EET402 ELECTRICAL SYSTEM DESIGN & ESTIMATION

MODULE 2

Lighting design calculations: Definitions of luminous flux, Lumen, Luminous intensity/ illuminance (Lux). Illumination calculations, factors affecting Coefficients of Utilisation (COU) and Light Loss Factor (LLF).

Benefits of LED lamps over the yesteryear luminaires, Efficacy of present day LED lamps.

Design of illumination systems: Average lumen method, Space to mounting height ratio.

Design of lighting systems for a medium area seminar hall using LED luminaires

Exterior lighting design: point to point method, road lighting and public area lighting, Space to mounting height ratio

Selection of luminaires, Metal Halide lamps, High & Low pressure Sodium lamps, LED lamps

Principles of good lighting

- Good lighting is necessary for all buildings & has the primary aim viz

i) Promote work & other activities carried on within the building

ii) Promote safety of people using the building

iii) Create, in conjunction with the structure & decoration, a pleasing environment conductive to interest & sense of well being

Realization of these aims involve:

a) Careful planning of brightness & colour patterns within the working area & surrounding so that attention is drawn naturally to the important areas

b) Using directional lighting to assist perception of task detail & to give good modelling

c) Controlling direct & reflected glare from light sources to eliminate visual discomfort

d) Minimizing flicker from certain types of lamps in artificial lighting installations & paying attention to colour rendering properties of lights

e) Corelating lighting throughout the building to prevent excessive difference between adjacent areas so as to reduce the risk of accidents

f) Installing emergency lighting systems where necessary

Good lighting design shall take into account the following

a) Planning the brightness pattern from point of view of visual performance, safety & surroundings

b) Form & texture in the task areas & surroundings

c) Controlling glare & flicker

d) Colour rendering

e) Lighting for movement

f) Provision for emergency

g) Maintenance factor in lighting installations

h) Maximum energy effectiveness of the lighting system

Terminologies used

Light : It is that radiant energy which produces a sensation of vision upon the human eye

Luminous flux (F) **:** Light energy radiated per second from a source over visible wavelength. Its unit is lumen.

*Lumen***:** Lumen is the unit of luminous flux. It is defined as the flux contained per unit solid angle of a source of one candela or standard candle

1 Lumen = 0.0016Watt (approx.)

Luminous intensity (I) or candle power : The power or strength of light source is known as luminous intensity. Its unit is candela.

Luminous intensity of a light source= Total lumen output of lamp/4π

Illuminance (E) or illumination : It is the luminous flux per unit area. It is a measure of the light falling on a surface. Illuminance is measured in lux.

*The Steradian***:** This is like a three-dimensional radian, sometimes called the unit solid angle. The steradian is the solid angle subtended at the centre of a sphere by surface areas equal to r^2.

Laws of illumination

1. Illuminance at a point on a plane is directly proportional to the luminous intensity of the source

i.e, E α I

2. Inverse square law of illuminance

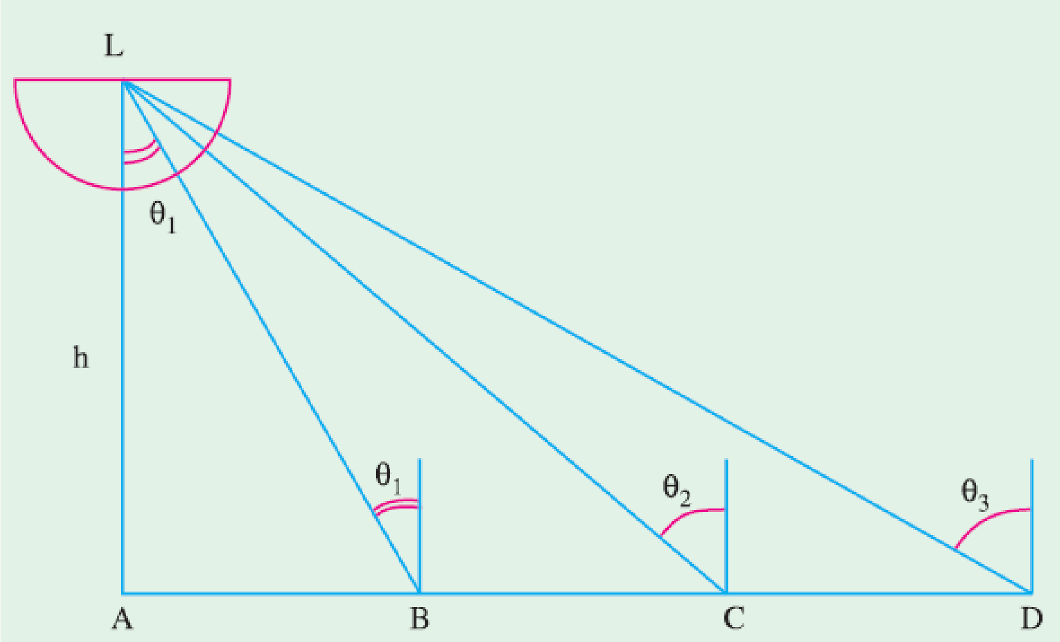
- This law states that the Illuminance (E) at any point on a plane is inversely proportional to the square of the distance between the source and plane
- i.e, $E \propto 1/d^2$

3. The cosine law of illuminance

- This law states that the illuminance (E) at a point on a plane is directly proportional to the cosine of angle between the normal at that point & the direction of luminous flux

