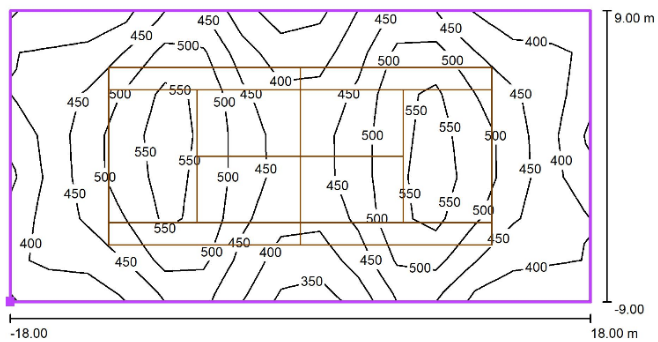


Figure 12: Isoline Diagram for Class-II

Non-Televised Class-III Event- The required lighting design parameters for Class-II Non-Televised lighting are given below

$$\text{Average Illuminance, } E_(avg) >= 300lx\text{; Uniformity } (\frac{E_(min)}{E_(avg)}),\ U_0 >= 0.5;$$
$$\text{Glare Rating, } GR < 50.$$

THe DIALux simulated result for Class-III Non-televised lighting is given in Table 8.

Table 5: DIALux simulated result of Class-III lighting

Area	E_{avg}(lx)	E_{min}(lx)	E_{max}(lx)	U2	U1	Glare (Maximum)
TPA	291	209	407	0.72	0.51	42
PPA	301	248	407	0.82	0.61	42

The Isoline diagram of TPA for Class-III lighting after DIALux simulation is as follows-

Televised Lighting Event- For Televised event,vertical illuminance level is more important than the horizontal.The estimated vertical illuminance is obtained from the graph between vertical illuminance versus Maximum camera shooting distance in Figure-1.Their required parameters for Televised lighting Event are-

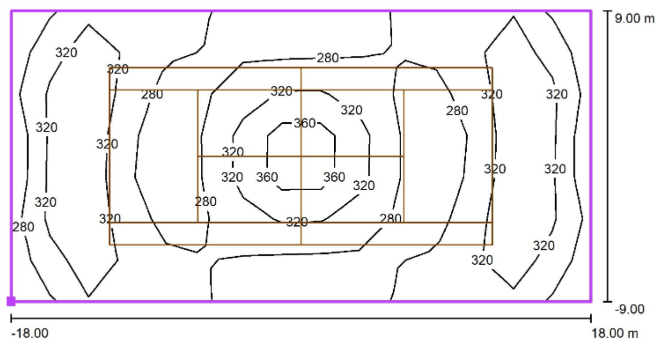


Figure 13: Isoline Diagram for Class-III

$$U1 >= 0.5$$
$$U2 >= 0.7$$

and Average Horizontal to Average Vertical illuminance ratio shold be within 0.5 to 2.

where, $U1 = E_{min}/E_{max}$ and $U2 = E_{min}/E_{avg}$.

The DIALux simulated result for Televised Tennis court is given in the below table.

Table 6: DIALux simulated result of Televised lighting

Type	E_{avg}(lx)	E_{min}(lx)	E_{max}(lx)	U2	U1	Eh_{avg}/Ev_{avg}
Horizontal	731	568	963	0.78	0.59	NA
Camera	728	579	937	0.80	0.62	1.5

Where, Eh_{avg} =Average horizontal illuminance
Ev_{avg} =Average vertical illuminance

- From the above discussion, it is clear that the values of Average Illuminance, Uniformity ratio and Glare were matched with the values given in NLC 2010 for Non-Televised Event.For Televised case, the values of Minimum Illuminance and Maximum Illuminance and their ratio,average horizontal to average vertical ratio has been looked after, since there is specific recommendation in NLC 2010 on the same if the game is shot with a camera for

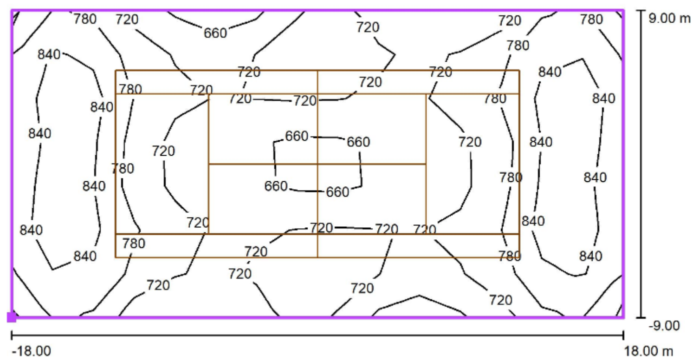


Figure 14: Isoline diagram of Televised Tennis Court

the purpose of broadcasting.Reasonable percentage of Upward Light Ratio (ULR) or Upward Light Output Ratio (ULOR) in both Non-Televised and Televised design has been observed.

5 Conclusion and Future scopes

Tennis is a sport that depends on proper lighting quite a bit. Both players and spectators need good visibility for the court, and this can make setting up illumination a major challenge. Not only does the light need to be intense and evenly spread out, but it must also cause minimal glare and eye fatigue. With this in mind, there are many approaches to choose from for modern tennis court lighting. Nowadays, LED lights are considered to be the top choice, as they cause minimal complications and use as little energy as possible—making them the best option.If the goal is to improve the lighting approach for a tennis court, the current infrastructure should be inspected and compared to the industry standards. Installing new lights is difficult without ascertaining the capacity of the court and electrical infrastructure. The weight and sail area of the lights has to be considered before they are installed in a court, as existing fixtures may not be able to support them. The lighting design performed here is for a typical outdoor tennis court without any site inspection and physical measurement, using LED sports lighting luminaire.LED lamps can reach 90-95 percent efficiency,it is convenient for flexible lighting and light distribution design to achieve energy saving;cooperate with professional high hanging long life led light sources to achieve lumen maintenance and longer life.There are lighting control system in LED lighting system that allows the requirements of manual control using control board to adjust lights during a game. Some improvements that can be made in this study as Integrating Human Centric lighting(HCL) so that the players can receive biologically effective lights and this can also neutralize the jet lag when they are travelling from one time zone to another.

6 References

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(11) Philips Lighting. Sports Lighting: Key Considerations for illuminating the field of play and the spectator zones.

7 Annexure

Here, the detailed design results from the DIALux software are given for each cases of LED floodlighting. In this part,televise and non-televised design results are given.

Tennis Court Floodlighting For Televised Event

Lighting Design parameters to be acheived according to National Lighting Code 2010:
Eavg>=700lx
U0>=0.7
GR<50.

Maintenance Factor: 0.80

Partner for Contact:
Order No.:
Company:
Customer No.:

Date: 08.11.2022
Operator: Mr.Sagar Das

Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

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Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

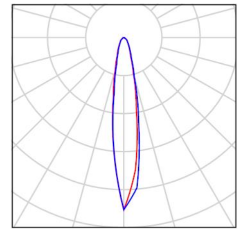
Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Tennis Court Floodlighting For Televised Event / Luminaire parts list

24 Pieces

INTEGRATED POWER FL FLA400BL5KN01
Article No.: FL
Luminous flux (Luminaire): 51486 lm
Luminous flux (Lamps): 51115 lm
Luminaire Wattage: 440.0 W
Luminaire classification according to CIE: 100
CIE flux code: 82 96 99 100 102
Fitting: 1 x User defined (Correction Factor 1.000).

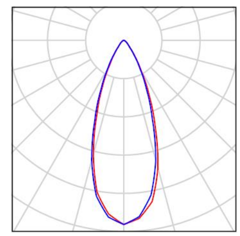
See our luminaire catalog for an image of the luminaire.



4 Pieces

INTEGRATED POWER FL FLA400BL5KN03
Article No.: FL
Luminous flux (Luminaire): 53838 lm
Luminous flux (Lamps): 53655 lm
Luminaire Wattage: 440.0 W
Luminaire classification according to CIE: 100
CIE flux code: 91 98 100 100 101
Fitting: 1 x User defined (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.

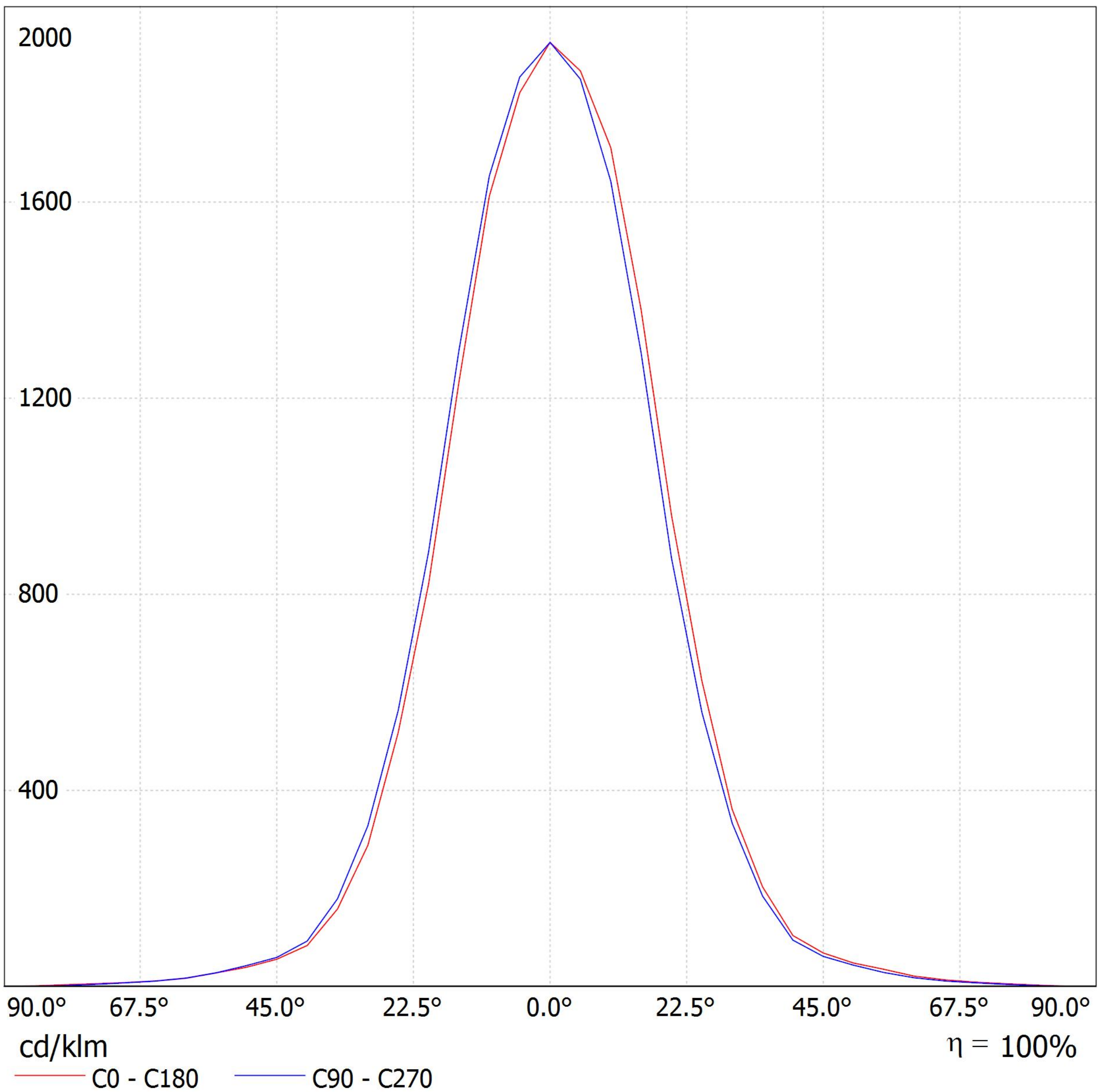


Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

INTEGRATED POWER FL FLA400BL5KN03 / LDC (Linear)

Luminaire: INTEGRATED POWER FL FLA400BL5KN03
Lamps: 1 x

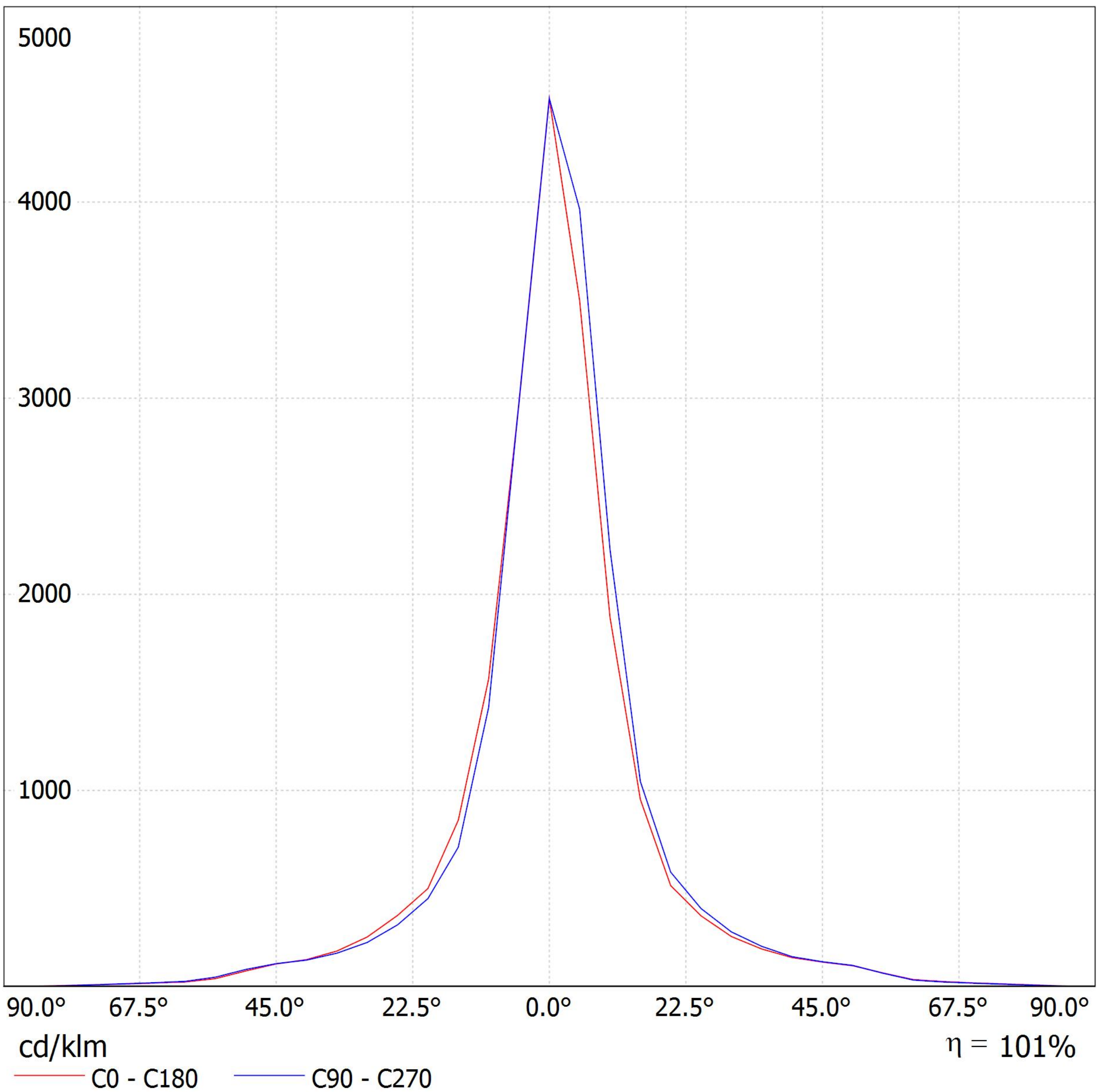


Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

INTEGRATED POWER FL FLA400BL5KN01 / LDC (Linear)

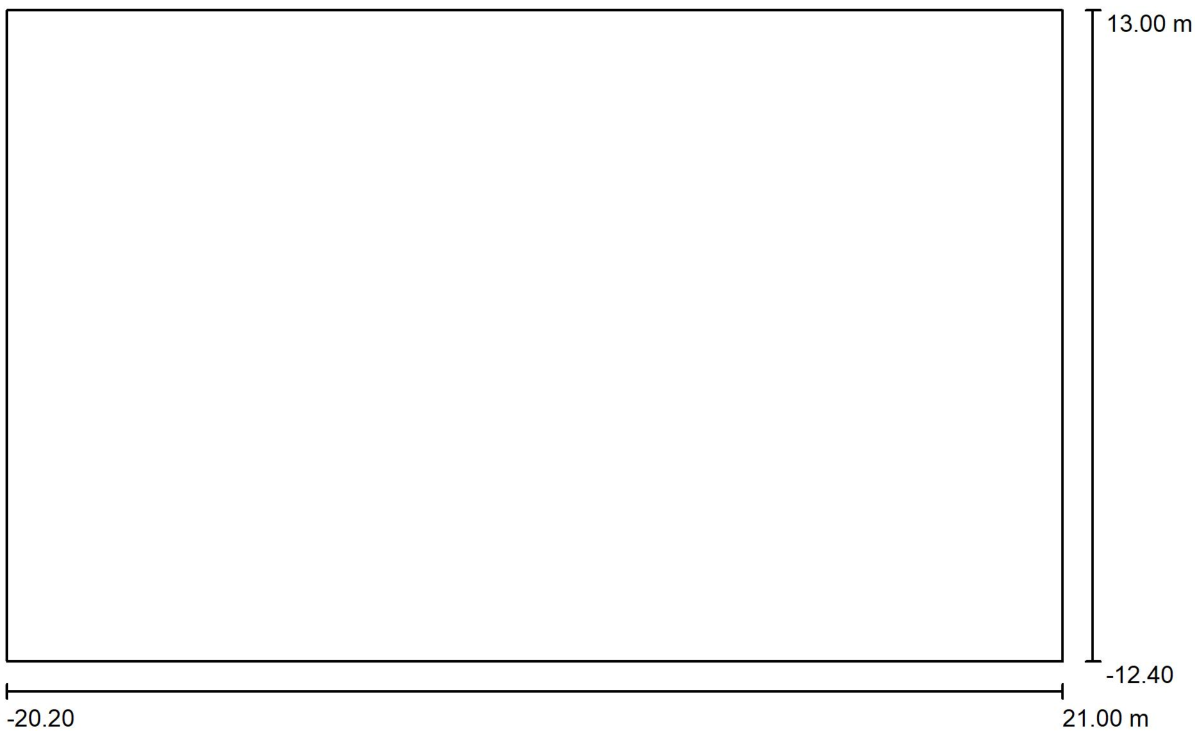
Luminaire: INTEGRATED POWER FL FLA400BL5KN01
Lamps: 1 x



Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Planning data



Light loss factor: 0.80, ULR (Upward Light Ratio): 9.5%

Scale 1:295

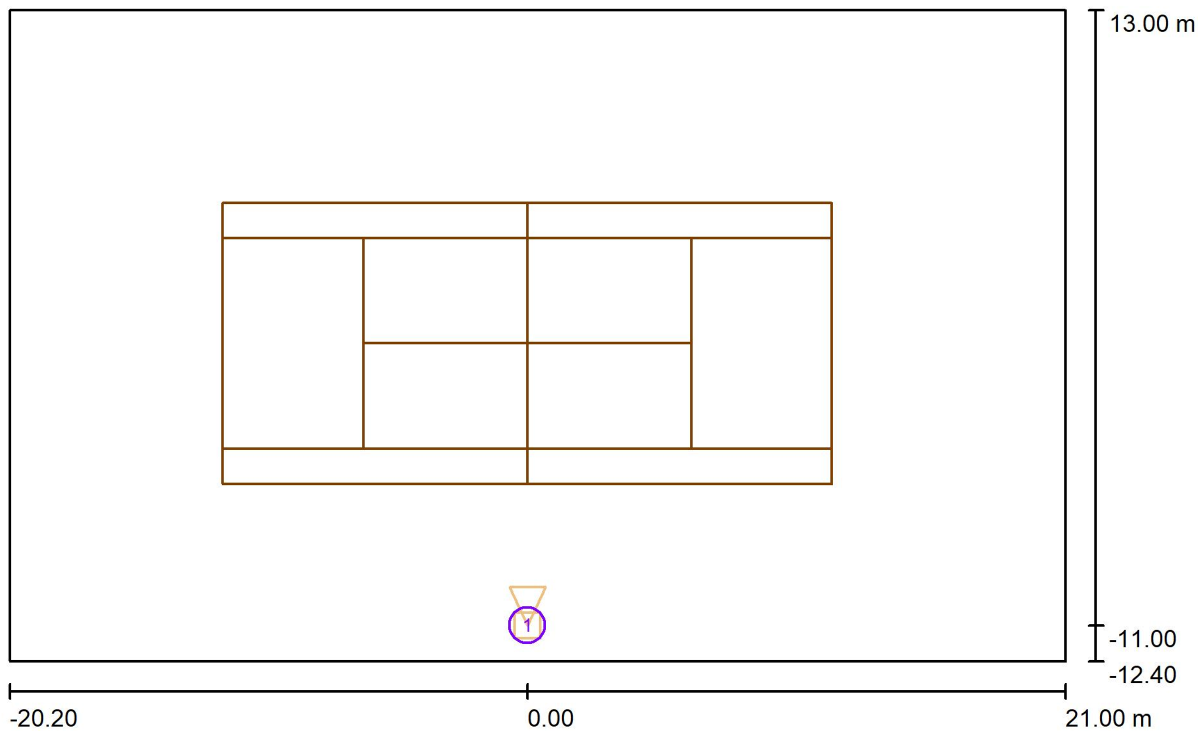
Luminaire Parts List

No.	Pieces	Designation (Correction Factor)		Φ (Luminaire) [lm]		Φ (Lamps) [lm]	P [W]
1	24	INTEGRATED POWER FL FLA400BL5KN01 (1.000)		51486		51115	440.0
2	4	INTEGRATED POWER FL FLA400BL5KN03 (1.000)		53838		53655	440.0
			Total:	1451019	Total:	1441382	12320.0

Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / TV Cameras (Coordinates List)



Scale 1 : 295

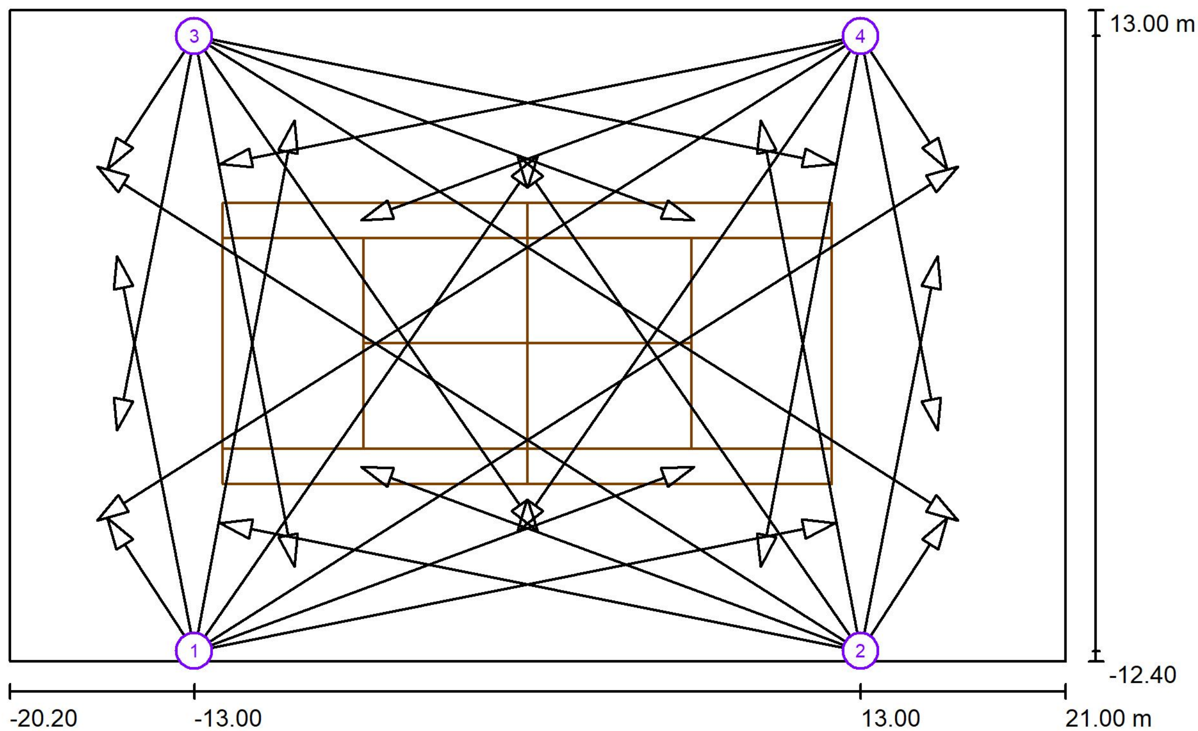
List of the TV Cameras

No.	Designation	Position [m] X	Y	Z
1	TV Camera 1	0.000	-11.000	8.000

Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Sport Luminaires (Coordinates List)



Scale 1 : 295

List of the Sport Luminaires

Luminaire	Index	Position [m] X	Position [m] Y	Position [m] Z	Aiming Point [m] X	Aiming Point [m] Y	Aiming Point [m] Z	Angle [°]	Alignment	Pole
INTEGRATED POWER FL FLA400BL5KN01	1	-13.000	-12.000	12.000	0.400	7.326	0.000	27.0	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	1	-13.000	-12.000	12.000	-9.100	8.700	0.000	29.7	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	13.000	-12.000	12.000	-0.400	7.326	0.000	27.0	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	13.000	-12.000	12.000	9.100	8.700	0.000	29.7	(C 0, G 0)	/

Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Sport Luminaires (Coordinates List)

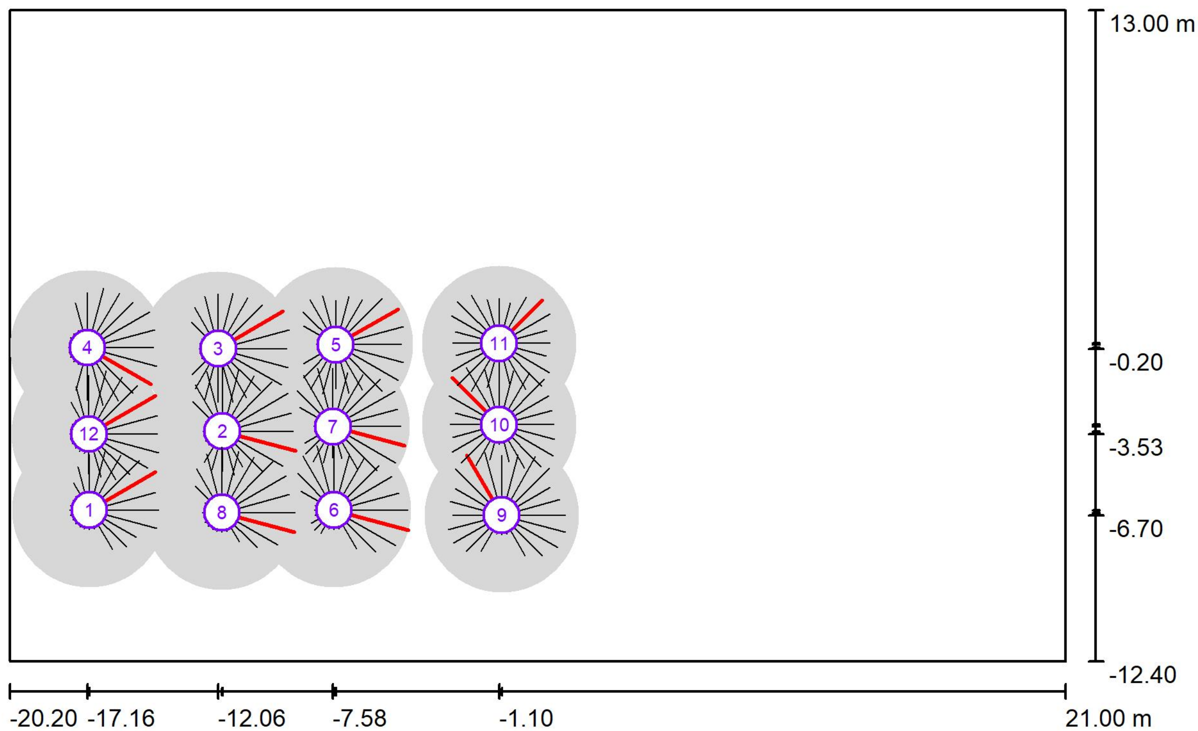
List of the Sport Luminaires

Luminaire	Index	Position [m]			Aiming Point [m]			Angle [°]	Alignment	Pole
		X	Y	Z	X	Y	Z			
INTEGRATED POWER FL FLA400BL5KN01	3	-13.000	12.000	12.000	0.400	-7.326	0.000	27.0	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-13.000	12.000	12.000	-9.100	-8.700	0.000	29.7	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	13.000	12.000	12.000	-0.400	-7.326	0.000	27.0	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	13.000	12.000	12.000	9.100	-8.700	0.000	29.7	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	1	-13.000	-12.000	12.000	6.500	-4.800	0.000	30.0	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	1	-13.000	-12.000	12.000	12.000	-7.000	0.000	25.2	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	13.000	-12.000	12.000	-6.500	-4.800	0.000	30.0	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	13.000	-12.000	12.000	-12.000	-7.000	0.000	25.2	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-13.000	12.000	12.000	6.500	4.800	0.000	30.0	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-13.000	12.000	12.000	12.000	7.000	0.000	25.2	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	13.000	12.000	12.000	-6.500	4.800	0.000	30.0	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	13.000	12.000	12.000	-12.000	7.000	0.000	25.2	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	1	-13.000	-12.000	12.000	-16.000	3.400	0.000	37.4	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	13.000	-12.000	12.000	16.000	3.400	0.000	37.4	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-13.000	12.000	12.000	-16.000	-3.400	0.000	37.4	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	13.000	12.000	12.000	16.000	-3.400	0.000	37.4	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN03	1	-13.000	-12.000	12.000	-16.386	-6.800	0.000	62.7	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN03	2	13.000	-12.000	12.000	16.386	-6.800	0.000	62.7	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN03	3	-13.000	12.000	12.000	-16.386	6.800	0.000	62.7	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN03	4	13.000	12.000	12.000	16.386	6.800	0.000	62.7	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	1	-13.000	-12.000	12.000	16.800	6.900	0.000	18.8	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	13.000	-12.000	12.000	-16.800	6.900	0.000	18.8	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-13.000	12.000	12.000	16.800	-6.900	0.000	18.8	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	13.000	12.000	12.000	-16.800	-6.900	0.000	18.8	(C 0, G 0)	/

Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / GR Observer (Results Overview)



Scale 1 : 295

GR Observerlist

No.	Designation	Position [m] X	Y	Z	Viewing sector [°] Start	End	Increment	Slope angle	Max
1	GR Observer 1	-17.083	-6.500	1.500	0.0	360.0	15.0	-2.0	39 2)
2	GR Observer 2	-11.900	-3.424	1.500	0.0	360.0	15.0	-2.0	39 2)
3	GR Observer 3	-12.056	-0.200	1.500	0.0	360.0	15.0	-2.0	38 2)
4	GR Observer 4	-17.157	-0.159	1.500	0.0	360.0	15.0	-2.0	37 2)

Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / GR Observer (Results Overview)

GR Observerlist

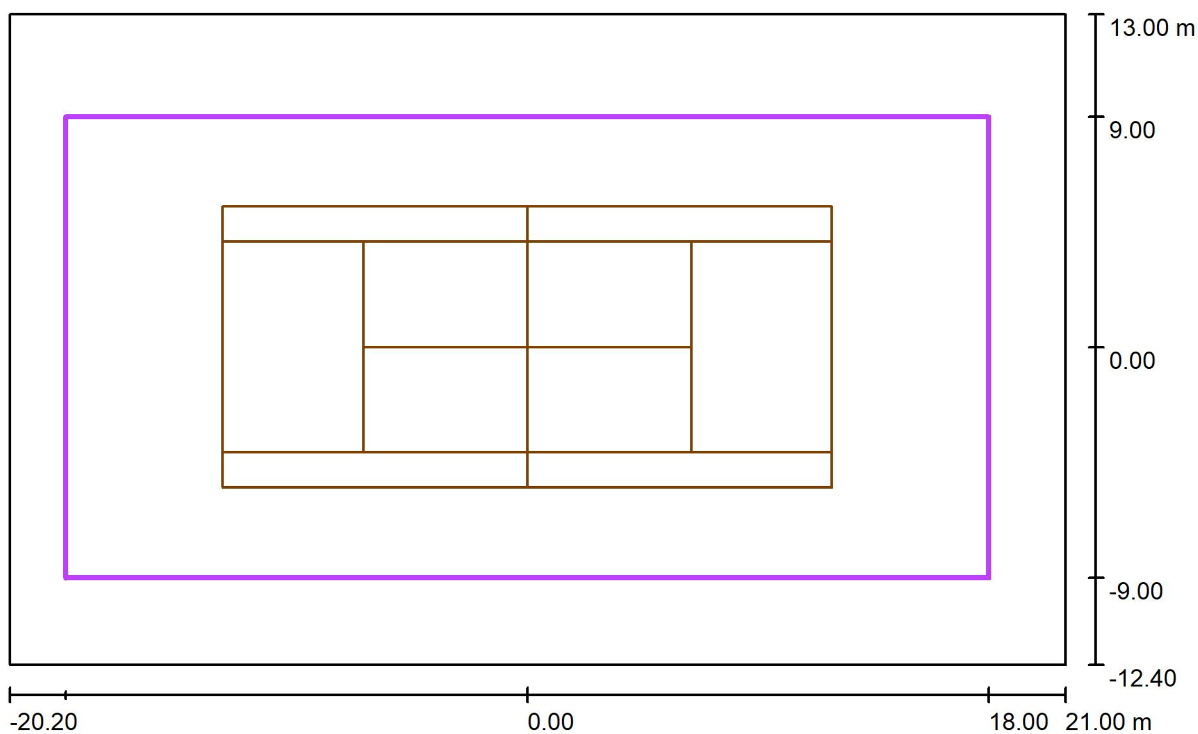
No.	Designation	Position [m]			Viewing sector [°]				Max
		X	Y	Z	Start	End	Increment	Slope angle	
5	GR Observer 5	-7.470	-0.049	1.500	0.0	360.0	15.0	-2.0	36 2)
6	GR Observer 6	-7.544	-6.500	1.500	0.0	360.0	15.0	-2.0	39 2)
7	GR Observer 7	-7.580	-3.241	1.500	0.0	360.0	15.0	-2.0	38 2)
8	GR Observer 8	-11.910	-6.600	1.500	0.0	360.0	15.0	-2.0	38 2)
9	GR Observer 9	-1.000	-6.700	1.500	0.0	360.0	15.0	-2.0	35 2)
10	GR Observer 10	-1.100	-3.167	1.500	0.0	360.0	15.0	-2.0	34 2)
11	GR Observer 11	-1.100	0.000	1.500	0.0	360.0	15.0	-2.0	31 2)
12	GR Observer 12	-17.100	-3.534	1.500	0.0	360.0	15.0	-2.0	39 2)

2) The calculated equivalent veil luminance of the environment is based on the assumption of a complete diffuse reflection behavior of the environment (acc. EN 12464-2).

Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Tennis 1 Calculation Grid (PA) / Summary



Scale 1 : 295

Position: (0.000 m, 0.000 m, 0.000 m)
Size: (36.000 m, 18.000 m)
Rotation: (0.0°, 0.0°, 0.0°)
Type: Normal, Grid: 15 x 7 Points
Belongs to the following sport arena: Tennis Court

Results overview

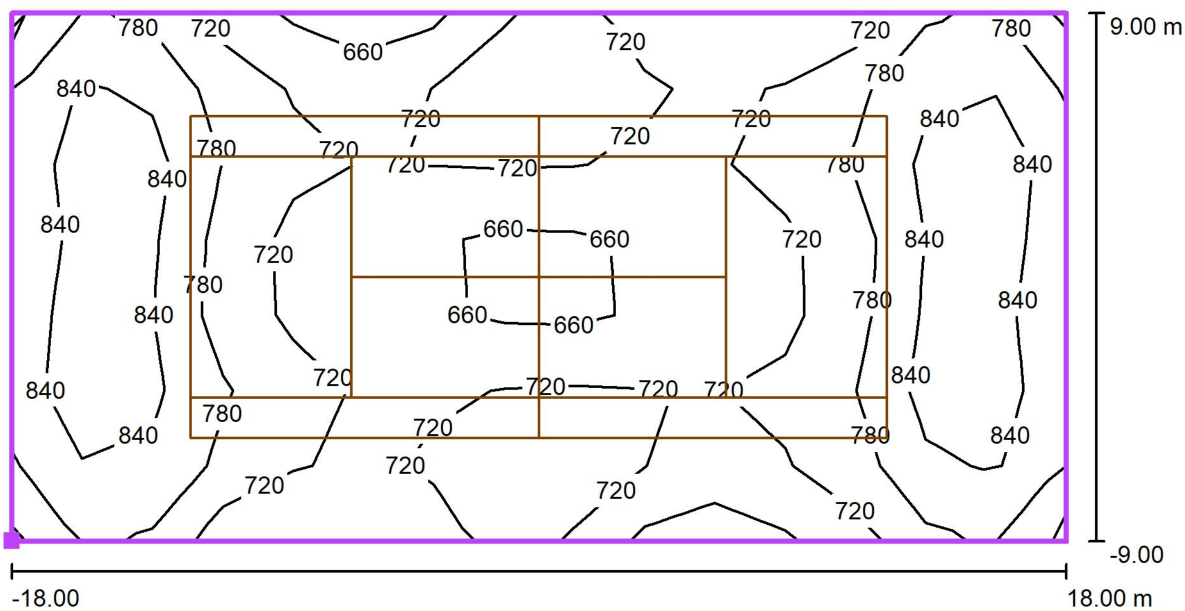
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\ m}/E_m$	H [m]	Camera
1	perpendicular	758	622	916	0.82	0.68	/	0.000	/

$E_{h\ m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

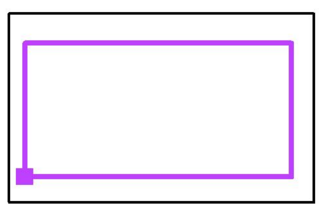
Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Tennis 1 Calculation Grid (PA) / Isolines (E, Perpendicular)



Values in Lux, Scale 1 : 258

Position of surface in external scene:
Marked point: (-18.000 m, -9.000 m, 0.000 m)



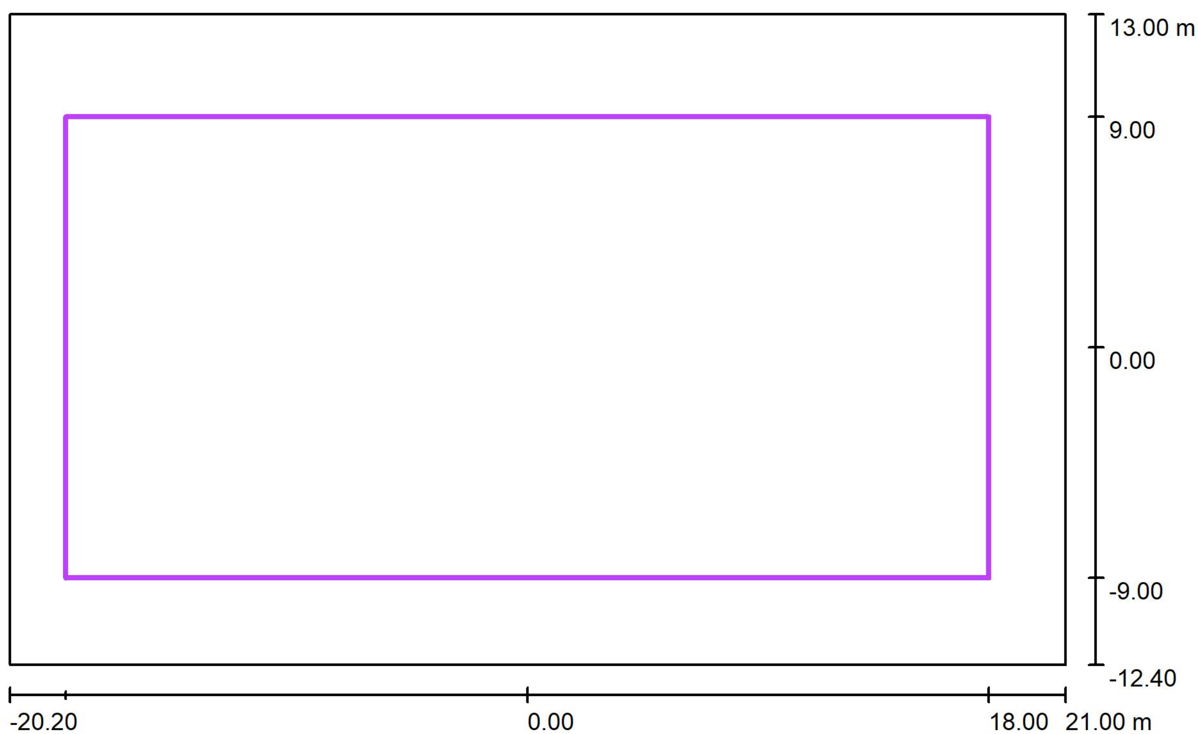
Grid: 15 x 7 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
758	622	916	0.82	0.68

Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid_Eavg_TPA / Summary



Scale 1 : 295

Position: (0.000 m, 0.000 m, 0.000 m)
Size: (36.000 m, 18.000 m)
Rotation: (0.0°, 0.0°, 0.0°)
Type: Normal, Grid: 19 x 10 Points

Results overview

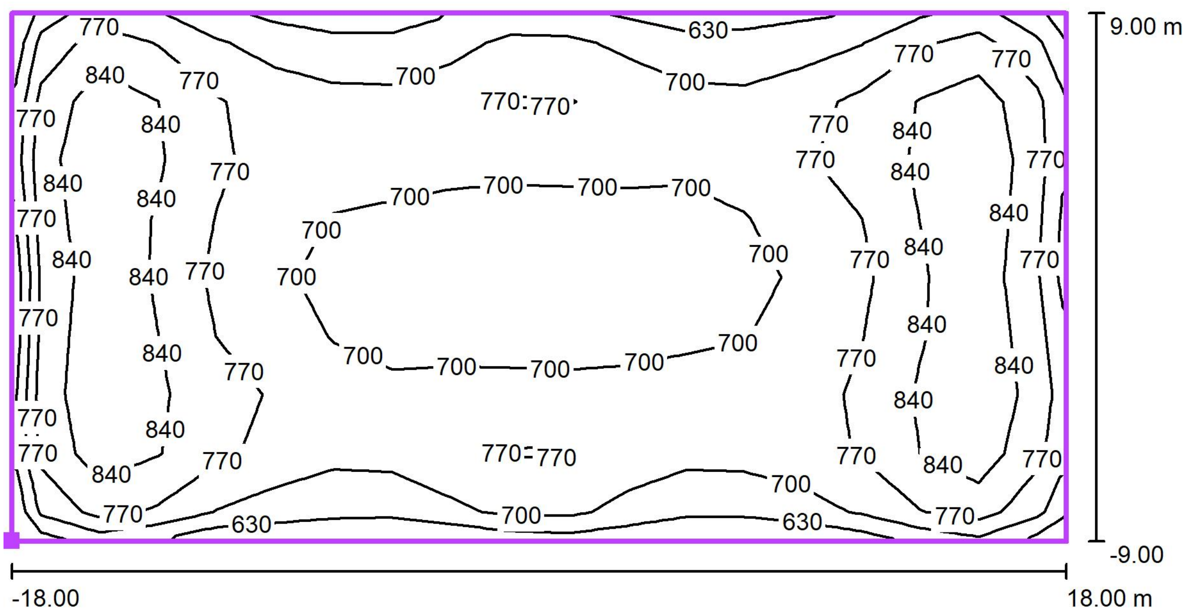
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	horizontal	736	581	917	0.79	0.63	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

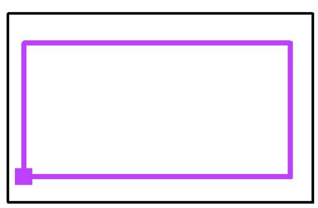
Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid_Eavg_TPA / Isolines (E, Horizontal)



Values in Lux, Scale 1 : 258

Position of surface in external scene:
Marked point: (-18.000 m, -9.000 m, 0.000 m)



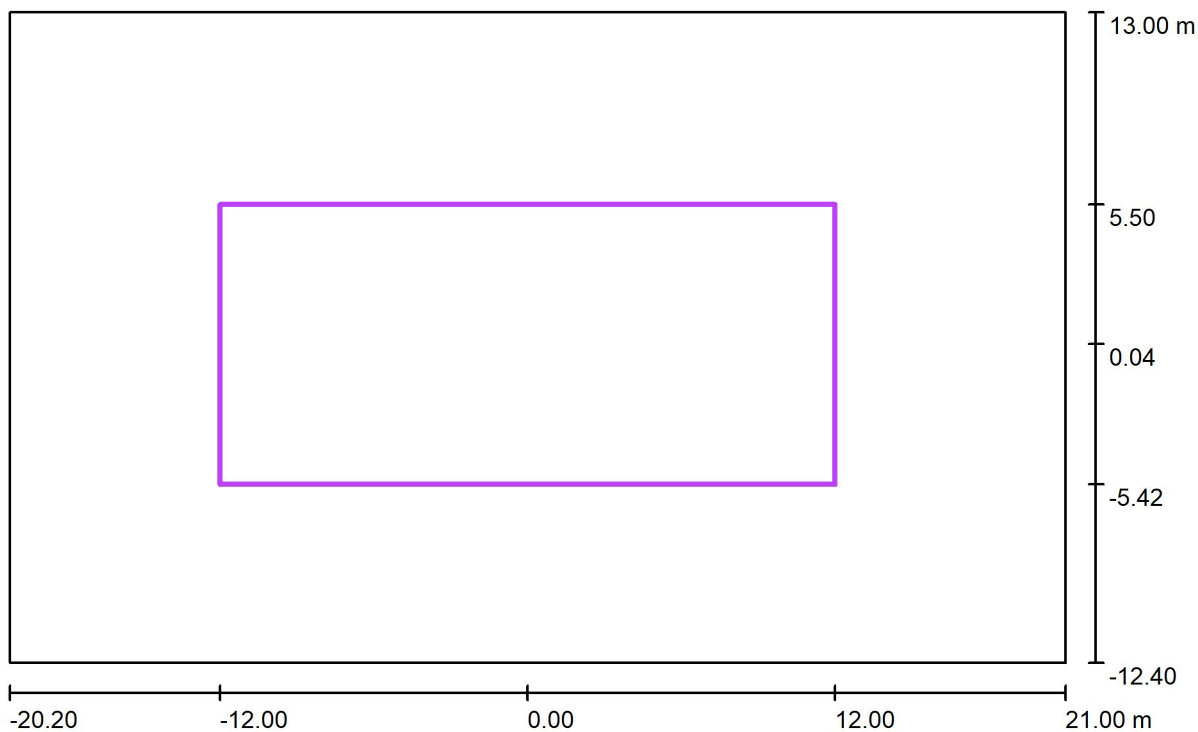
Grid: 19 x 10 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
736	581	917	0.79	0.63

Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid_Eavg_PPA / Summary



Scale 1 : 295

Position: (0.000 m, 0.039 m, 0.000 m)
Size: (24.000 m, 10.922 m)
Rotation: (0.0°, 0.0°, 0.0°)
Type: Normal, Grid: 13 x 6 Points

Results overview

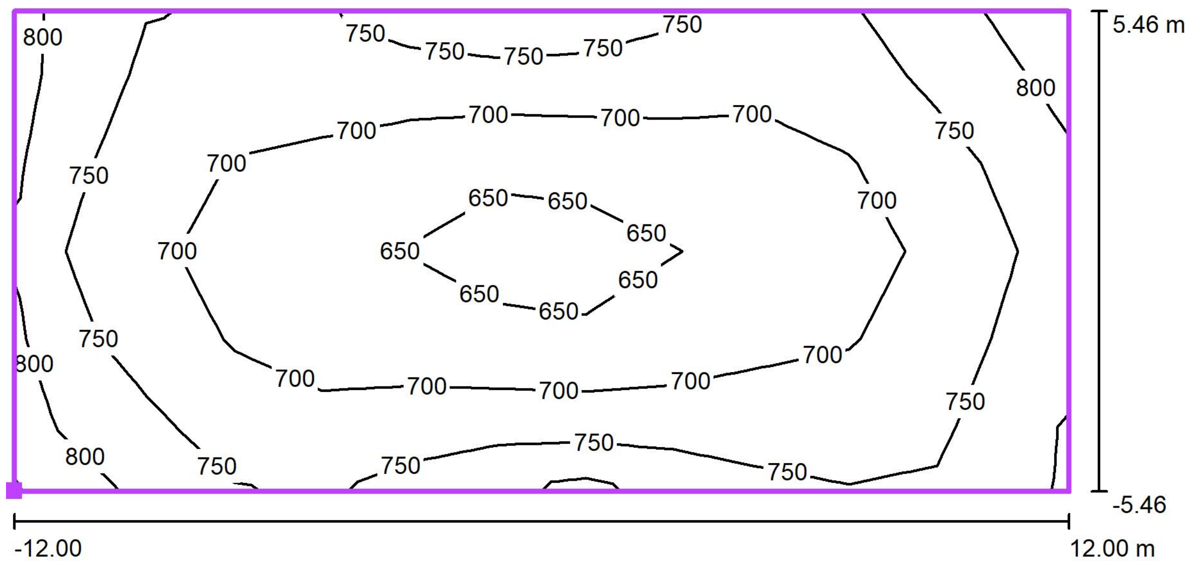
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	horizontal	727	622	828	0.86	0.75	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

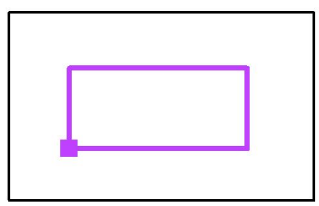
Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid_Eavg_PPA / Isolines (E, Horizontal)



Values in Lux, Scale 1 : 172

Position of surface in external scene:
Marked point: (-12.000 m, -5.422 m, 0.000 m)



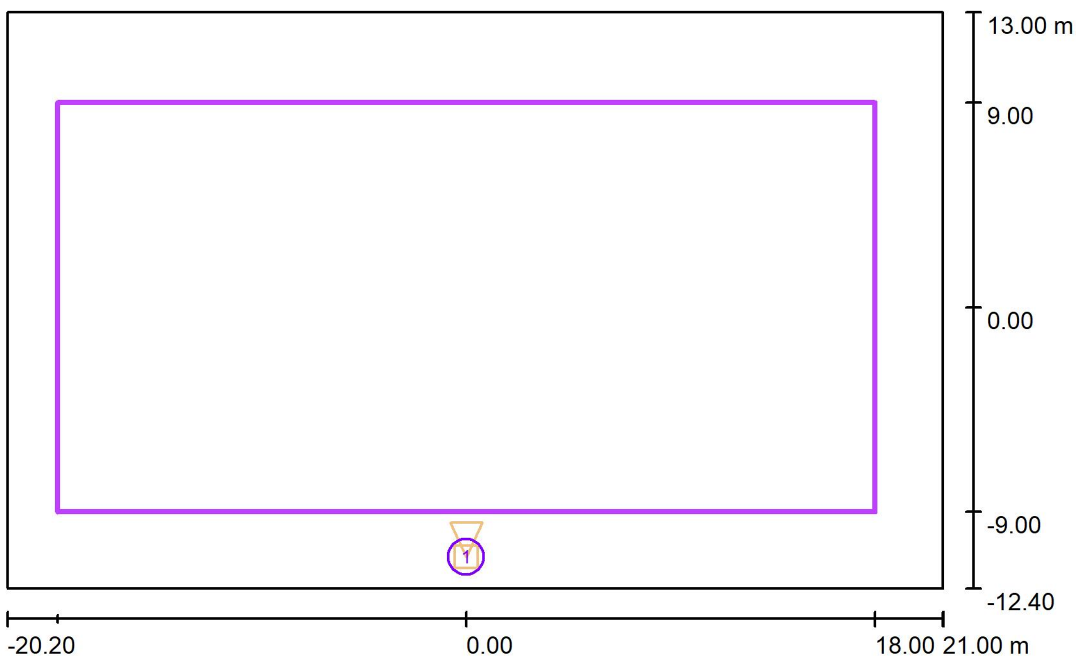
Grid: 13 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
727	622	828	0.86	0.75

Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid_Ecam_TPA / Summary



Scale 1 : 333

Position: (0.000 m, 0.000 m, 0.000 m)
Size: (36.000 m, 18.000 m)
Rotation: (0.0°, 0.0°, 0.0°)
Type: Normal, Grid: 8 x 4 Points

Results overview

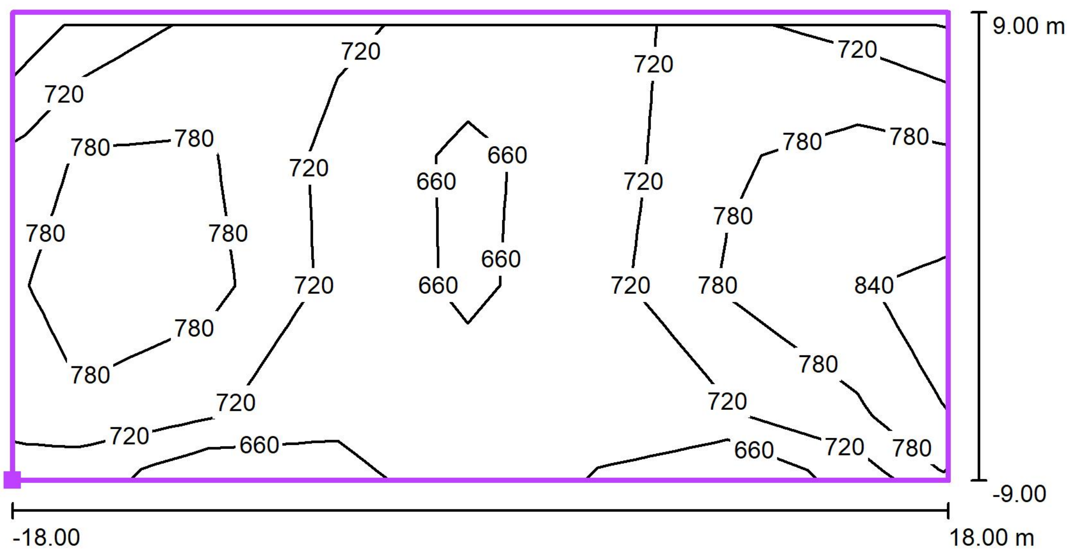
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	Camera	737	610	876	0.83	0.70	/	1.500	1

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

Jadavpur University.
Electrical Engineering Department
Jadavpur ,Kolkata-700032.

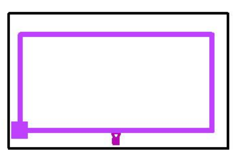
Operator Mr.Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid_Ecam_TPA / Isolines (E, Camera)



Values in Lux, Scale 1 : 291

Position of surface in external scene:
Marked point: (-18.000 m, -9.000 m, 0.000 m)
Camera Position: (0.000 m, -11.000 m, 8.000 m)



Grid: 8 x 4 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
737	610	876	0.83	0.70

Tennis Court Floodlighting For Class -I

Lighting Design Parameters to be acheived according to National Lighting Code 2010.

Eavg>=700lx
U0>=0.7
GR<50.

