Module 4

Lighting Application

Lesson 18

Lighting Calculations

Instructional Objectives

- List the issues for Lighting Calculations
- Learn the quick way of estimating recommended levels
- Understand the use of Iso-lux diagrams
- List the factors to be accounted for calculation
- What is room index

Lighting Calculations

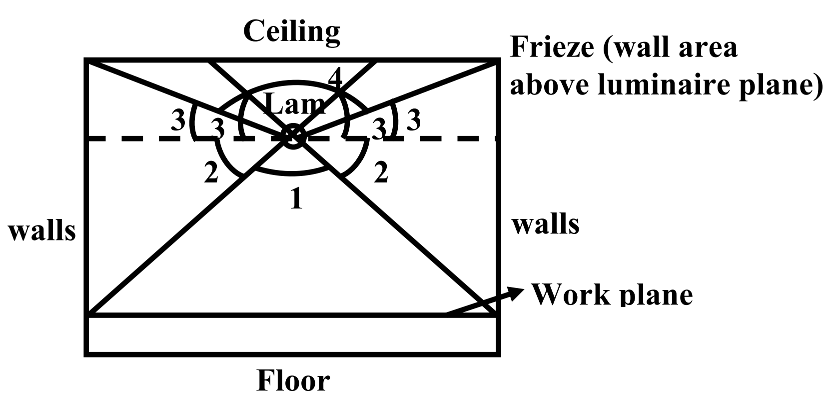
In order to do calculate, manufactures manuals data sheets are the first source. For the Engineer/Architect several softwares, fast, accurate and convenient are available which rapidly assess requirements on field. One should be able to check if software is giving right solution! This needs understanding of long hand calculations discussed in this lesson. Various issues involved are Illuminance – horizontal and vertical may be got from Tables. Also given in the form of graphs, called Isolux diagrams. The other issue is the Luminance of the source in question.

Horizontal Illuminance

Specified as Average illuminance on the work plane while Sitting 0.75 – 0.9m above floor and while Standing 0.85 – 1.2m above floor.

Thus $E_{ar} = \dfrac{\phi_{tot}}{A}\ \text{U.F.} \times \text{M}$, where

E = Average horizontal illuminance in lux.
ϕ = Total light output in Lumens.
A = Area in m^2
U.F = Utilization factor
M = Maintenance factor



1 – work plane, 2 – wall area below the luminaire, 3 – on the frieze, 4 – ceiling

Fig. 1 Schematic showing various zones in an interior of a room.

Utilization Factor UF depends on Light distribution of luminaire, Reflectance of ceiling, walls and Room Index K. Room surface reflectance which depends on the dimensions shown in Fig. 1 is specified in the form of reflectance code as given in the next section

Reflectance code

Code 7751 connotes a reflectance from Ceiling of 0.7, Frieze of 0.7, Walls of 0.5 and work plane of 0.1. Similarly 751 denote reflectance from Ceiling of 0.7, Walls of 0.5 and Work plane of 0.1. That is to say there is no frieze at all. If not known or available average value of 753 is taken for a room with light colors.

If l = length, b = breadth then the h_m = Mounting height of luminaires.

Room Index $$k = \frac{lb}{h_m(l+b)}$$

Table I lists the minimum number of luminaries required for different room indices, if there be M luminaries length wise and N luminaries width wise.

Table I

K	0.6	0.8	1.0	1.25	1.5	2.0	2.5	3.0	4.0	5.0
M	2	2	3	3	4	4	5	6	8	10
N	1	2	2	3	3	4	4	4	5	6

Direct component at a point p due to a point source is as already discussed is shown in Fig. 2 and that due to a line source is shown in Fig. 3.