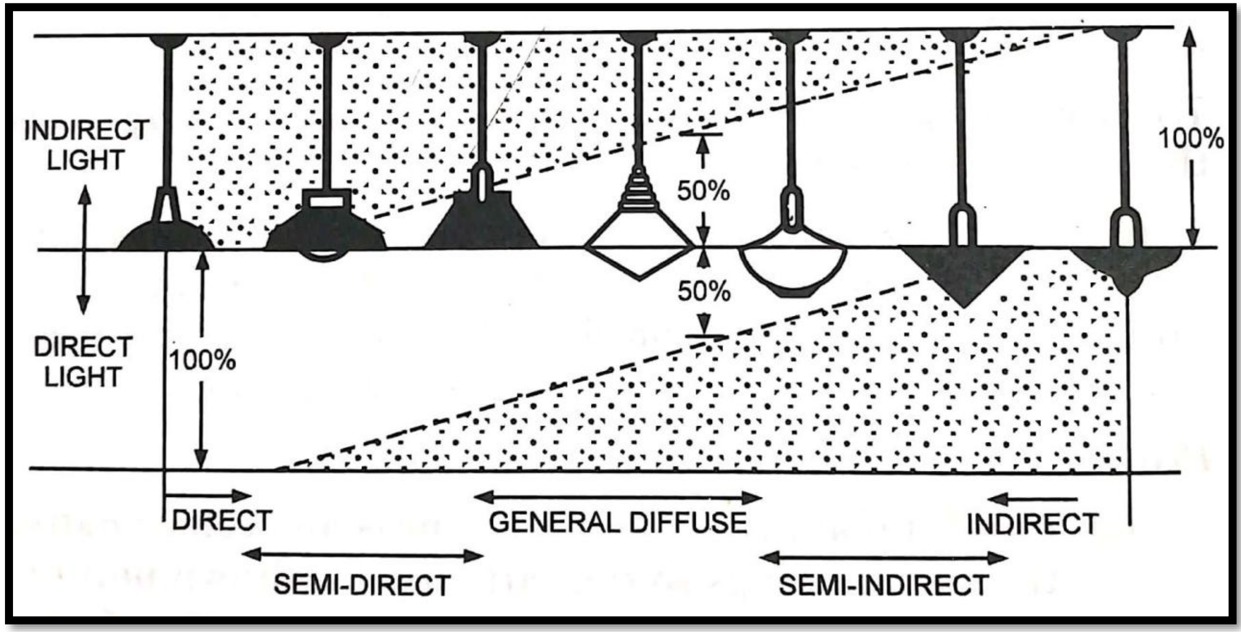
i.e, $E \propto \cos\theta$

Combining the 3 laws, $E = (I/d^2)\cos\theta$



Types of lighting schemes

- The distribution of light emitted by lamps is usually controlled to some extent by means of reflection & translucent screens or even lenses



- The interior lighting schemes may be classified as

a) Direct lighting

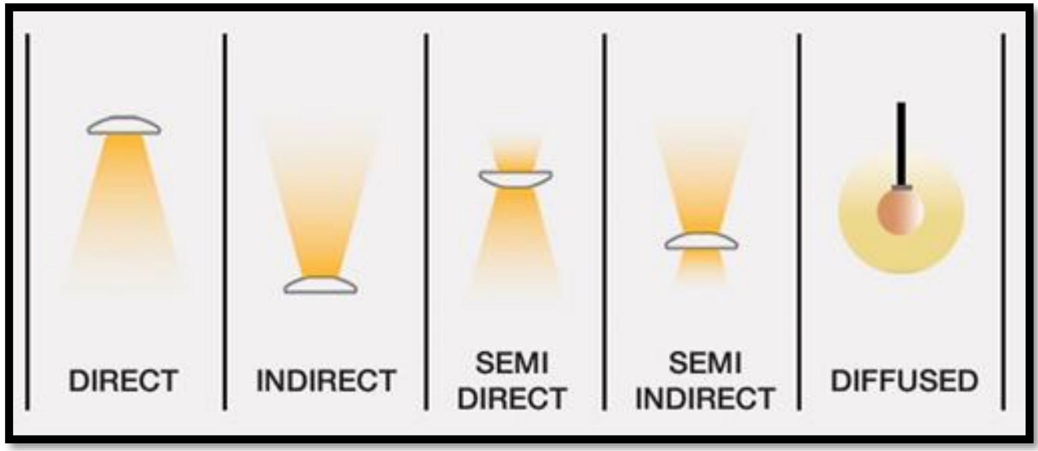
- It is the most commonly used type of lighting scheme
- In this lighting scheme more than 90% of total light flux is made to fall directly on the working plane with the help of direct reflectors
- Though it is most efficient, it causes hard shadows & glare
- It used for industrial & general outdoor lighting

b) Semi-direct lighting

- In this lighting scheme, 60 to 90% of the total light flux is made to fall downwards directly with the help of semi-direct reflectors, remaining light is used to illuminate the ceiling where a high level of uniformly distributed illumination is desirable
- Here glare is avoided by using diffusing globes

c) Semi-indirect lighting

- In this lighting scheme, 60 to 90% of total light flux is thrown upward to the ceiling for diffuse reflection & rest reaches the working plane direct
- This lighting scheme is with soft shadows & glare free
- It is mainly used for indoor light decoration purposes



d) Indirect lighting

- In this lighting scheme, more than 90% of total light flux is thrown upwards to the ceiling for diffuse reflection by using inverted or bowl reflectors
- In such a system the ceiling acts as the light source & the glare is reduced to minimum
- The resulting illumination is softer & more diffused, the shadows are less prominent & appearance of the room is much improved
- It is used for decoration purposes in cinemas, theatres, hotels etc.