Maintenance Factor: 0.80

Partner for Contact:
Order No.:
Company:
Customer No.:

Date: 08.11.2022
Operator: Mr. Sagar Das

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

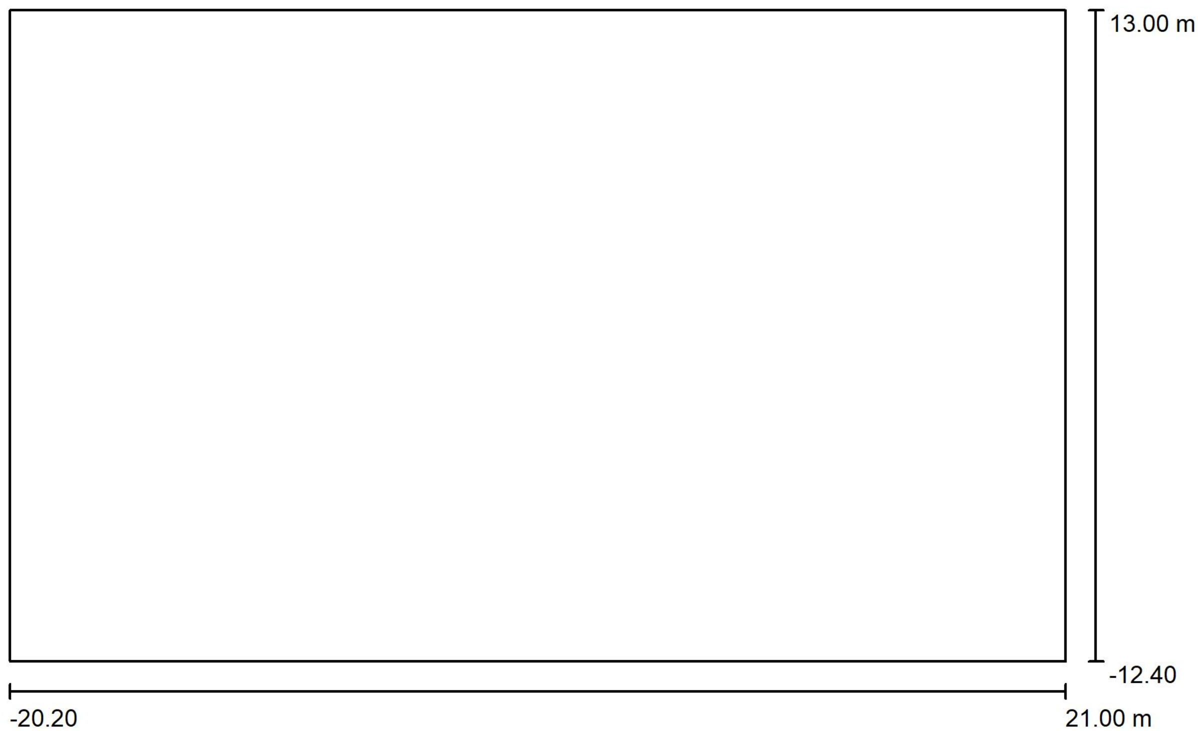
Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Table of contents

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Planning data



Light loss factor: 0.80, ULR (Upward Light Ratio): 9.0%

Scale 1:295

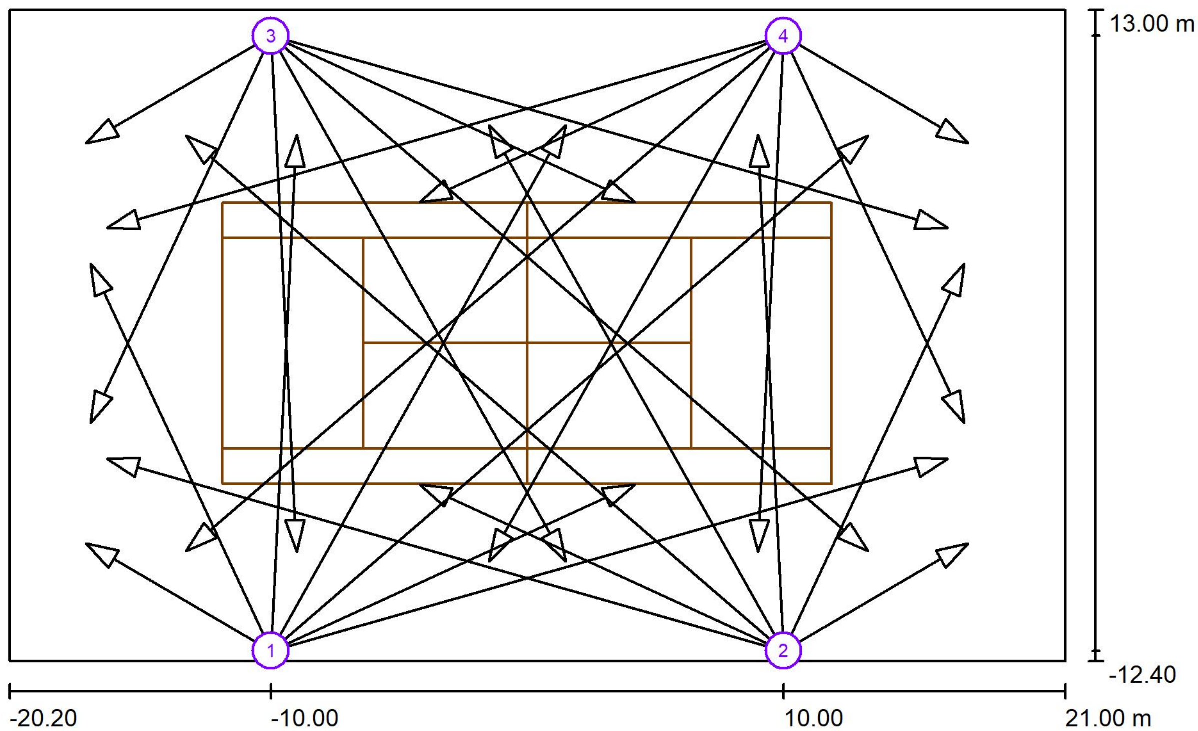
Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	28	INTEGRATED POWER FL FLA400BL5KN01 (1.000)	51486	51115	440.0
			Total: 1441611	Total: 1431221	12320.0

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Sport Luminaires (Coordinates List)



Scale 1 : 295

List of the Sport Luminaires

Luminaire	Index	Position [m] X	Y	Z	Aiming Point [m] X	Y	Z	Angle [°]	Alignment	Pole
INTEGRATED POWER FL FLA400BL5KN01	1	-10.000	-12.000	12.000	-9.000	8.133	0.000	30.8	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	1	-10.000	-12.000	12.000	-17.046	3.107	0.000	35.7	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	10.000	-12.000	12.000	9.000	8.133	0.000	30.8	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	10.000	-12.000	12.000	17.046	3.107	0.000	35.7	(C 0, G 0)	/

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Sport Luminaires (Coordinates List)

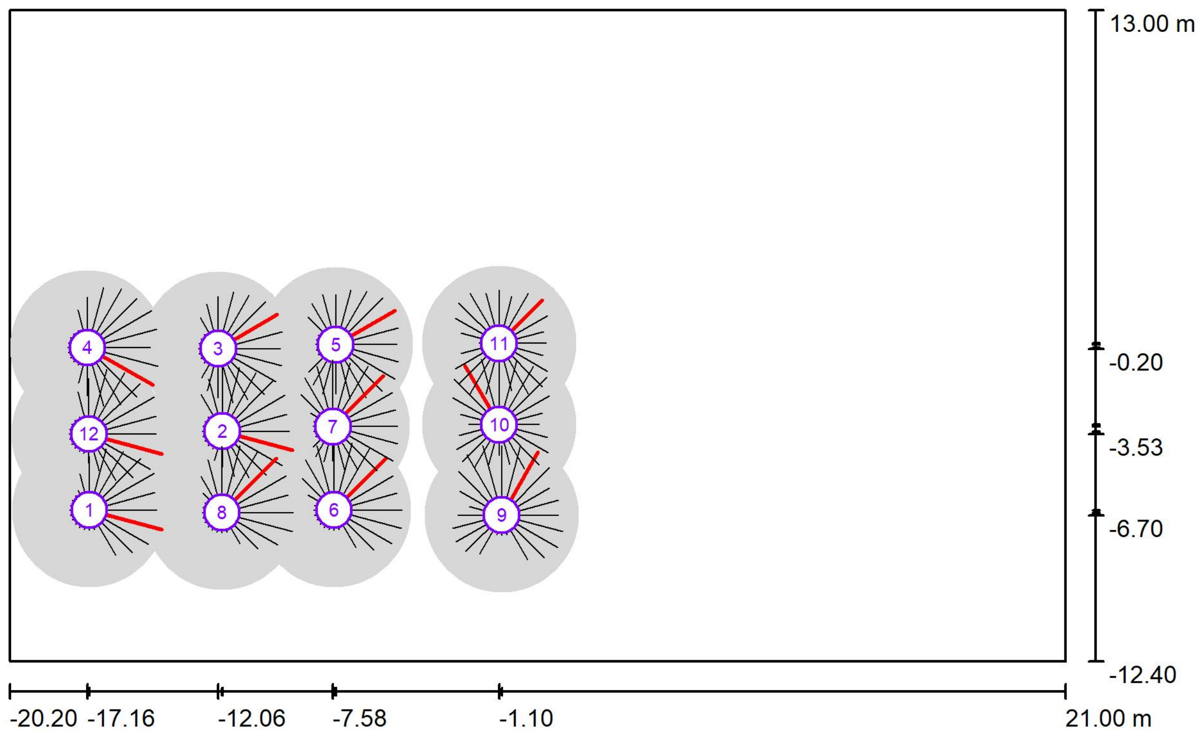
List of the Sport Luminaires

Luminaire	Index	Position [m]			Aiming Point [m]			Angle [°]	Alignment	Pole
		X	Y	Z	X	Y	Z			
INTEGRATED POWER FL FLA400BL5KN01	3	-10.000	12.000	12.000	-9.000	-8.133	0.000	30.8	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-10.000	12.000	12.000	-17.046	-3.107	0.000	35.7	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	10.000	12.000	12.000	9.000	-8.133	0.000	30.8	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	10.000	12.000	12.000	17.046	-3.107	0.000	35.7	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	1	-10.000	-12.000	12.000	13.300	8.100	0.000	21.3	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	1	-10.000	-12.000	12.000	4.200	-5.500	0.000	37.5	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	10.000	-12.000	12.000	-13.300	8.100	0.000	21.3	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	10.000	-12.000	12.000	-4.200	-5.500	0.000	37.5	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-10.000	12.000	12.000	13.300	-8.100	0.000	21.3	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-10.000	12.000	12.000	4.200	5.500	0.000	37.5	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	10.000	12.000	12.000	-13.300	-8.100	0.000	21.3	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	10.000	12.000	12.000	-4.200	5.500	0.000	37.5	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	1	-10.000	-12.000	12.000	-17.200	-7.800	0.000	55.2	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	10.000	-12.000	12.000	17.200	-7.800	0.000	55.2	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-10.000	12.000	12.000	-17.200	7.800	0.000	55.2	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	10.000	12.000	12.000	17.200	7.800	0.000	55.2	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	1	-10.000	-12.000	12.000	16.400	-4.500	0.000	23.6	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	10.000	-12.000	12.000	-16.400	-4.500	0.000	23.6	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-10.000	12.000	12.000	16.400	4.500	0.000	23.6	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	10.000	12.000	12.000	-16.400	4.500	0.000	23.6	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	1	-10.000	-12.000	12.000	1.500	8.500	0.000	27.0	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	10.000	-12.000	12.000	-1.500	8.500	0.000	27.0	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-10.000	12.000	12.000	1.500	-8.500	0.000	27.0	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	10.000	12.000	12.000	-1.500	-8.500	0.000	27.0	(C 0, G 0)	/

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / GR Observer (Results Overview)



Scale 1 : 295

GR Observerlist

No.	Designation	Position [m] X	Y	Z	Viewing sector [°] Start	End	Increment	Slope angle	Max
1	GR Observer (-17.1,-3.1)	-17.083	-6.500	1.500	0.0	360.0	15.0	-2.0	37 2)
2	GR Observer (-12.00,-3.1)	-11.900	-3.424	1.500	0.0	360.0	15.0	-2.0	36 2)
3	GR Observer (-12.00,0)	-12.056	-0.200	1.500	0.0	360.0	15.0	-2.0	34 2)
4	GR Observer (-17.1,0)	-17.157	-0.159	1.500	0.0	360.0	15.0	-2.0	37 2)

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / GR Observer (Results Overview)

GR Observerlist

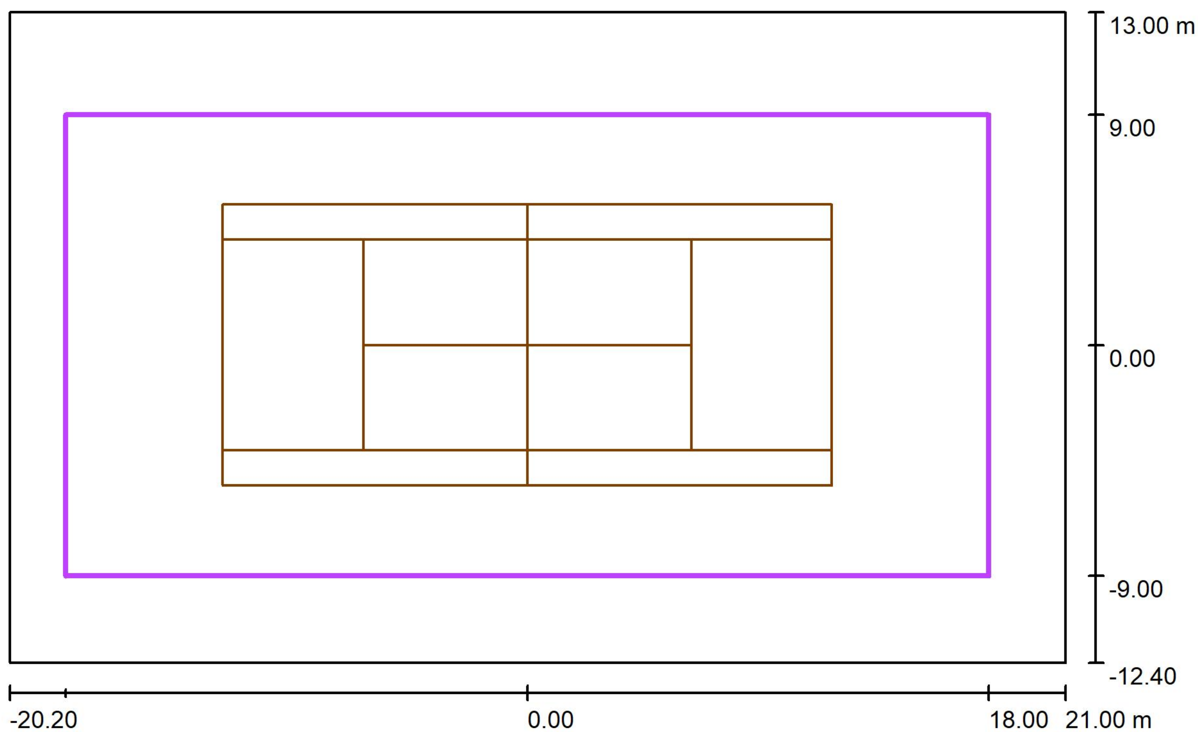
No.	Designation	Position [m]			Viewing sector [°]				Max
		X	Y	Z	Start	End	Increment	Slope angle	
5	GR Observer (-7.5,0)	-7.470	-0.049	1.500	0.0	360.0	15.0	-2.0	34 2)
6	GR Observer(-7.5 ,-6.8)	-7.544	-6.500	1.500	0.0	360.0	15.0	-2.0	37 2)
7	GR Observer (-7.5,-3.1)	-7.580	-3.241	1.500	0.0	360.0	15.0	-2.0	35 2)
8	GR Observer (-12.00,-6.8)	-11.910	-6.600	1.500	0.0	360.0	15.0	-2.0	38 2)
9	GR Observer (-1.00,-6.8)	-1.000	-6.700	1.500	0.0	360.0	15.0	-2.0	36 2)
10	GR Observer (-1.00,-3.1)	-1.100	-3.167	1.500	0.0	360.0	15.0	-2.0	34 2)
11	GR Observer (-1.00,0)	-1.100	0.000	1.500	0.0	360.0	15.0	-2.0	30 2)
12	GR Observer (-17.1,-3.1)	-17.100	-3.534	1.500	0.0	360.0	15.0	-2.0	38 2)

2) The calculated equivalent veil luminance of the environment is based on the assumption of a complete diffuse reflection behavior of the environment (acc. EN 12464-2).

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Tennis 1 Calculation Grid (PA) / Summary



Scale 1 : 295

Position: (0.000 m, 0.000 m, 0.000 m)
Size: (36.000 m, 18.000 m)
Rotation: (0.0°, 0.0°, 0.0°)
Type: Normal, Grid: 15 x 7 Points
Belongs to the following sport arena: Ground Element

Results overview

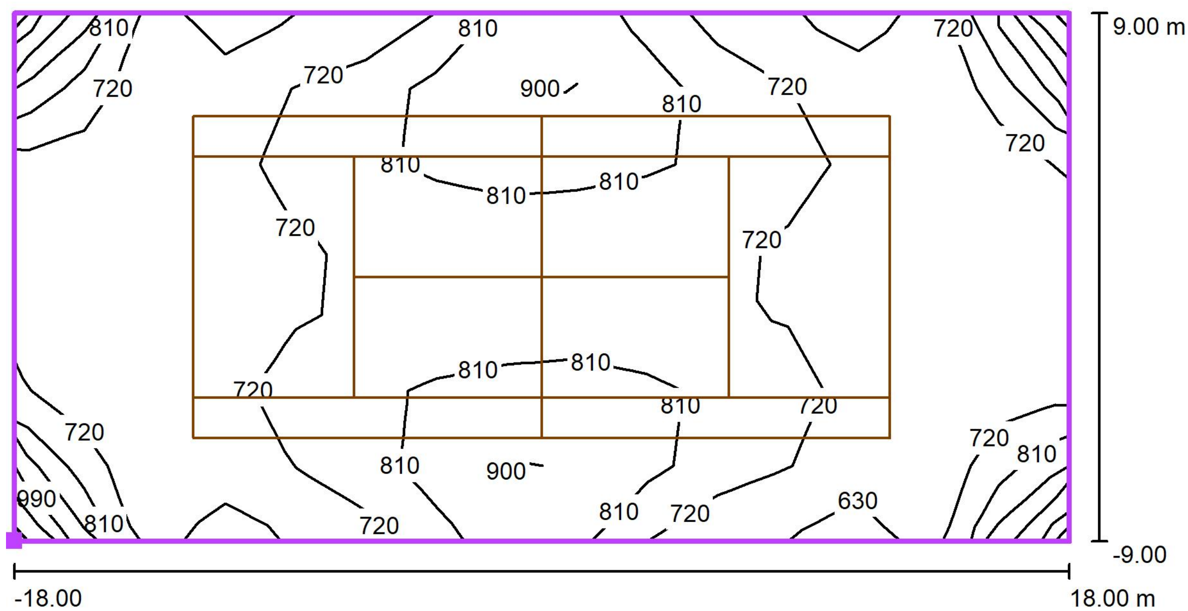
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	perpendicular	742	596	1003	0.80	0.59	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

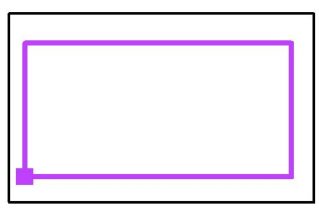
Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Tennis 1 Calculation Grid (PA) / Isolines (E, Perpendicular)



Values in Lux, Scale 1 : 258

Position of surface in external scene:
Marked point: (-18.000 m, -9.000 m, 0.000 m)