$$E_p = \frac{I_\alpha}{h_m^2}\cos^3\alpha$$

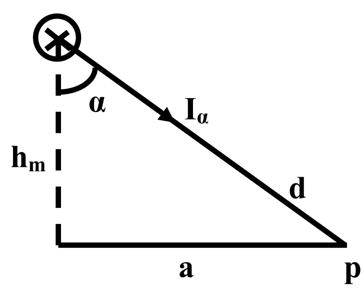
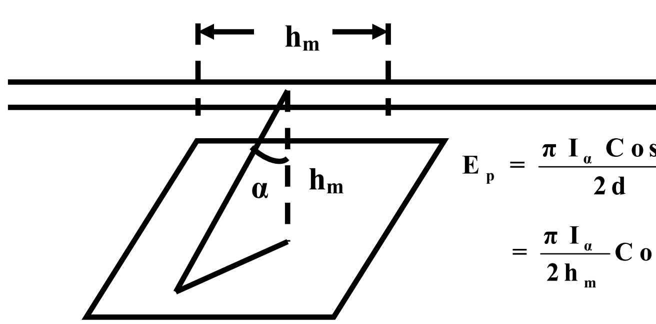


Fig. 2 Illuminance due to a point source

Linear source of infinite length



$$E_p = \frac{\pi I_\alpha \cos\alpha}{2d} = \frac{\pi I_\alpha}{2h_m}\cos\alpha$$

Fluorescent lamp

Fig. 3 Illuminance due to line source.

Calculating from Isolux diagram involves no of steps. Let us consider source placed at P be a point source. Then place the Isolux diagram on that plane.

Step1. From the luminous intensity table for the luminaire calculate illuminance on the working plane and distances to each point.

Step2. Plot E and a using this 2 illuminance distribution curves draw isolux curves as shown.

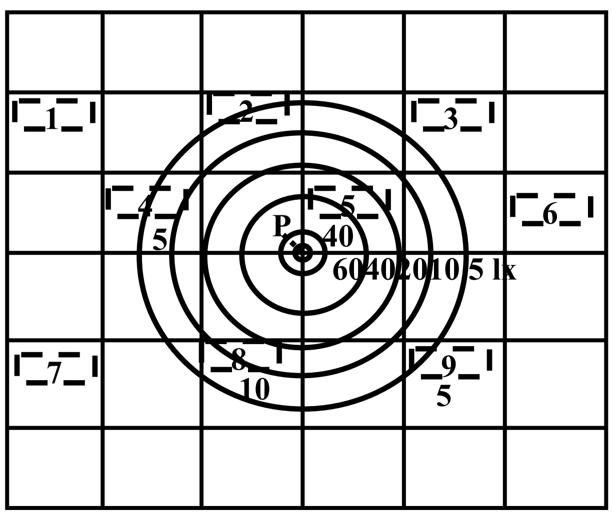
Step3. Extend to four quadrants using tracing or transparent paper. Then

Step4. Place isolux diagram on the plan of the luminaire layout. Positioning: centre over the point of interest. Sum the illuminance.

Step5. If 1000 lumens per luminaire is assumed,

$$E_p = \frac{\phi_n E}{1000}$$

N = no. of lamps per luminaire
E = value from step 4.



5 – 40
4 – 5
8 – 10
9 – 5

Ep$_e$ 594
n = 3
3300 = ϕ

Fig. 4 Typical Isolux diagram

Indirect component at ‘p’

$$E_{ind} = \frac{\phi}{\sum F_n} \frac{e_{av}}{1 - e_{av}}$$

ϕ = light flux leaving in lumens.

$\sum F_n$ = total area of the room surfaces

e_{av} = average reflectance of the surface.

$$e_{av} = \frac{\sum e_n F_n}{\sum F_n}$$

Where en = reflectance of the nth surface

Vertical Illuminance

It becomes important in case of an Average wall, wall mounted object, black board – chalk board and wall display in a shop.

Illuminance is given by

$$E_{av} = \frac{\phi_{tot}}{A} \; (R)n_w M$$

Where ϕ = Luminous Flux – Lumens,

A = Area of the work plane,

$(R)N_W$ = U.F,

M = maintenance Factor.