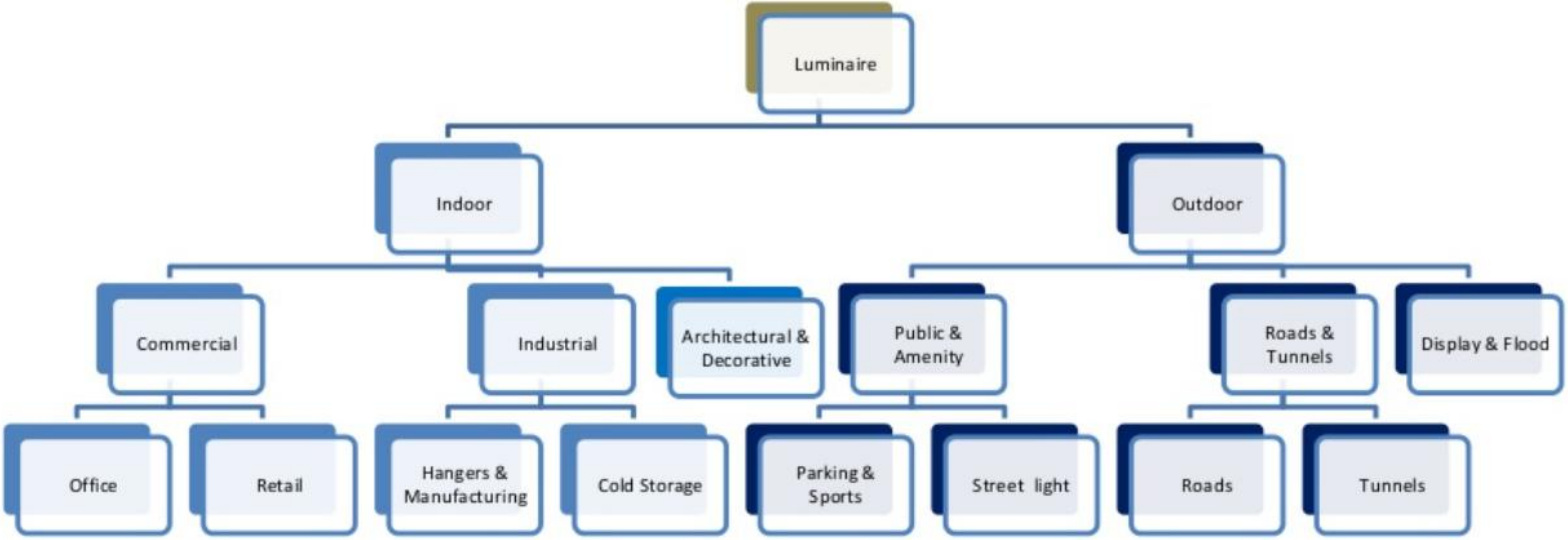
e) General lighting

- In this scheme, the lamps made of diffusing glass which give nearly equal illumination in all directions

Classification of luminaires

a) Classification based on the application

- Based on application, luminaires are generally classified into indoor & outdoor



1. **Indoor lighting luminaires** : These are luminaires used for indoor lighting applications. They are again classified into the following.

1.1 *Commercial lighting* : These are luminaires used for lighting commercial buildings. They are again classified into 2

1.1.1 Office : These are usually low power systems & mostly CFL or LED lights are used.

1.1.2 Retail : Here prime consideration is lighting quality which support the shopping experience & maintenance. Mostly LED, CFL, HID lamps are used.

1.2 *Industrial lighting* : Here prime consideration is high intensity illumination, energy saving & maintenance cost. Common lighting solutions are LED, HID, fluorescent lamps etc.

1.2.1 Hangars & manufacturing industrial lighting : Here ceiling can have a height of 7 to 10 m or higher. Special luminaires are required for each lamp due to unique lamp shade & dimension. A typical luminaire type is highbay.

1.2.2 Cold storage industries : Here prime considerations are maintenance & relamping cost. The popular solutions are metal halides. Advised light colour is yellow for better visibility in frost mist.

1.3 Architectural & decorative lighting : Here prime considerations are light quality, light angle, initial cost & maintenance. LED, halogen, CFL etc. are commonly used.

2. Outdoor lighting luminaires : These are luminaires used for outdoor lighting applications. Here we have to consider maintenance cost, public safety, IP protection of lamp etc. They are classified as

2.1 Public & amenity : these are again classified as

2.1.1 Parking & sports : Here main considerations are illumination coverage, light beam orientation, light quality & maintenance cost.

2.1.2 Street light : Here prime consideration is orientation & light coverage with low maintenance. LED, HID lamps are commonly used.

2.2 Roads & tunnel

2.2.1 Roads : Road lighting is characterized by high wattage light source depending on road width & traffic volume. In regions with mist & fog, a yellow lighting is advised for better visibility.

2.2.2 Tunnels : Key criteria for tunnel lighting is maintenance cost. Normally flat or wall packed types are used.

2.3 Display & flood lighting : Here major concern is luminaire grade for superb illumination quality, system maintenance due to high ground locations

b) Classification of luminaires based on protection offered against electric shock

- According to the type of protection provided against electric shock, they are classified into 3

1. Class I : Here along with the mains insulation, an additional protection in the form of earthing the conductive body parts of the light fitting is provided.
2. Class II : Here along with the mains insulation, an additional protection is provided in the form of double insulation.
3. Class III : Here protection is provided by making the light fitting to operate at a low safety voltage

Coefficient of Utilization (CU)

- Coefficient of Utilization (CU) or Utilization factor is a factor used to determine the efficiency of a lighting fixture in delivering light for a specific application
- *The coefficient of utilization of a lamp is defined as the ratio of light output from the lamp that reaches the workplace to the total light output of the lamp*
- *Factors influencing CU are*
  - The efficiency of luminaire
  - The luminaire distribution
  - Geometry of space
  - The reflectance of the room surface

Light Loss Factor (LLF) or Maintenance factor(MF)

- A Light Loss Factor is a multiplier that is used to predict future performance (maintained illuminance) based on the initial properties of a lighting system.
- LLF = 1 – Expected Depreciation
- Light loss factor is also known as Maintenance factor (MF).

- Depreciation factor = 1/maintenance factor
- The Total LLF is determined by multiplying the independent effects of multiple factors
- The various factors that contribute to light loss are of 2 types

1. Recoverable factors
2. Non recoverable factors

The recoverable factors include

a) Luminaire Dirt Deprecation

- The greatest loss of light output is due to the dirt accumulation on lamps & luminaire reflecting surface
- Proper selection of maintenance schedule can greatly this factor
- In general, the following guidelines may be followed for maintenance schedule
    - Air conditioned spaces – once in 2 years
    - Non A/C rooms, school etc. – once in a year
    - Industrial areas – 3-6 times a year
    - Food preparation area – every week

b) Room surface dirt depreciation

- This factor takes into account the dirt or dust accumulation on surfaces
- A proper schedule for cleaning the reflecting surface must be followed to maintain the reflectance

c) Lamp lumen depreciation

- Lamp lumen depreciation is an inherent characteristic of all lamps
- Hence unless a suitable re-lamping policy is followed, the illumination level may be adversely affected.
- 2 types of re-lamping methods used are
  1. Spot re-lamping – Process of changing lamps when a lamp burns out
  2. Group re-lamping – Process of replacing all the lamps in an installation after useful life period of lamp

d) Lamp burn out

- A lamp is said to be burned out if it has stopped working permanently

Non-recoverable factors

- These include

1. Luminaire ambient temperature

- A variation in the ambient temperature does not have much effect on the incandescent lamp & high intensity discharge (HID) lamps
- However, fluorescent lamps are affected by a change in ambient temperature
- Fluorescents produce peak output at about 25°C