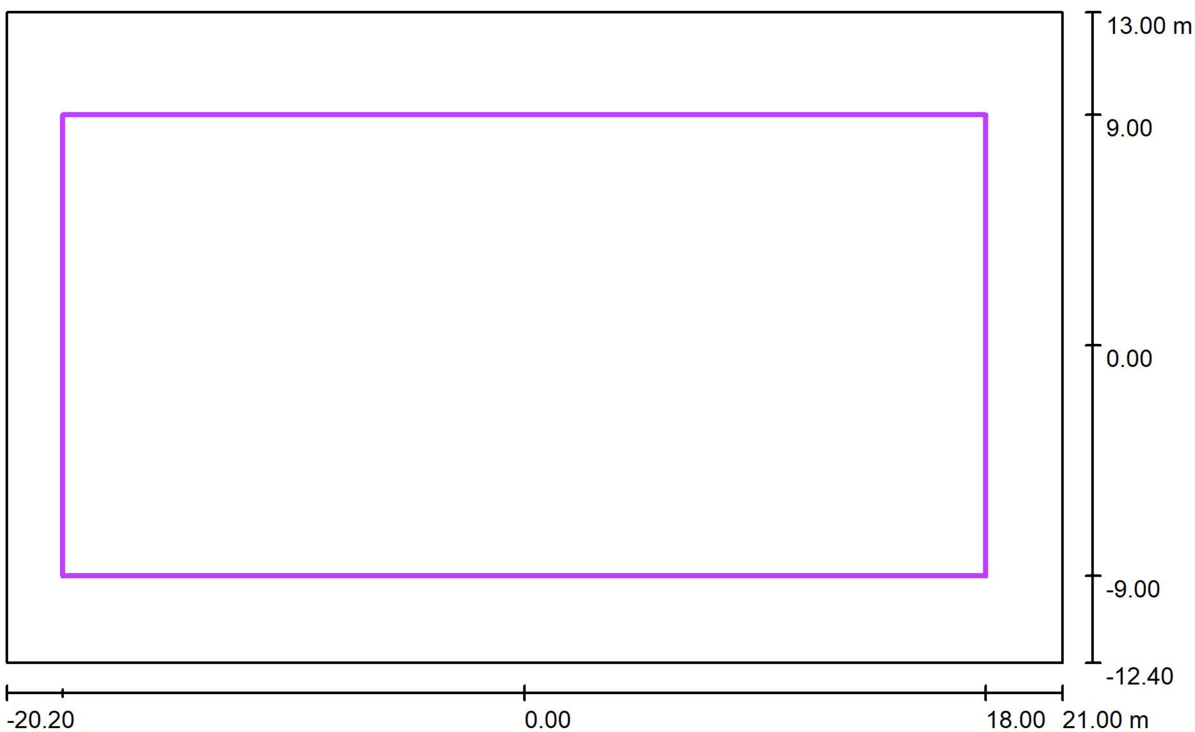
Grid: 15 x 7 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
742	596	1003	0.80	0.59

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid_Eavg_TPA / Summary



Scale 1 : 295

Position: (0.000 m, 0.000 m, 0.000 m)
Size: (36.000 m, 18.000 m)
Rotation: (0.0°, 0.0°, 0.0°)
Type: Normal, Grid: 19 x 10 Points

Results overview

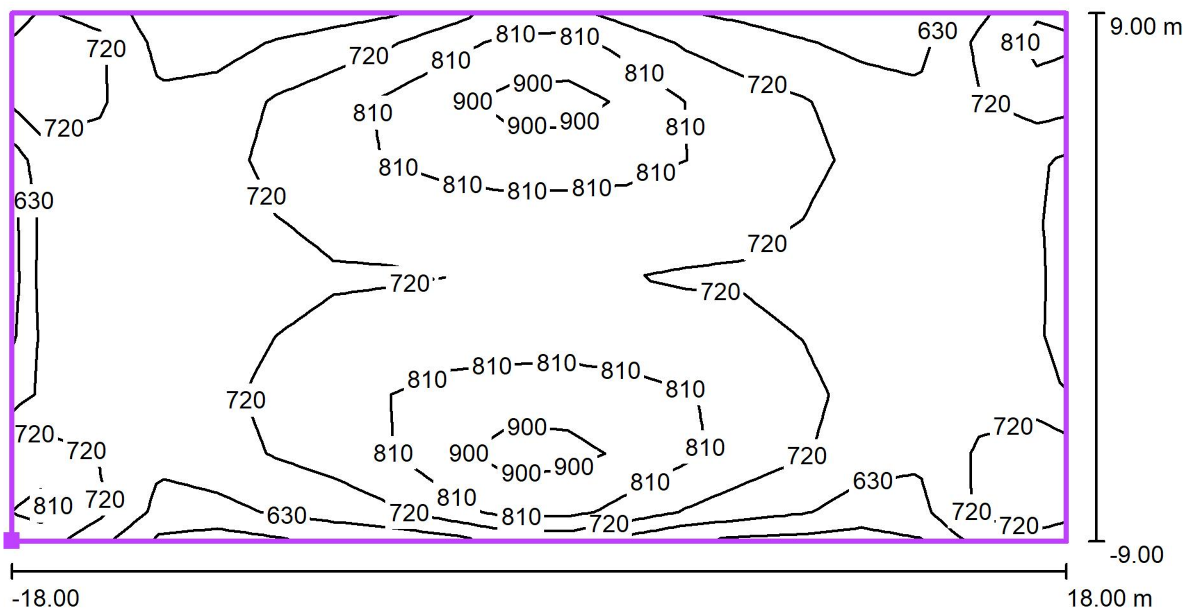
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\ m}/E_m$	H [m]	Camera
1	horizontal	720	526	949	0.73	0.55	/	0.000	/

$E_{h\ m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

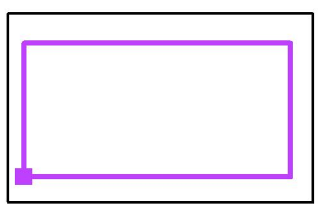
Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid_Eavg_TPA / Isolines (E, Horizontal)



Values in Lux, Scale 1 : 258

Position of surface in external scene:
Marked point: (-18.000 m, -9.000 m, 0.000 m)



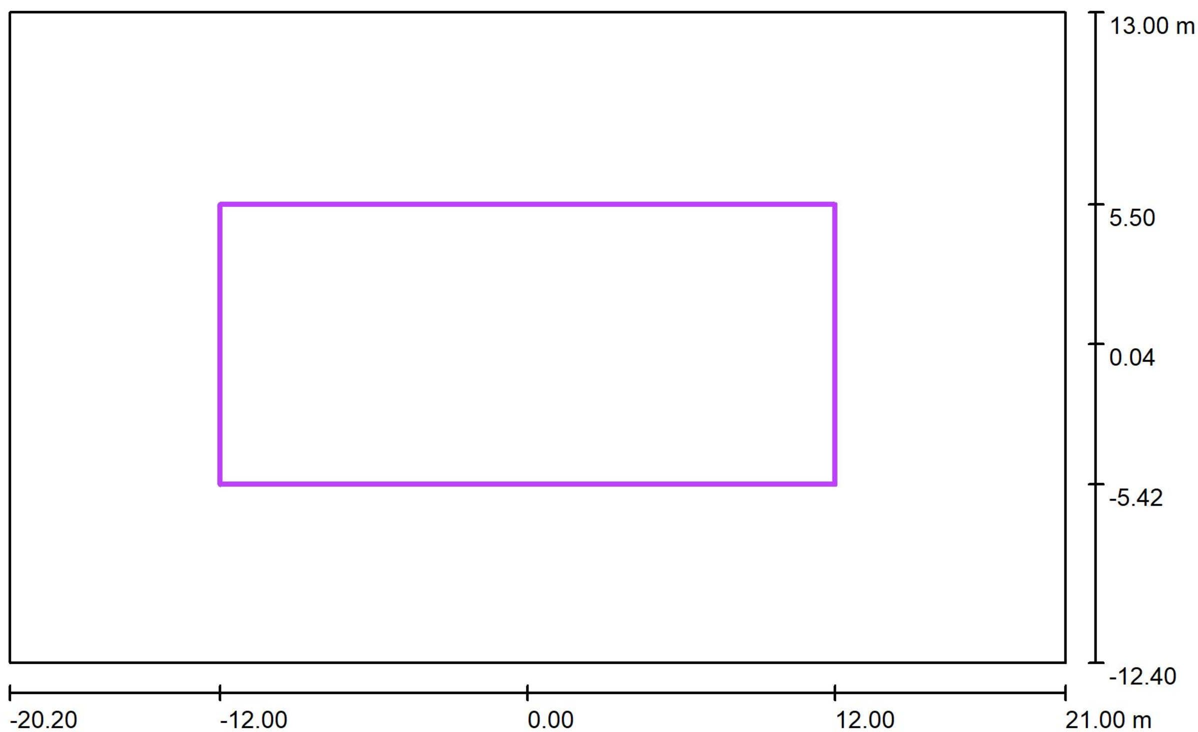
Grid: 19 x 10 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
720	526	949	0.73	0.55

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid_Eavg_PPA / Summary



Scale 1 : 295

Position: (0.000 m, 0.039 m, 0.000 m)
Size: (24.000 m, 10.922 m)
Rotation: (0.0°, 0.0°, 0.0°)
Type: Normal, Grid: 13 x 6 Points

Results overview

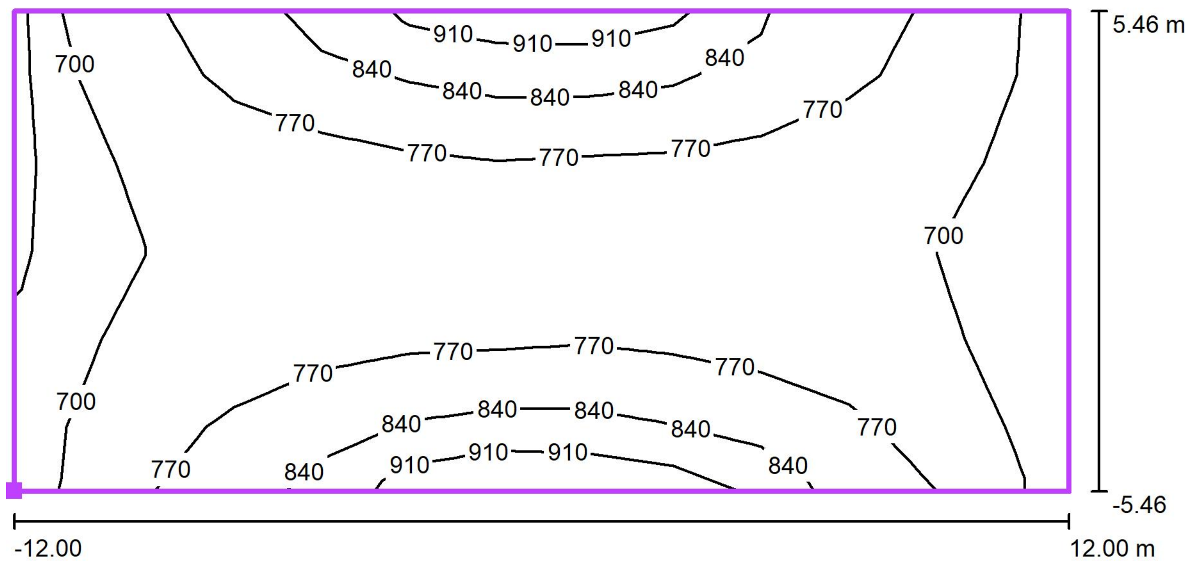
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\ m}/E_m$	H [m]	Camera
1	horizontal	753	620	937	0.82	0.66	/	0.000	/

$E_{h\ m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

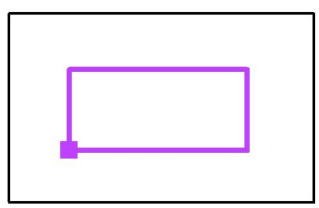
Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid_Eavg_PPA / Isolines (E, Horizontal)



Values in Lux, Scale 1 : 172

Position of surface in external scene:
Marked point: (-12.000 m, -5.422 m, 0.000 m)



Grid: 13 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
753	620	937	0.82	0.66

Tennis Court Floodlighting For Class-II

Lighting Design Parameters to be acheived according to National Lighting Code 2010.

Eavg>=500lx
U0>=0.7
GR<50.

Maintenance Factor : .80

Partner for Contact:
Order No.:
Company:
Customer No.:

Date: 08.11.2022
Operator: Mr. Sagar Das

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

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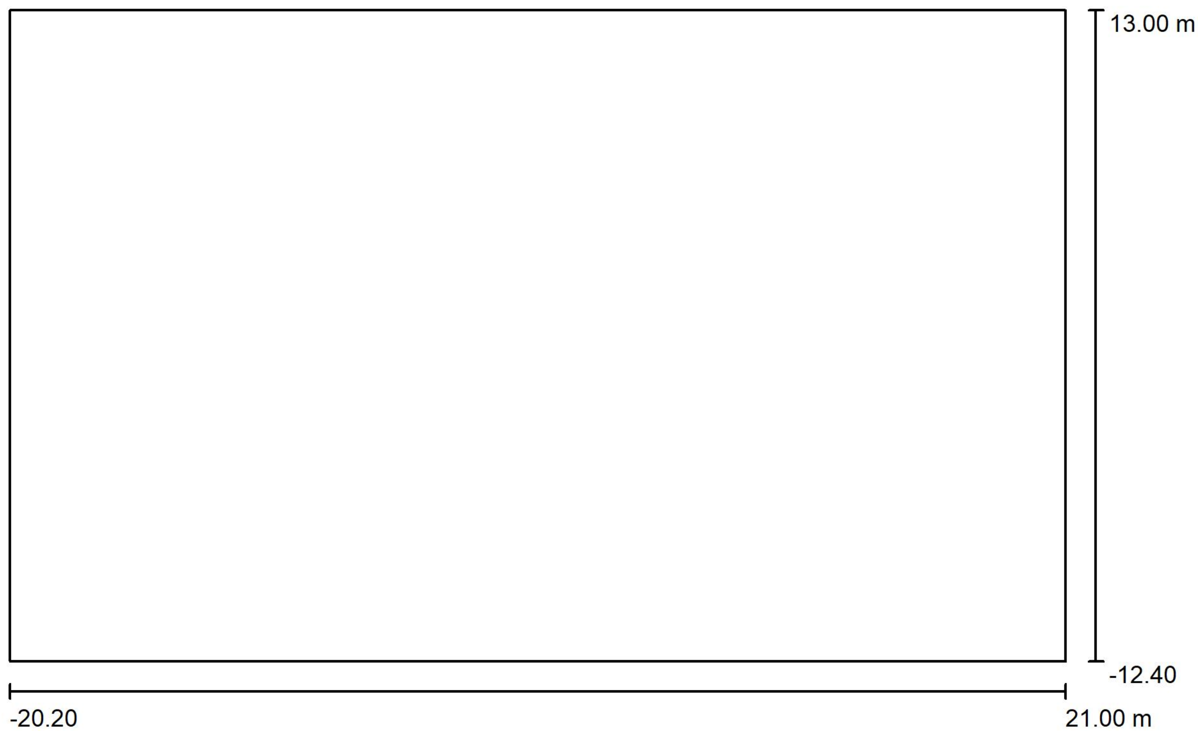
Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Planning data



Light loss factor: 0.80, ULR (Upward Light Ratio): 12.0%

Scale 1:295

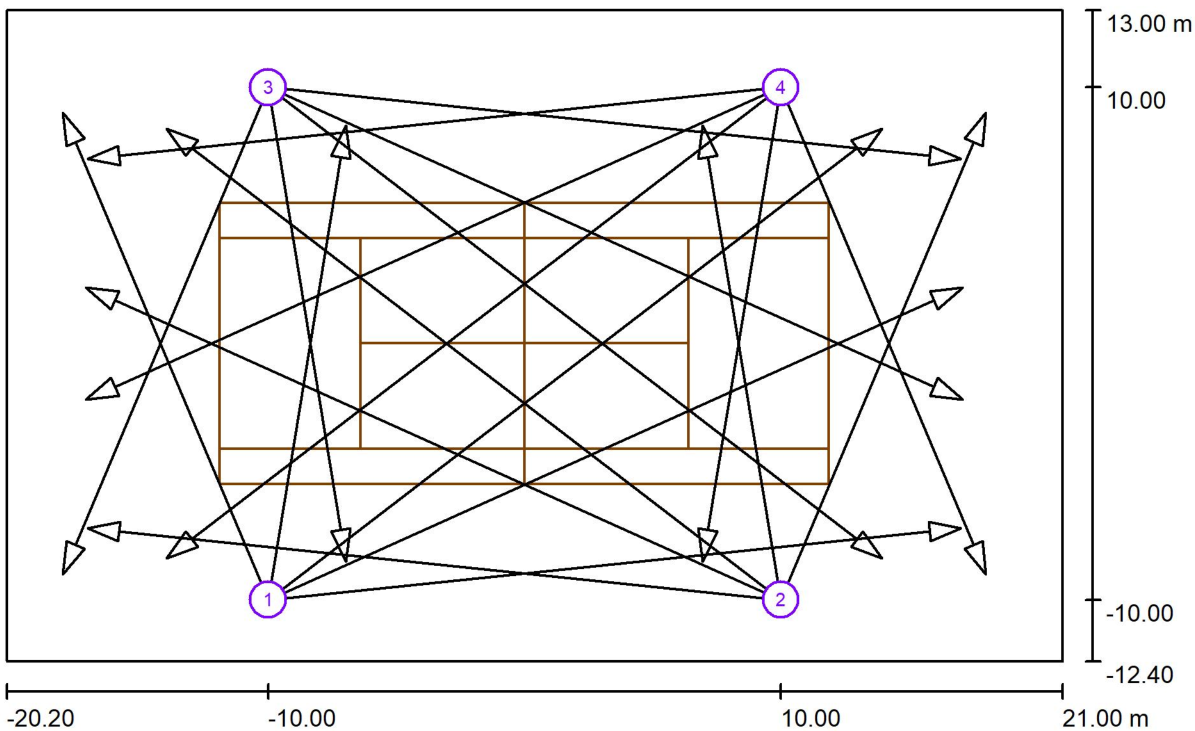
Luminaire Parts List

No.	Pieces	Designation (Correction Factor)		Φ (Luminaire) [lm]		Φ (Lamps) [lm]	P [W]
1	20	INTEGRATED POWER FL FLA400BL5KN01 (1.000)		51486		51115	440.0
			Total:	1029722	Total:	1022300	8800.0

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Sport Luminaires (Coordinates List)



Scale 1 : 295

List of the Sport Luminaires

Luminaire	Index	Position [m]			Aiming Point [m]			Angle [°]	Alignment	Pole
		X	Y	Z	X	Y	Z			
INTEGRATED POWER FL FLA400BL5KN01	1	-10.000	-10.000	12.000	-6.956	8.500	0.000	32.6	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	10.000	-10.000	12.000	6.956	8.500	0.000	32.6	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-10.000	10.000	12.000	-6.956	-8.500	0.000	32.6	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	10.000	10.000	12.000	6.956	-8.500	0.000	32.6	(C 0, G 0)	/