Figure 5. shows the vertical illuminance at a point ‘P’

Direct component at a point P

$$E_p = \frac{I_\alpha}{h^2} \text{Cos}^2\alpha \, \text{Sin}\alpha$$

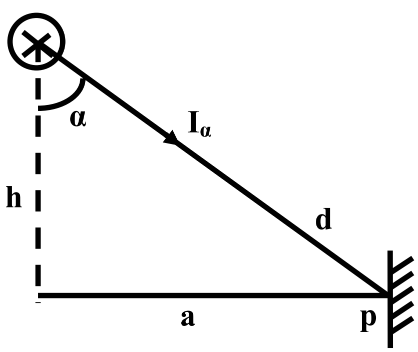


Fig. 5 Vertical Illuminance due to a point source

At any point total Illuminance due to all luminaries is given by

E_P (total) = $E_1 + E_2 + \ldots + E_n$

Linear sources Permanent length

$$E_p = \frac{\pi I\alpha}{2h} \text{Sin}\alpha \, \text{Cos}\alpha \qquad \text{Infinite Length}$$

$$= \frac{\pi I\alpha}{2a} \text{Sin}^2\alpha$$

$$I_\alpha = \frac{\phi}{9.25} \qquad \text{Finite Length}$$

Luminaire Luminance

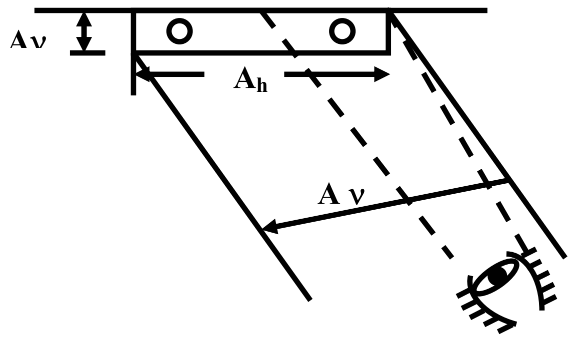


Fig. 6 Luminaire Luminance Calculation

$$L_\nu = \frac{I_\nu}{A_\nu} \rightarrow \text{Apparant area}$$

$$A_\nu = A_h \text{Cos}\nu + A_\nu \text{Sin}\nu$$

1000 Lumen – $0 < \nu < 85^o$

Lecture Summary

- Illuminance level depends on the nature of working environment & is specified in terms of horizontal, vertical & inclined illuminance. These are obtained graphically from numerical tables.
- Isolux diagrams are used for calculation of illumnance & luminance levels
- A room can be divided into four zones for calculation of illumination level :
    - work plane
    - wall area below luminaire
    - on the fieze (wall area above luminaire)
    - ceiling
- Horizontal illuminance is given by:

$$E_{avg} = \frac{\phi_{tot}}{A} \times UF \times M$$

- Utilization Factor (UF) depends on:
    - light distribution of luminaire
    - reflectance of ceiling / walls
- Room index (k) is given by : $k = \frac{l \times b}{h_m \times (l + b)}$
- Vertical Illumination is given by:

$$E_{avg} = \frac{\phi_{tot}}{A} \times UF \times M$$

- Luminaire Luminance is given by: $L_\gamma = \frac{I_\gamma}{A_\gamma}$

Where A_γ is the apparent area in the specified direction & is given by

$$A_\gamma = A_h \times \cos\gamma + A_v \times \sin\gamma$$

Tutorial Questions

- What do you mean by surface reflectance of 7751 & 751?
- What are isolux diagrams?
- What do you mean by fieze?

Answer to Questions of previous Lecture

- What is silhouette?

  It is brightness towards the observer rather than illuminance on the road surface.

- Why do lamps have asymmetrical light distribution on roadways? How is it achieved?

  We have light directed towards the street only with ample light on the pavement to enhance the aesthetics of the buildings & lower level of lighting on the street. Asymmetrical distribution is achieved by use of reflectors, refractors & prisms.

- On what factor does the arrangement of luminaires depend?

  It depends on the electrical aspect. We may have one side or opposite or staggered lighting depending on the number of circuits available. Optimization is achieved by using double lamps at middle of road.

- What is the importance of supplementary lighting in tunnels?

  While entering or coming out of the tunnel drivers may face problem due to abrupt change in brightness. So supplementary lighting are used to avoid abrupt changes.