2. Voltage variation factor

- For incandescent lamps, a voltage variation of 1% may cause as much as 3% variation in light output
- For HID & fluorescents also variation in voltage affects their output

3. Ballast factor

- It is defined as the ratio of light output by a commercial ballast to that by reference ballast
- If the ballast used in the luminaire is different from that specified by the manufacturer, light output will differ

4. Luminaire surface depreciation factor

- Changes in the various components used in the manufacture of luminaires can cause reduction in light output
- For example, due to ageing, the painted or polished surface will have reduced reflectance.
- Similarly plastic louvers tend to turn yellow, thereby reducing the light output

All these 4 non recoverable factors will depreciate the output permanently & nothing can be done to recover them

Luminous efficacy of a lamp or Lamp efficacy

- It is the ratio of the light output from a light source to the power consumed
- Measured in lumens per Watt (lm/W).
- The higher the efficacy value of a lamp or lighting system, the more energy-efficient it is.

Quality of lighting

- Quality assessment in lighting is related to measurement of glare, color appearance & modelling
- Glare can be broadly classified into 2 types
  - Direct glare – it comes into picture with all tasks with heads up position
  - Indirect glare – it comes into picture with tasks that involve heads down position
- Color rendering : it is the general expression for the effect of a light source on the color appearance of object

Space to mounting height ratio

- Space to mounting height ratio = $\dfrac{\text{Horizontal distance between two lamps}}{\text{mounting height of lamps}}$

- To obtain a uniform illumination on the working plane, it is essential to choose a correct value of this ratio
- For reflectors normally used in indoor lighting, the value of this ratio lies between 1 & 2

Methods of lighting calculation

- Lighting design is the process of selecting the right kind of luminaries to produce light of the required quantity & quality at the right location
- All light designs are related to 2 major considerations

  a. Quantity of lighting

  b. Quality of lighting
- There are 2 basic design techniques to determine quantity of illuminance. They are

1. Point by point method

- This method permits determination of illumination level due to one or more source upon a specific point within an area
- Here the lighting calculations are done by using the equation, $E = (I/d^2)\cos\theta$

Q1. A point source produces 3000 cd in the direction of interest. The angle of incidence with respect to the vertical is 30°. Determine the illuminance at a point 5m away from the light source.

The illuminance, $E = (I/d^2)\cos\theta = (3000/5^2) \times \cos 30 = 103.92$ lux

2. Average lumen method

- This method offers a much more simplified way of calculating an average uniform illuminance level on a plane in interiors
- By this method the illuminance on a surface is given by, $E = \frac{L_n \, x \, N \, x \, CU \, x \, LLF}{A}$

where, E = illuminance

L_n = initial lumen output per luminaire

N = Number of luminaire

CU = Coefficient of Utilization

LLF = Light Loss Factor (Also known as Maintenance factor)

A = Area in square meter

- The number of luminaires required, $N = \frac{A \, x \, E}{L_n \, x \, CU \, x \, LLF}$
- From above equation, it is clear that for a given level of illuminance & area, the only means of reducing the number of luminaires is by using the highest values of Ln, CU & LLF
- The lower the number of luminaires, the less the power consumption

Design considerations of good lighting scheme

- In designing a good lighting scheme, we have to consider mainly

a) The intensity of illumination required

b) The selection of the required lamp & fittings

c) The size of the room

d) The conditions under which the illumination is used

a) The intensity of illumination required

- The intensity of illumination required for different types of work differ
- The recommended level of illumination for different type of buildings as per NEC is available in Data hand book (Table number 4,5,6,7 & 8)

b) The selection of the required lamp & fittings or luminaires

- A luminaire is the apparatus which distributes, filters or transforms the light given by a lamp or lamps
- It includes all the items necessary for fixing & protecting the lamps & for connecting them to the supply
- The choice of lamps for different types of occupancies differ
- In small premises, tubular fluorescent lamps or filament lamps can be used

- In large premises, HID lamps can be used
- The linear output of lamp can be modified by using suitable reflectors & diffusers
- Depending upon the type of illumination required (direct, indirect etc.) the type of reflector is decided

c) Size of the room

- To consider the condition of room (size & shape of room, reflection factors, arrangement of fittings etc.) the factor Coefficient of Utilization is used

d) The conditions under which the illumination is used

- To consider the condition of use (dust & dirt deposition, decrease in light output with time), the factor called Maintenance factor is used

Design procedures (Refer page No. 3 – 6 in Data handbook)

- The best option available for lighting design is the use of standard lighting software
- If no such facility is available, one of the following technique may be used
  1. Short hand method
  2. Long hand method
  3. Simplified method

1. Short hand method

- Here it is assumed that the average maintained quantity of lumens arriving on the work plane will be half the quantity of the total new lamp lumens
- This method assumes normal sized rooms, normal surface reflection & normal dirt conditions
- A normal sized room is one in which the mounting height is less than half the smallest room dimension
- It also assumes that conventional light fixtures are used
- High bay fixtures are used when the mounting height is over 6m, otherwise low bay fixtures are used

- The total number of fixtures (luminaires) to be used can be calculated as follows

Step 1 : Obtain the required level of illumination in lux

Step 2 : Choose a particular lamp & obtain the lamp lumens from the lamp data

Step 3 : Delivered maintained lamp lumen (DMLL) = 0.5 x rated lamp lumen

Step 4 : Number of fixtures = (Room area x Lux)/DMLL

Step 5 : Area per fixture = Room area/number of fixtures

Step 6 : Spacing between fixtures = √(Area per fixture)

Check

- Spacing should not be more than the mounting height for high bay fixtures & 1.5 times the mounting height for low bay fixtures
- If the spacing is too large, go back to step 2 & start again with a lower lamp rating