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Sport Luminaires (Coordinates List)

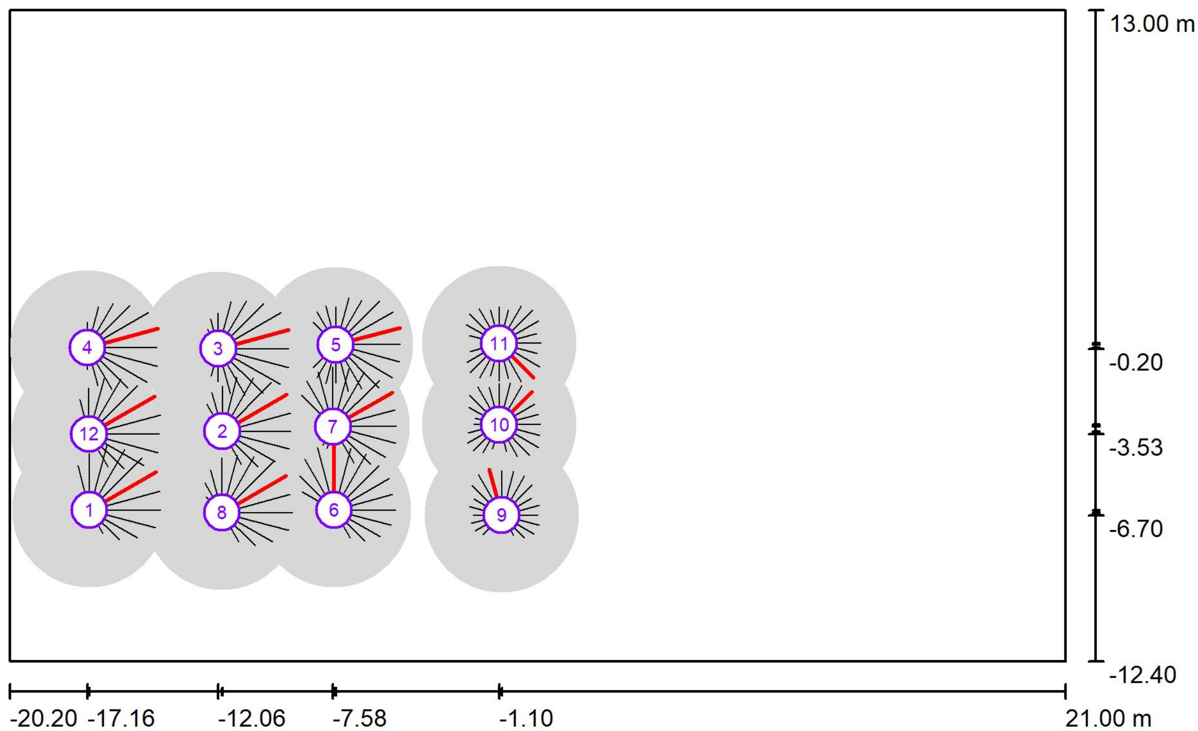
List of the Sport Luminaires

Luminaire	Index	Position [m] X	Position [m] Y	Position [m] Z	Aiming Point [m] X	Aiming Point [m] Y	Aiming Point [m] Z	Angle [°]	Alignment	Pole
INTEGRATED POWER FL FLA400BL5KN01	1	-10.000	-10.000	12.000	17.100	2.190	0.000	22.0	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	10.000	-10.000	12.000	-17.100	2.190	0.000	22.0	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-10.000	10.000	12.000	17.100	-2.190	0.000	22.0	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	10.000	10.000	12.000	-17.100	-2.190	0.000	22.0	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	1	-10.000	-10.000	12.000	-18.000	9.000	0.000	30.2	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	10.000	-10.000	12.000	18.000	9.000	0.000	30.2	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-10.000	10.000	12.000	-18.000	-9.000	0.000	30.2	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	10.000	10.000	12.000	18.000	-9.000	0.000	30.2	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	1	-10.000	-10.000	12.000	17.039	-7.203	0.000	23.8	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	10.000	-10.000	12.000	-17.039	-7.203	0.000	23.8	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-10.000	10.000	12.000	17.039	7.203	0.000	23.8	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	10.000	10.000	12.000	-17.039	7.203	0.000	23.8	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	1	-10.000	-10.000	12.000	13.957	8.390	0.000	21.7	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	10.000	-10.000	12.000	-13.957	8.390	0.000	21.7	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-10.000	10.000	12.000	13.957	-8.390	0.000	21.7	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	10.000	10.000	12.000	-13.957	-8.390	0.000	21.7	(C 0, G 0)	/

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / GR Observer (Results Overview)



Scale 1 : 295

GR Observerlist

No.	Designation	Position [m] X	Y	Z	Viewing sector [°] Start	End	Increment	Slope angle	Max
1	GR Observer (-17.1,-3.1)	-17.083	-6.500	1.500	0.0	360.0	15.0	-2.0	46 [2)]
2	GR Observer (-12.00,-3.1)	-11.900	-3.424	1.500	0.0	360.0	15.0	-2.0	44 [2)]
3	GR Observer (-12.00,0)	-12.056	-0.200	1.500	0.0	360.0	15.0	-2.0	43 [2)]
4	GR Observer (-17.1,0)	-17.157	-0.159	1.500	0.0	360.0	15.0	-2.0	43 [2)]

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / GR Observer (Results Overview)

GR Observerlist

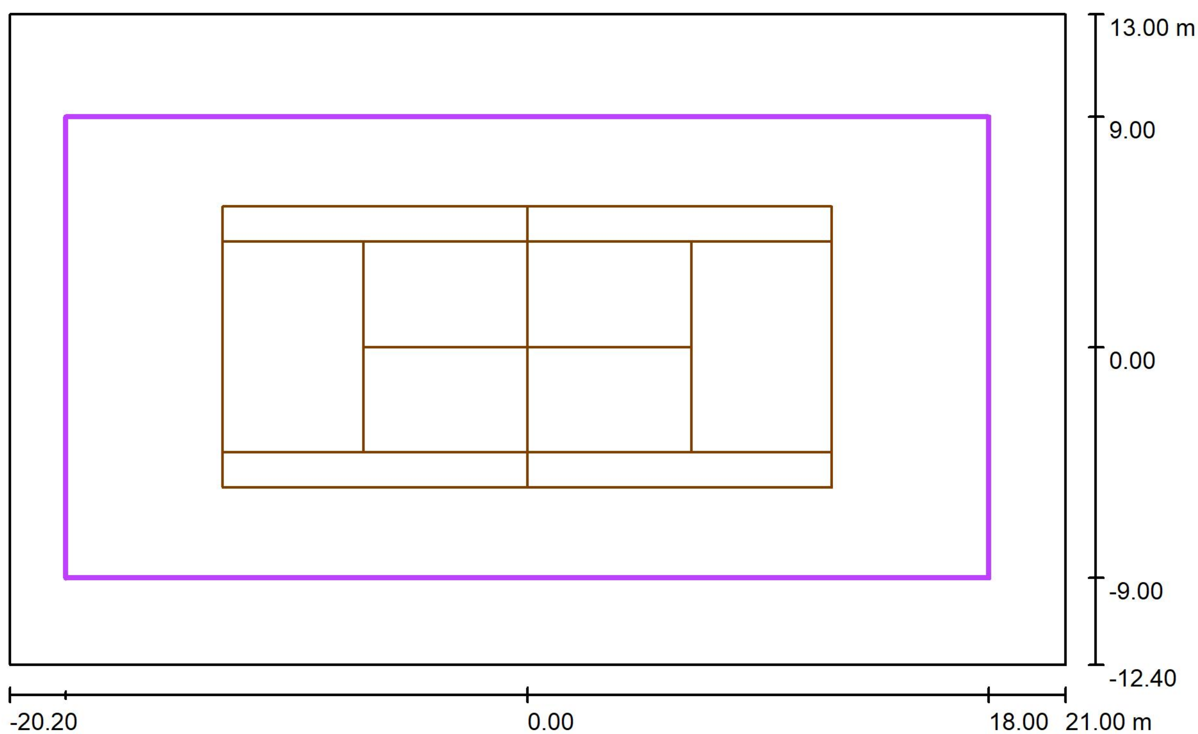
No.	Designation	Position [m]			Viewing sector [°]				Max
		X	Y	Z	Start	End	Increment	Slope angle	
5	GR Observer (-7.5,0)	-7.470	-0.049	1.500	0.0	360.0	15.0	-2.0	39 2)
6	GR Observer(-7.5 ,-6.8)	-7.544	-6.500	1.500	0.0	360.0	15.0	-2.0	39 2)
7	GR Observer (-7.5,-3.1)	-7.580	-3.241	1.500	0.0	360.0	15.0	-2.0	40 2)
8	GR Observer (-12.00,-6.8)	-11.910	-6.600	1.500	0.0	360.0	15.0	-2.0	44 2)
9	GR Observer (-1.00,-6.8)	-1.000	-6.700	1.500	0.0	360.0	15.0	-2.0	28 2)
10	GR Observer (-1.00,-3.1)	-1.100	-3.167	1.500	0.0	360.0	15.0	-2.0	28 2)
11	GR Observer (-1.00,0)	-1.100	0.000	1.500	0.0	360.0	15.0	-2.0	29 2)
12	GR Observer (-17.1,-3.1)	-17.100	-3.534	1.500	0.0	360.0	15.0	-2.0	45 2)

2) The calculated equivalent veil luminance of the environment is based on the assumption of a complete diffuse reflection behavior of the environment (acc. EN 12464-2).

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Tennis 1 Calculation Grid (PA) / Summary



Scale 1 : 295

Position: (0.000 m, 0.000 m, 0.000 m)
Size: (36.000 m, 18.000 m)
Rotation: (0.0°, 0.0°, 0.0°)
Type: Normal, Grid: 15 x 7 Points
Belongs to the following sport arena: Ground Element

Results overview

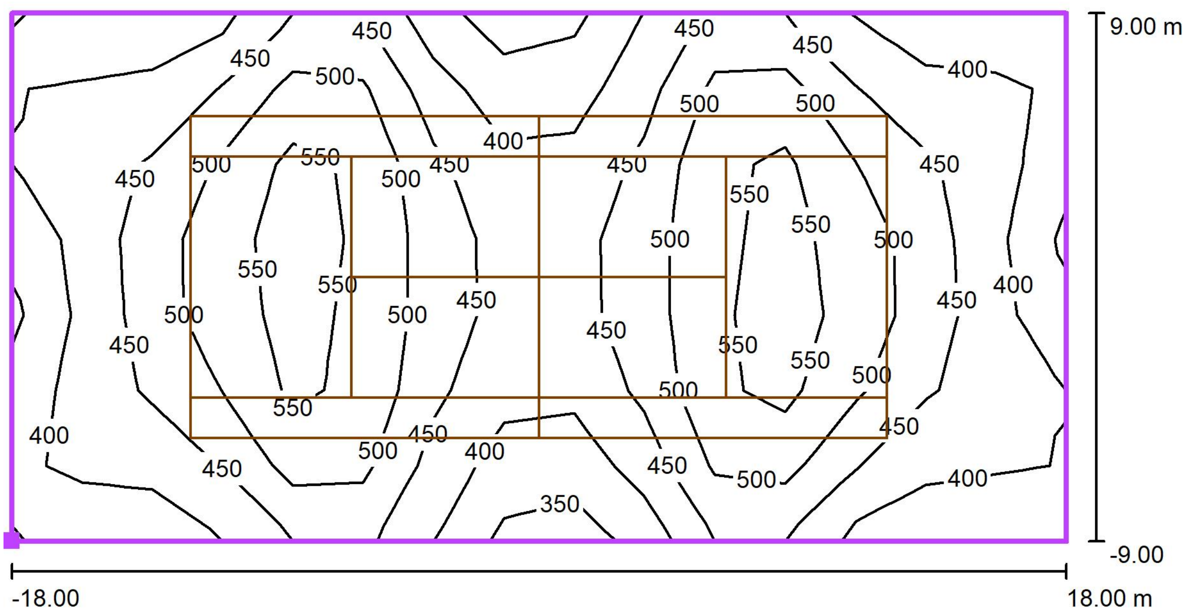
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	perpendicular	459	344	590	0.75	0.58	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

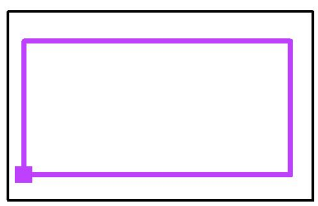
Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Tennis 1 Calculation Grid (PA) / Isolines (E, Perpendicular)



Values in Lux, Scale 1 : 258

Position of surface in external scene:
Marked point: (-18.000 m, -9.000 m, 0.000 m)



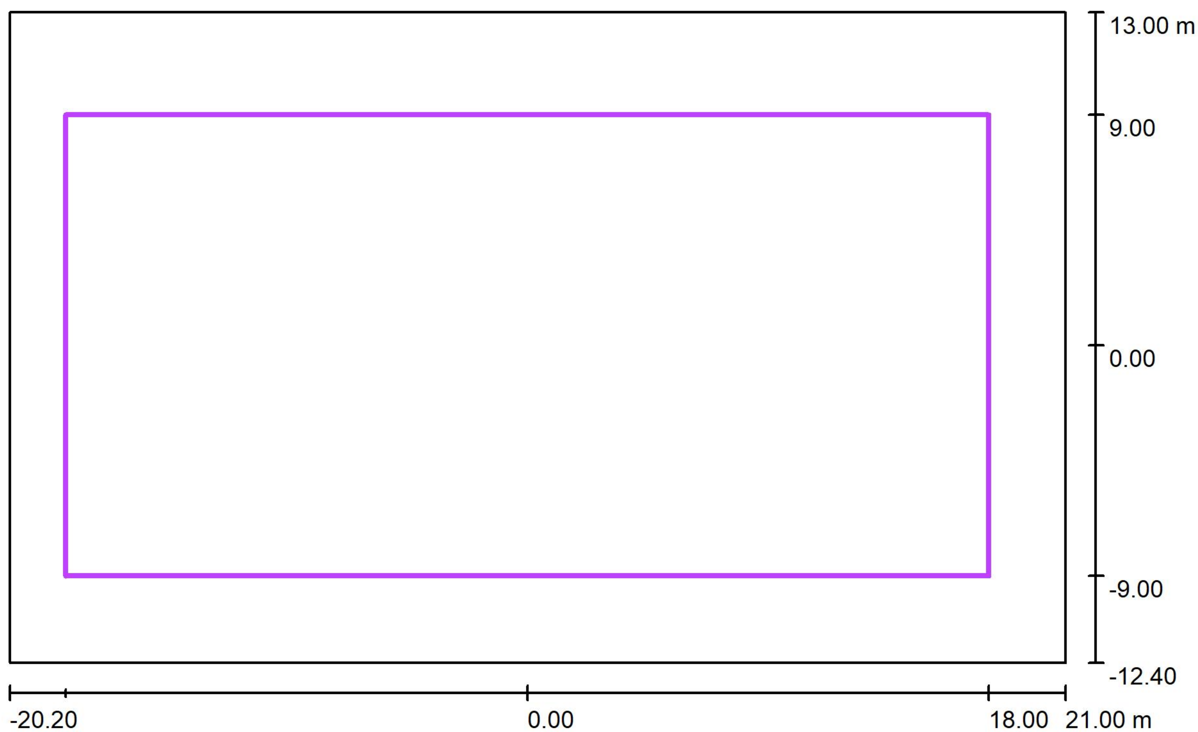
Grid: 15 x 7 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
459	344	590	0.75	0.58

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid TPA / Summary



Scale 1 : 295

Position: (0.000 m, 0.000 m, 0.000 m)
Size: (36.000 m, 18.000 m)
Rotation: (0.0°, 0.0°, 0.0°)
Type: Normal, Grid: 19 x 10 Points

Results overview

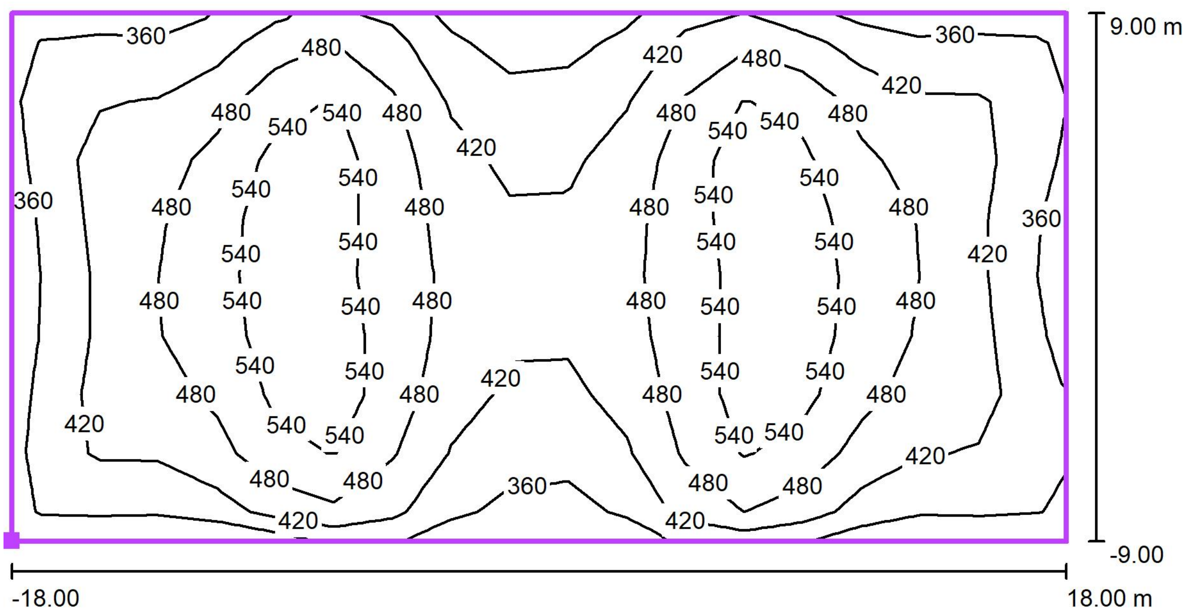
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	horizontal	439	306	585	0.70	0.52	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

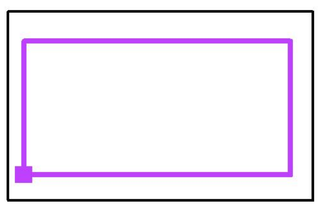
Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid TPA / Isolines (E, Horizontal)



Values in Lux, Scale 1 : 258

Position of surface in external scene:
Marked point: (-18.000 m, -9.000 m, 0.000 m)