2. Long hand method

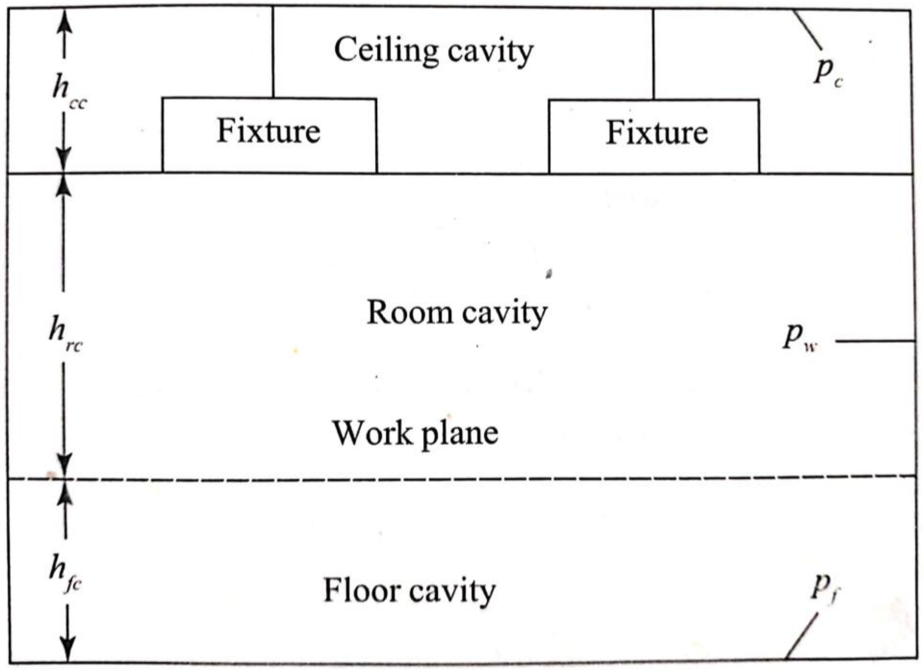
- This is a more accurate & effective method of estimating the number of fixtures & their spacing
- Because this method takes into account the differences in photometric performance caused by room geometry & system lumen depreciation
- The core idea of this method is the determination of coefficient of utilization (CU) by dividing the area to be lightened into 3 cavities/spaces that have effective reflectance w.r.to each other & work plane as shown in figure
- The space between ceiling & the bottom of luminaire is known as ceiling cavity
- The space between the work plane & bottom of luminaire is room cavity
- The space between work plane & the floor is floor cavity
- The cavity ratios represent the geometric properties of the ceiling, room & floor cavities & that can be found using the formula,

Cavity ratio = (2.5 x h(perimeter))/Area

where, h =hcc, for ceiling cavity ratio

= hrc, for room cavity ratio

= hfc, for floor cavity ratio



Step 1 - Study the site plan & elevation of the installation. Determine the lighting needs in consultation with standards & end user

Step 2 – Select the light sources & luminaire, appropriate to the installation geometry, nature of visual task & energy criteria

Step 3 – Calculate the ceiling, room & floor cavity ratios & using table 17 find out the effective ceiling & floor cavity reflectance

Step 4 – Use the given chart for coefficient of utilization, the effective ceiling & floor reflectance & RCR, find out the value of effective coefficient of utilization

Step 5 – Select the light loss factor, this factor was previously referred to as maintenance factor. Generally accepted values are

A/C rooms, clean rooms etc - 0.8

Industrial environment - 0.7

Dusty areas - 0.6

Step 6 – Use the formula to arrive at the quantity of luminaires

Number of luminaires = (Area x Illumination)/(CU x LLF x Lumen output of luminaire)

Step 7 – Arrange the luminaires symmetrically giving due considerations to spacing criterion to achieve uniformity of illumination

Area per luminaire = room area/number of fixtures

Therefore, fixture spacing = √(area per fixture)

Check

- Spacing should not be more than the mounting height for high bay fixtures & 1.5 times the mounting height for low bay fixtures
- If the spacing is too large, go back to step 2 & start again with a lower lamp rating

3. Simplified design procedure

- A simplified lighting design procedure by lumen method for a simple interior is given below

Step 1 – Study the site plan & elevation of the installation. Determine the lighting needs in consultation with standards & end user

Step 2 – Select the light sources & luminaire, appropriate to the installation geometry, nature of visual task & energy criteria

Step 3 – Calculate the Room Index using the formula

Room Index (RI) = (Length x Breadth)/((Length + Breadth) x Mounting height)

Step 4 – Based on this, coefficient of utilization value can be obtained from the C.O.U. table for the selected luminaire. These values are generally based on the RI & room surface reflectance which are generally 70% for light colored, 50% for average & 30% for dark walls & 50%, 30% & 10% for corresponding ceilings

Step 5 – Select the light loss factor (LLF), this factor was previously referred to as maintenance factor (MF). Generally accepted values are

A/C rooms, clean rooms etc - 0.8

Industrial environment - 0.7

Dusty areas - 0.6

Step 6 – Use the formula to arrive at the quantity of luminaires

Number of luminaires = (Area x Illumination)/(CU x LLF x Lumen output of luminaire)

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- Spacing should not be more than the mounting height for high bay fixtures & 1.5 times the mounting height for low bay fixtures
- If the spacing is too large, go back to step 2 & start again with a lower lamp rating

Arrangement of fixtures

- Fixtures shall be arranged from the middle of the room to the outside
- A square array is the best option but rectangular array also will work satisfactorily as long as the spacing to mounting height ratio is not violated
- With an odd quantity of fixture rows or columns, there will be a fixture line on the centre line.
- With even quantities of rows or columns, the locations are half the spacing of the centre line.
- The closest fixture to a wall should be one half the spacing or less

Q2. A small assembly shop 15m long, 9m wide & 3m up to trusses is to be illuminated to a level of 200 lux. The coefficient of utilization is 0.75 & maintenance factor is 0.8. Calculate the number of lamps required to illuminate the whole area if the lumen output of the lamp selected is 3000 lumens.

Ans:

Working area, A = 15m x 9m = 135m^2

Required illumination level, E = 200 lux

Lumen output of lamp, L_n = 3000 lumens

Coefficient of utilization, CU = 0.75

Maintenance factor, MF = 0.8 = Light loss factor (LLF)

Number of lamps required, $N = \frac{A \; x \; E}{L_n \; x \; CU \; x \; LLF} = \frac{135 \; x \; 200}{3000 \; x \; 0.75 \; x \; 0.8}$ = 15 lamps

Q3. An office 30m x 15m is illuminated by 40W fluorescent lamps of lumen output 2700 lumens. The average illumination required at the work place is 200 lux. Calculate the number of lamps required to be fitted in the office. Assume coefficient of utilization to be 0.6 & depreciation factor 1.25

Ans:

Working area, A = 30m x 15m = 450m^2

Required illumination level, E = 200 lux

Lumen output of lamp, L_n = 2700 lumens

Coefficient of utilization, CU = 0.6

Maintenance factor, MF or Light Loss Factor (LLF) = 1/Depreciation factor = 1/1.25 = 0.8

Number of lamps required, $N = \frac{A\ x\ E}{L_n\ x\ CU\ x\ LLF} = \frac{450\ x\ 200}{2700\ x\ 0.6\ x\ 0.8}$ = 69.44 ≈ 70lamps

(U)Q4. A certain incandescent lamp hangs from the ceiling of a room. The illuminance received on a small horizontal screen laying on a bench 2m vertically below the lamp is 63.5 lux. Calculate the illuminance at a point when the screen is moved horizontally a distance of 1.5m along the bench.

Ans: Assume that, initially screen is at position A

Illuminance at point A = E_A = 63.5 lux

Distance between screen & lamp = d_A = h = 2m

Luminous intensity of lamp = I = $E_A \times d_A^2$ (From inverse square law, $E = I/d^2$)

$= 63.5/2^2 = 254$ candela

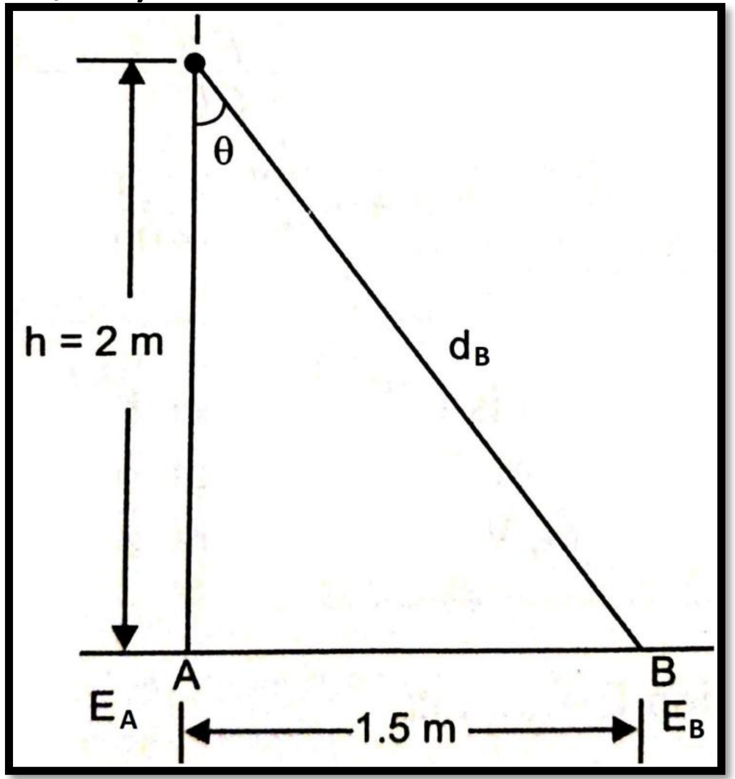
When the screen is moved horizontally a distance of 1.5m, let the new position be B

Now, the distance between lamp & screen = $d_B = \sqrt{(2^2+1.5^2)} = 2.5$m

Illuminance at point B = $E_B = (I/d_B^2)\cos\theta$

But $\cos\theta = h/d_B = d_A/d_B$

i.e, $E_B = (I/d_B^2) \times d_A/d_B = (I \times d_A)/d_B^3 = (254 \times 2)/2.5^3 = 32.5$ lux



Q5. Two light sources each having a uniform intensity of 600 cd are mounted 8m high & 30 m apart. Determine a) the illumination directly underneath one lamp b) the illumination at a distance midway between the lamps.

Ans: Luminous intensity of lamps = $I_1 = I_2$ = 600 cd

Mounting height, h = 8m

a) Illumination directly underneath the source 1, E = Illumination underneath source 1 due to source 1 + Illumination underneath source 1 due to source 2

Illumination underneath source 1 due to source 1 = I_1/d_1^2 (here d_1 = h) = $600/8^2$ = 9.4 lux

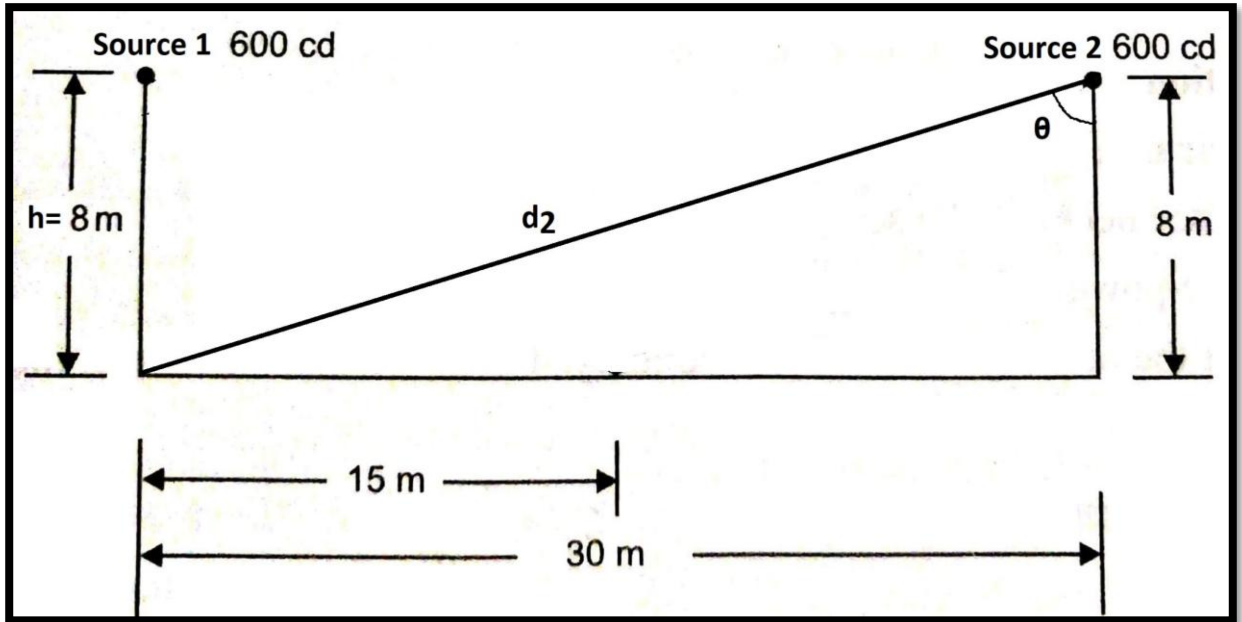
Illumination underneath source 1 due to source 2 = $(I_2/d_2^2)\cos\theta$