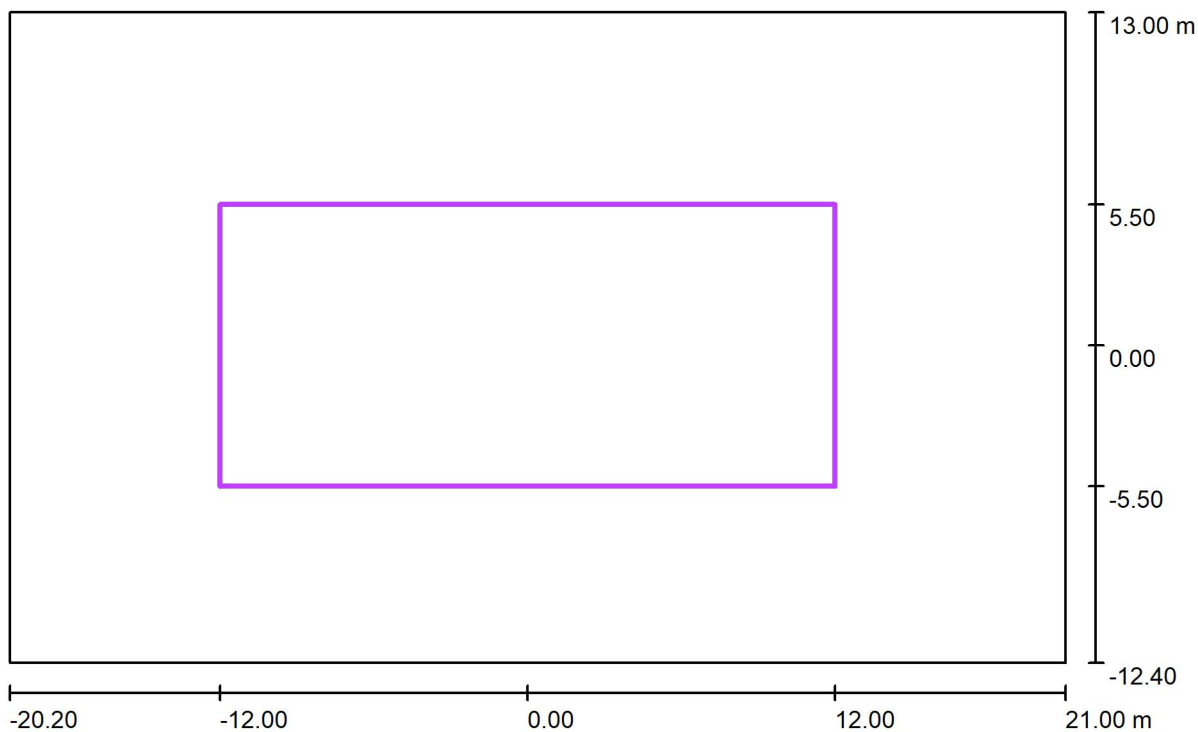
Grid: 19 x 10 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
439	306	585	0.70	0.52

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid PPA / Summary



Scale 1 : 295

Position: (0.000 m, 0.000 m, 0.000 m)
Size: (24.000 m, 11.000 m)
Rotation: (0.0°, 0.0°, 0.0°)
Type: Normal, Grid: 13 x 6 Points

Results overview

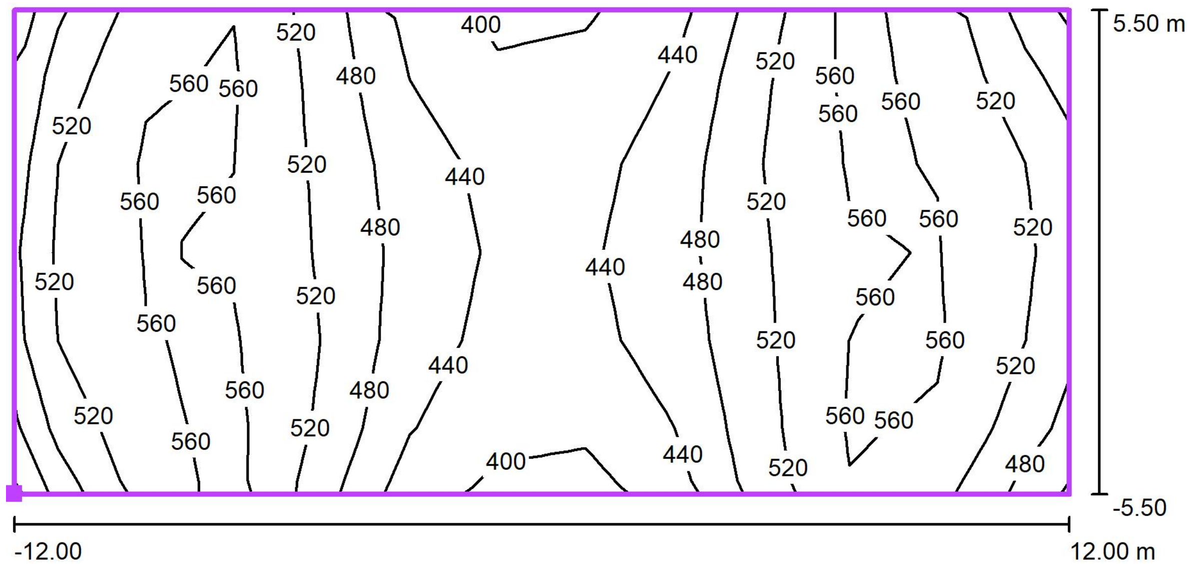
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	horizontal	499	394	585	0.79	0.67	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

Jadavpur University
Electrical Engineering Department
Jadavpur, Kolkata 700032

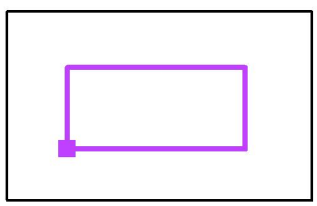
Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid PPA / Isolines (E, Horizontal)



Values in Lux, Scale 1 : 172

Position of surface in external scene:
Marked point: (-12.000 m, -5.500 m, 0.000 m)



Grid: 13 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
499	394	585	0.79	0.67

Tennis Court Floodlighting For Class -III

Lighting Design Parameters to be acheived according to National Lighting code 2010.

Eavg>=200lx
U0>=0.5
GR<55.

Maintenance Factor: 0.80

Partner for Contact:
Order No.:
Company:
Customer No.:

Date: 08.11.2022
Operator: Mr. Sagar Das

Jadavpur university
Electrical Engineering Department
Jadavpur,Kolkata. 700032
l

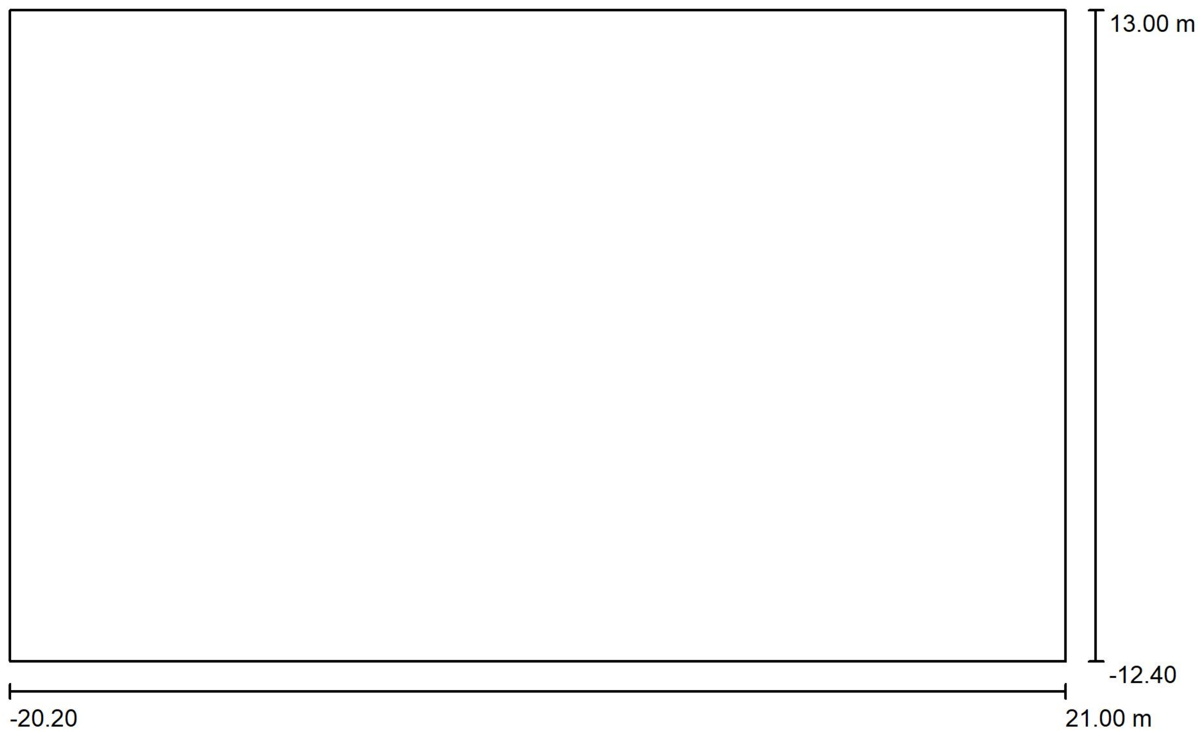
Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Table of contents

Jadavpur university
Electrical Engineering Department
Jadavpur,Kolkata. 700032
I

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Planning data



Light loss factor: 0.80, ULR (Upward Light Ratio): 7.5%

Scale 1:295

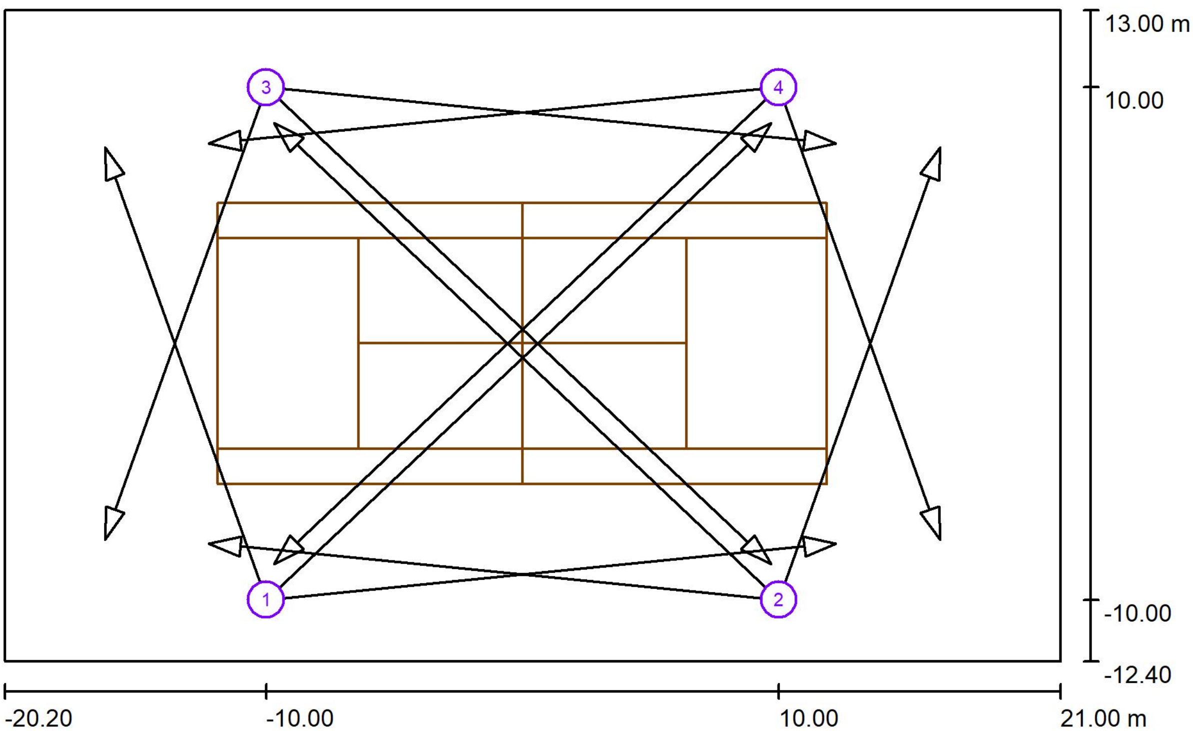
Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	4	INTEGRATED POWER FL FLA400BL5KN01 (1.000)	51486	51115	440.0
2	8	INTEGRATED POWER FL FLA400BL5KN02 (1.000)	53096	52790	440.0
			Total: 630710	Total: 626782	5280.0

Jadavpur university
Electrical Engineering Department
Jadavpur,Kolkata. 700032
l

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Sport Luminaires (Coordinates List)



Scale 1 : 295

List of the Sport Luminaires

Luminaire	Index	Position [m] X	Position [m] Y	Position [m] Z	Aiming Point [m] X	Aiming Point [m] Y	Aiming Point [m] Z	Angle [°]	Alignment	Pole
INTEGRATED POWER FL FLA400BL5KN01	1	-10.000	-10.000	12.000	12.233	-7.800	0.000	28.2	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	2	10.000	-10.000	12.000	-12.233	-7.800	0.000	28.2	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	3	-10.000	10.000	12.000	12.233	7.800	0.000	28.2	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN01	4	10.000	10.000	12.000	-12.233	7.800	0.000	28.2	(C 0, G 0)	/

Jadavpur university
Electrical Engineering Department
Jadavpur,Kolkata. 700032
I

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Sport Luminaires (Coordinates List)

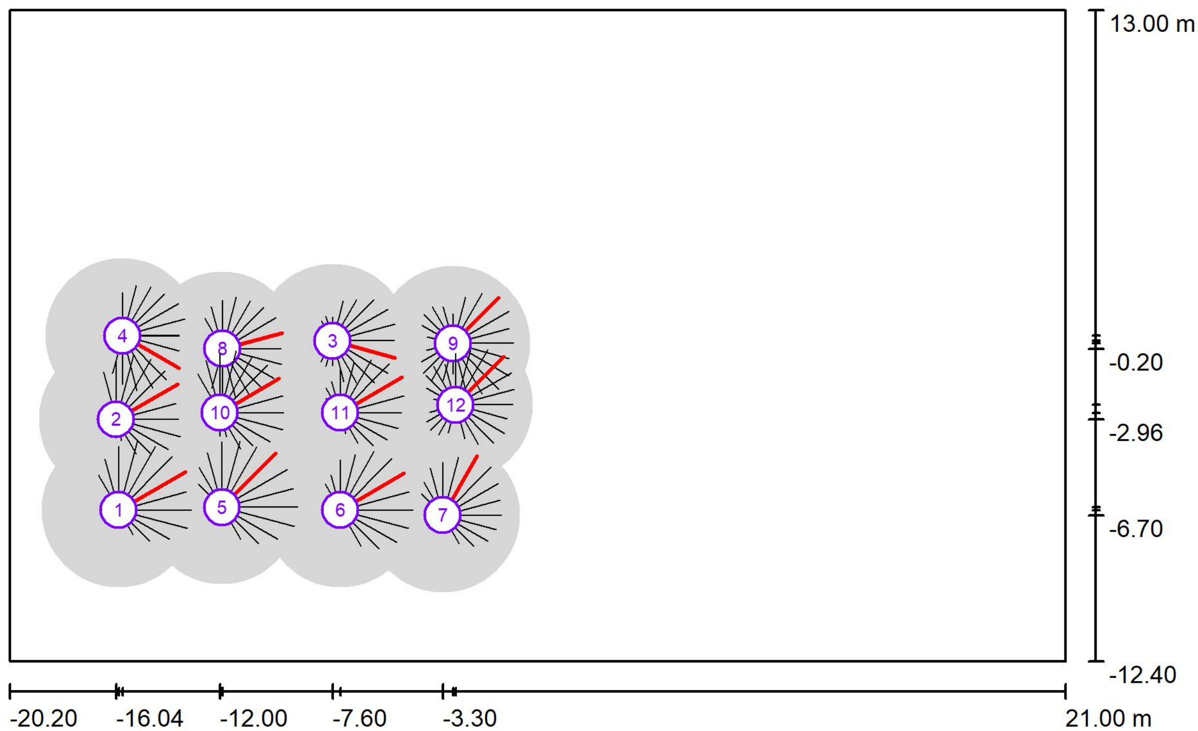
List of the Sport Luminaires

Luminaire	Index	Position [m] X	Position [m] Y	Position [m] Z	Aiming Point [m] X	Aiming Point [m] Y	Aiming Point [m] Z	Angle [°]	Alignment	Pole
INTEGRATED POWER FL FLA400BL5KN02	1	-10.000	-10.000	12.000	9.700	8.600	0.000	23.9	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN02	1	-10.000	-10.000	12.000	-16.300	7.656	0.000	32.6	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN02	2	10.000	-10.000	12.000	-9.700	8.600	0.000	23.9	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN02	2	10.000	-10.000	12.000	16.300	7.656	0.000	32.6	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN02	3	-10.000	10.000	12.000	9.700	-8.600	0.000	23.9	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN02	3	-10.000	10.000	12.000	-16.300	-7.656	0.000	32.6	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN02	4	10.000	10.000	12.000	-9.700	-8.600	0.000	23.9	(C 0, G 0)	/
INTEGRATED POWER FL FLA400BL5KN02	4	10.000	10.000	12.000	16.300	-7.656	0.000	32.6	(C 0, G 0)	/

Jadavpur university
Electrical Engineering Department
Jadavpur,Kolkata. 700032
I

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / GR Observer (Results Overview)



Scale 1 : 295

GR Observerlist

No.	Designation	Position [m] X	Y	Z	Viewing sector [°] Start	End	Increment	Slope angle	Max
1	GR Observer 1	-15.946	-6.500	1.500	0.0	360.0	15.0	-2.0	42 2)
2	GR Observer 2	-16.044	-2.961	1.500	0.0	360.0	15.0	-2.0	39 2)
3	GR Observer 3	-7.600	0.100	1.500	0.0	360.0	15.0	-2.0	35 2)
4	GR Observer 4	-15.800	0.300	1.500	0.0	360.0	15.0	-2.0	35 2)

Jadavpur university
Electrical Engineering Department
Jadavpur,Kolkata. 700032
I

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / GR Observer (Results Overview)