From figure, $d_2 = \sqrt{(30^2 + 8^2)}$ = 31m

$\cos\theta = 8/d_2 = 8/31 = 0.258$

Illumination underneath source 1 due to source 2 = $(I_2/d_2^2)\cos\theta = (600/31^2) \times 0.258$ = 0.161 lux

Illumination directly underneath the source 1, E = 9.4 + 0.161 = 9.561 lux



b) Illumination at midpoint due to the two sources

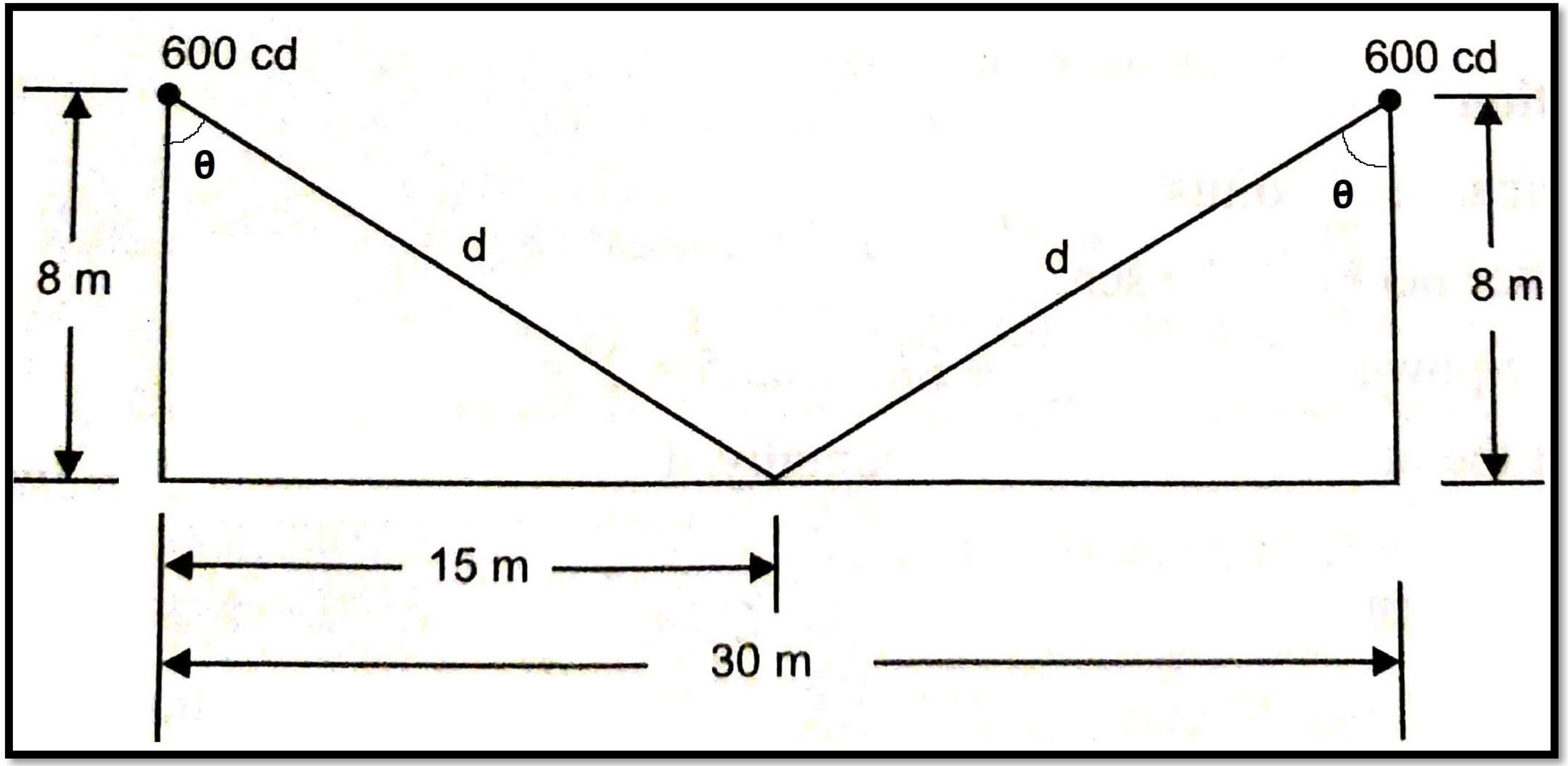
Distance between midpoint & each light source, $d = \sqrt{(15^2 + 8^2)} = 17m$

$\cos\theta = 8/17 = 0.47$

Now, Illumination at a midpoint due to the two sources,

E = illumination due to source 1 + illumination due to source 2

$= (I_1/d^2)\cos\theta + (I_2/d^2)\cos\theta = (600/17^2) \times 0.47 + (600/17^2) \times 0.47 = 1.95$ lux



Q6. An illumination of 50 lux is to be produced on the floor of a room 12m x 9m. 36 lamps are required to produce this illumination in the room, if 50% of the emitted light falls on the floor. What is the power of the lamp in candela?