GR Observerlist

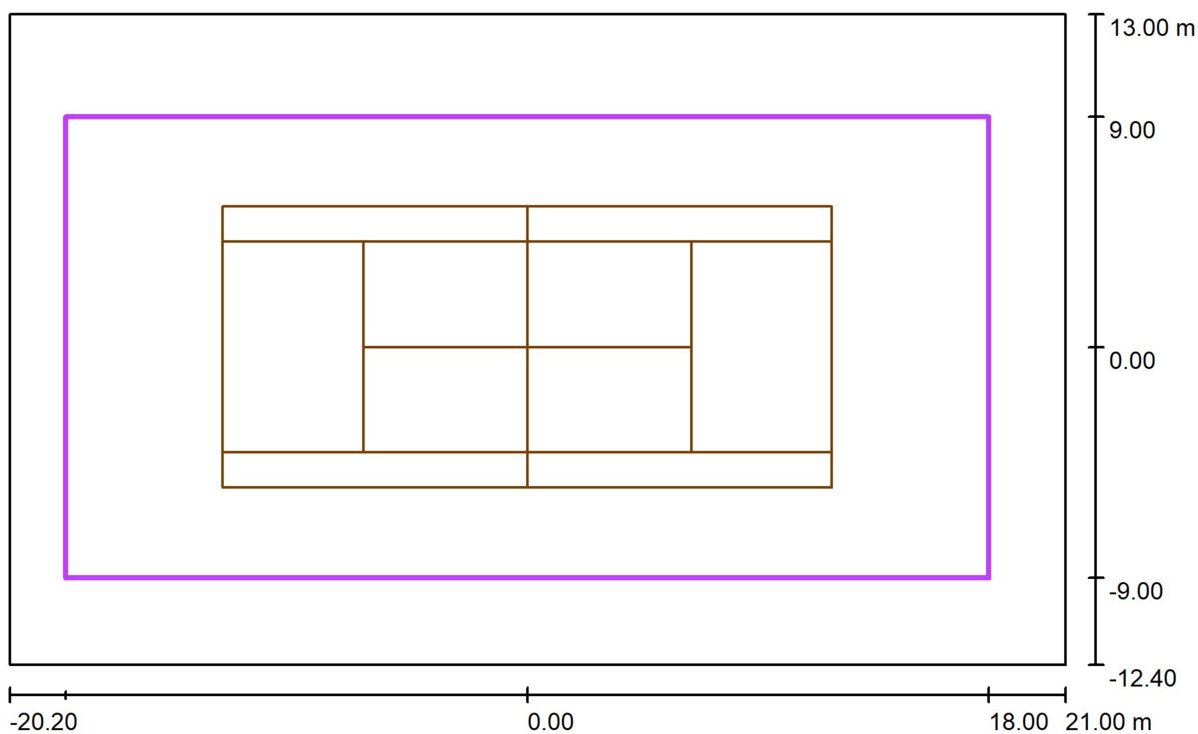
No.	Designation	Position [m]			Viewing sector [°]				Max
		X	Y	Z	Start	End	Increment	Slope angle	
5	GR Observer 5	-11.910	-6.391	1.500	0.0	360.0	15.0	-2.0	42 2)
6	GR Observer 6	-7.300	-6.500	1.500	0.0	360.0	15.0	-2.0	40 2)
7	GR Observer 7	-3.300	-6.700	1.500	0.0	360.0	15.0	-2.0	37 2)
8	GR Observer 8	-11.900	-0.200	1.500	0.0	360.0	15.0	-2.0	34 2)
9	GR Observer 9	-2.900	0.000	1.500	0.0	360.0	15.0	-2.0	35 2)
10	GR Observer 10	-12.000	-2.700	1.500	0.0	360.0	15.0	-2.0	37 2)
11	GR Observer 11	-7.300	-2.700	1.500	0.0	360.0	15.0	-2.0	39 2)
12	GR Observer 12	-2.800	-2.400	1.500	0.0	360.0	15.0	-2.0	37 2)

2) The calculated equivalent veil luminance of the environment is based on the assumption of a complete diffuse reflection behavior of the environment (acc. EN 12464-2).

Jadavpur university
Electrical Engineering Department
Jadavpur,Kolkata. 700032
I

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Tennis 1 Calculation Grid (PA) / Summary



Scale 1 : 295

Position: (0.000 m, 0.000 m, 0.000 m)
Size: (36.000 m, 18.000 m)
Rotation: (0.0°, 0.0°, 0.0°)
Type: Normal, Grid: 15 x 7 Points
Belongs to the following sport arena: Ground Element

Results overview

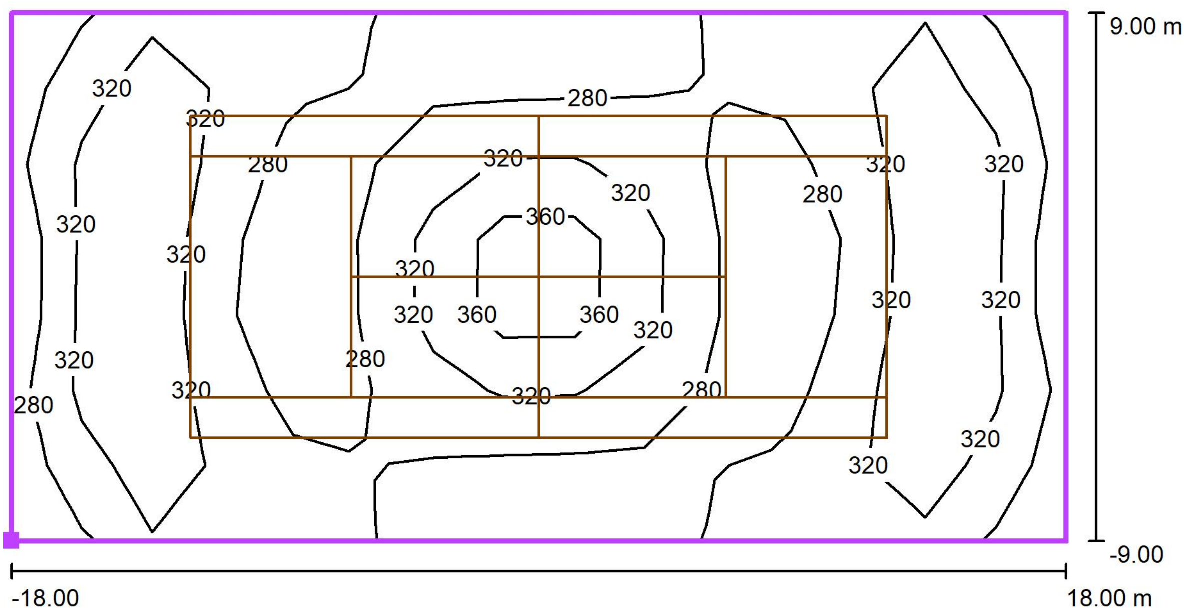
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\ m}/E_m$	H [m]	Camera
1	perpendicular	302	243	419	0.81	0.58	/	0.000	/

$E_{h\ m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

Jadavpur university
Electrical Engineering Department
Jadavpur,Kolkata. 700032
l

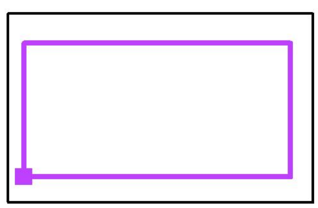
Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Tennis 1 Calculation Grid (PA) / Isolines (E, Perpendicular)



Values in Lux, Scale 1 : 258

Position of surface in external scene:
Marked point: (-18.000 m, -9.000 m, 0.000 m)



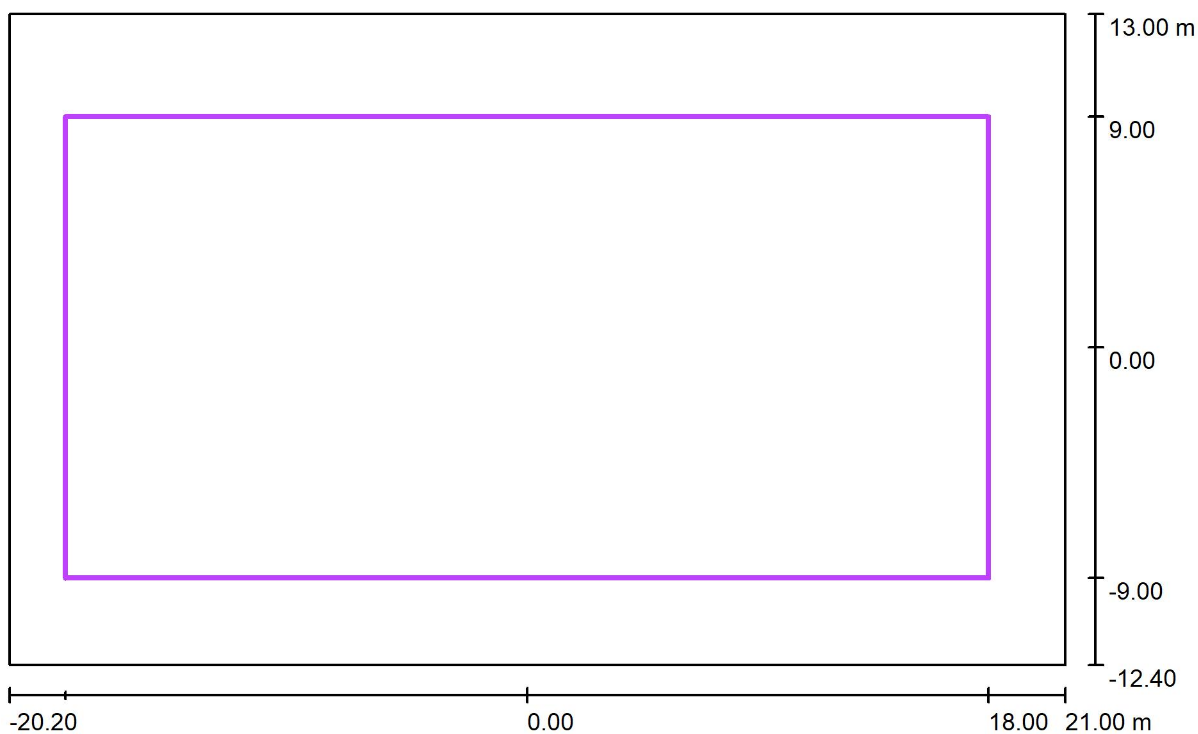
Grid: 15 x 7 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
302	243	419	0.81	0.58

Jadavpur university
Electrical Engineering Department
Jadavpur,Kolkata. 700032
I

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid TPA / Summary



Scale 1 : 295

Position: (0.000 m, 0.000 m, 0.000 m)
Size: (36.000 m, 18.000 m)
Rotation: (0.0°, 0.0°, 0.0°)
Type: Normal, Grid: 19 x 10 Points

Results overview

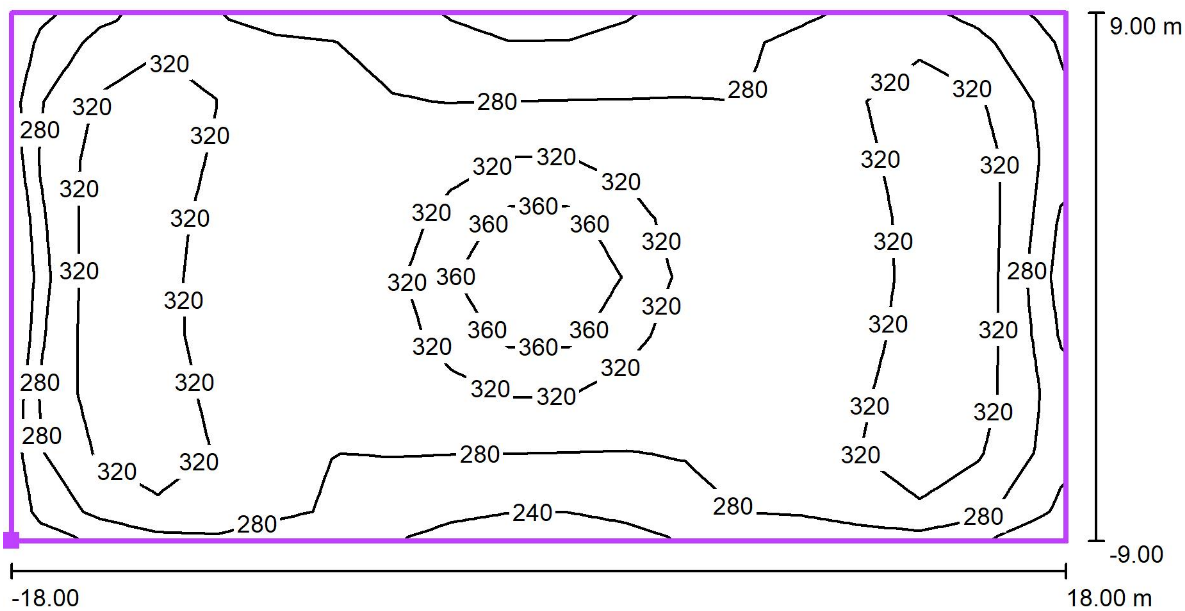
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\,m}/E_m$	H [m]	Camera
1	horizontal	291	209	407	0.72	0.51	/	0.000	/

$E_{h\,m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

Jadavpur university
Electrical Engineering Department
Jadavpur,Kolkata. 700032
I

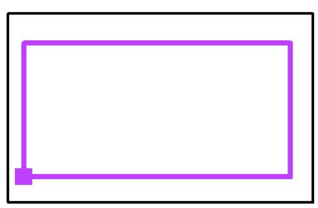
Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid TPA / Isolines (E, Horizontal)



Values in Lux, Scale 1 : 258

Position of surface in external scene:
Marked point: (-18.000 m, -9.000 m, 0.000 m)



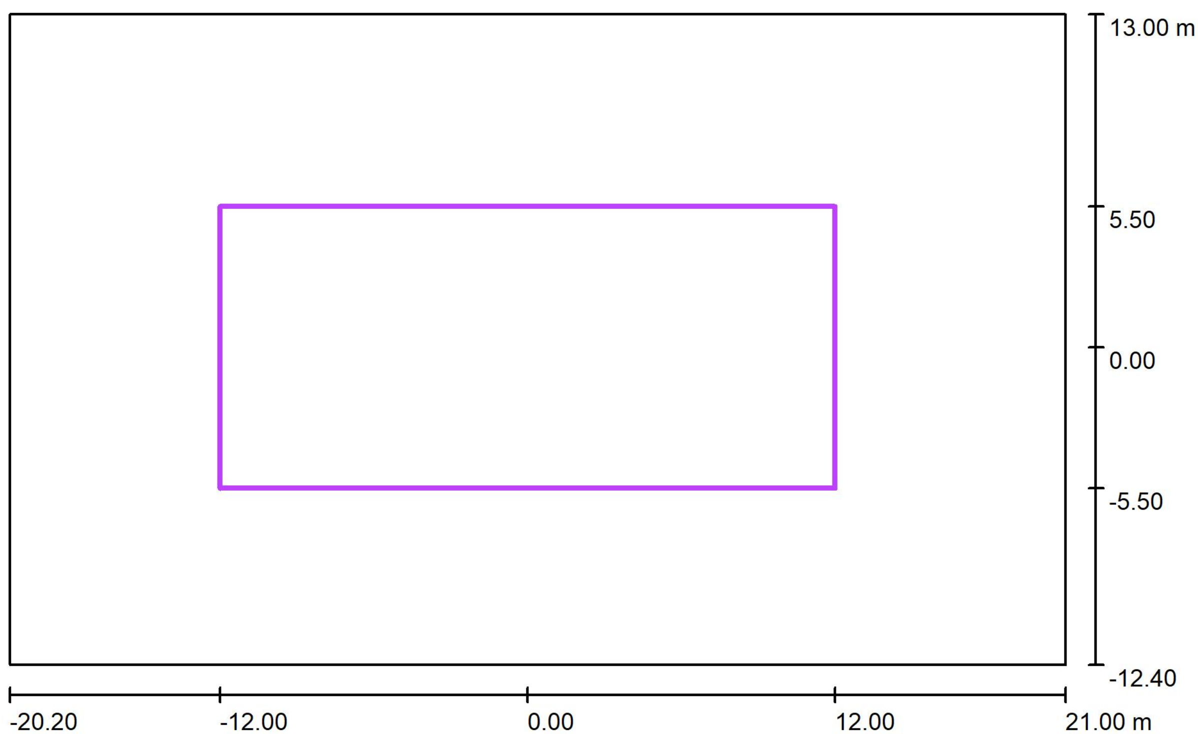
Grid: 19 x 10 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
291	209	407	0.72	0.51

Jadavpur university
Electrical Engineering Department
Jadavpur,Kolkata. 700032
I

Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid PPA / Summary



Scale 1 : 295

Position: (0.000 m, 0.000 m, 0.000 m)
Size: (24.000 m, 11.000 m)
Rotation: (0.0°, 0.0°, 0.0°)
Type: Normal, Grid: 13 x 6 Points

Results overview

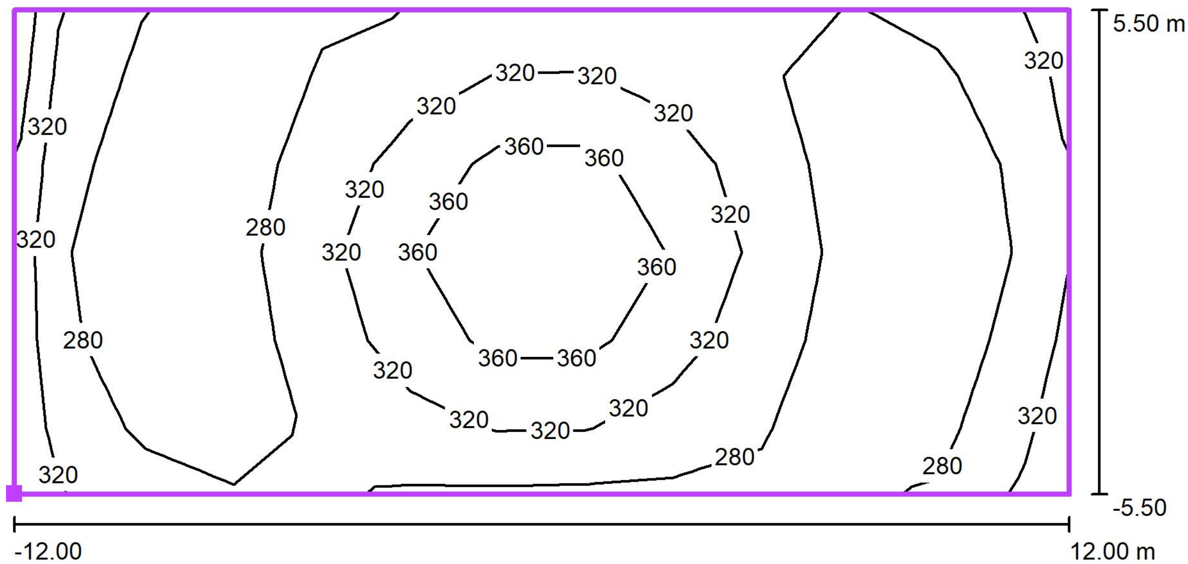
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	$E_{h\ m}/E_m$	H [m]	Camera
1	horizontal	301	248	407	0.82	0.61	/	0.000	/

$E_{h\ m}/E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

Jadavpur university
Electrical Engineering Department
Jadavpur,Kolkata. 700032
l

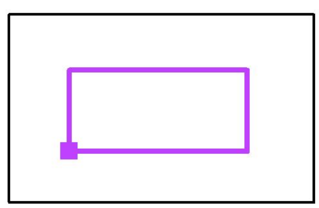
Operator Mr. Sagar Das
Telephone
Fax
e-Mail iamsagar12340@gmail.com

Exterior Scene 1 / Calculation Grid PPA / Isolines (E, Horizontal)



Values in Lux, Scale 1 : 172

Position of surface in external scene:
Marked point: (-12.000 m, -5.500 m, 0.000 m)



Grid: 13 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
301	248	407	0.82	0.61