Ans:

The illumination required, E = 50 lux

Working area, A = 12m x 9m = $108m^2$

Number of lamps, N = 36

Coefficient of utilization, CU = 0.5

Assume maintenance factor or LLF = 1

Lumen output of the lamp, L_n = $\frac{A\ x\ E}{Nx\ CU\ x\ LLF}$ = $\frac{108\ x\ 50}{36\ x\ 0.5\ x\ 1}$ = 300 lumen

Power of lamp in candela = Lumen output of lamp/4π = 300/ 4π = 24 cd

(U)Q7. An office 30m x 15m is illuminated by twin 40W fluorescent luminaires of lumen output 5600 lumens. The lamps being mounted at a height of 3m from the work plane, the average illumination required is 240 lux. Calculate the number of lamps required to be fitted in the office, assuming the CU 0.6 and maintenance factor to be 0.8. Assume the height of ceiling as 4.5m.

Ans:

Working area, A = 30m x 15m = 450m^2

Required illumination level, E = 240 lux

Lumen output of lamp, L_n = 5600 lumens

Coefficient of utilization, CU = 0.6

Maintenance factor, MF or Light Loss Factor (LLF) = 0.8

Number of lamps required, $N = \frac{A\ x\ E}{L_n\ x\ CU\ x\ LLF} = \frac{450\ x\ 240}{5600\ x\ 0.6\ x\ 0.8}$ =40.18 ≈ 40 lamps

(U)Q8. A shop 16m x 10m is illuminated with 200W incandescent lamps. If a CU of 0.8 and an MF of 0.75 are selected and an illumination of 260 lux is required at the work place, calculate the number of luminaires required. Take the mounting height as 2m.

Ans:

Working area, A = 16m x 10m = 160m^2

Required illumination level, E = 260 lux

Lumen output of 200W incandescent lamp can be found from the Table 9 in Data handbook.

From data handbook, Lumen output of 200W lamp = 2300 lumen

Coefficient of utilization, CU = 0.8

Maintenance factor, MF or Light Loss Factor (LLF) = 0.75

Number of lamps required, $N = \frac{A\ x\ E}{L_n\ x\ CU\ x\ LLF} = \frac{160\ x\ 260}{2300\ x\ 0.8\ x\ 0.75}$ =30.15 ≈ 30 lamps

Q9. A classroom measuring 6.5m x 8m is to be provided with an illumination level of 300 lux. The height of the ceiling is 4.5m. The height of the working plane is 1m above floor level. The ceiling/wall/floor reflectance are 70/50/20. Design a lighting scheme for the classroom using general purpose 2x40W fluorescent fixtures whose coefficient of utilization chart is given below. Assume that the luminaires are suspended from the ceiling at 1m below the ceiling level. The light loss factor (LLF) may be taken as 0.70. Spacing of lamps shall not exceed the mounting height. Initial lamp lumens = 4000.

Ans: *Since RCR values are given in table, we need to use long hand method*

Step 1 :

Ceiling cavity height, h_{cc} = 1m

Floor cavity height, h_{fc} = 1m

Room cavity height, h_{rc} = 2.5m

Step 2 :

Ceiling cavity ratio (CCR)

$= 2.5 \times h_{cc} \times (\text{perimeter/area})$

$$= 2.5 \; x \; 1 \; x \; \frac{(6.5+8)x2}{6.5 \; x \; 8} = 1.4$$

Coefficient of utilisation

(20% effective floor cavity reflectance)

Effective ceiling cavity reflectance	80%			50%		
Wall reflectance	50	30	10	50	30	10
RCR						
10	0.33	0.26	0.22	0.31	0.26	0.22
9	0.43	0.35	0.27	0.40	0.35	0.29
8	0.58	0.42	0.35	0.48	0.42	0.36
7	0.58	0.50	0.42	0.55	0.48	0.42
6	0.64	0.57	0.49	0.61	0.54	0.47
5	0.72	0.65	0.59	0.65	0.60	0.56
4	0.77	0.71	0.64	0.71	0.65	0.60
3	0.82	0.76	0.70	0.74	0.69	0.63
2	0.87	0.82	0.77	0.78	0.74	0.70
1	0.91	0.87	0.83	0.81	0.78	0.75

Similarly,

Floor cavity ratio (FCR) = 1.40

Room cavity ratio (RCR) = $2.5\ x\ 2.5\ x\ \frac{(6.5+8)x\ 2}{6.5\ x\ 8}$ = 3.5

Step 3:

By referring to the table 17 in data handbook,

- Corresponding to ceiling/wall reflectance of 70%/50% and CCR of 1.4 and effective ceiling cavity reflectance is 55%.

Table 17: PERCENTAGE EFFECTIVE CEILING OR FLOOR REFLECTANCES

(Source: IES lighting handbook-1981)

EFFECTIVE CAVITY REFLECTANCE

BASE REFLECTANCE PER CENT	90									
WALL REFLECTANCE PER CENT	90	80	70	60	50	40	30	20	10	0
ROOM CAVITY RATIO										
0.2	89	88	88	87	86	85	85	84	84	82
0.4	88	87	86	85	84	83	81	80	79	76
0.6	87	86	84	82	80	79	77	76	74	73
0.8	87	85	82	80	77	75	73	71	69	67
1	86	83	80	77	75	72	69	66	64	62
1.2	85	82	78	75	72	69	65	63	60	57
1.4	85	80	77	73	69	65	62	59	57	52
1.6	84	78	75	71	67	63	59	56	53	50
1.8	83	78	73	69	64	60	56	53	50	48
2	83	77	72	67	62	56	53	50	47	43
2.2	82	76	70	65	59	54	50	47	44	40
2.4	82	75	68	64	58	53	48	45	41	37
2.6	81	74	67	62	56	51	46	42	38	35
2.8	81	73	66	60	54	49	44	40	36	34
3	80	72	64	58	52	47	42	38	34	30
3.2	78	71	63	56	50	45	40	36	32	28
3.4	78	70	62	54	48	43	38	34	30	27
3.6	78	69	61	53	47	42	36	32	28	25
3.8	78	69	60	51	45	40	35	31	27	23
4	77	69	58	51	44	39	33	29	25	22
4.2	77	62	57	50	43	37	32	28	24	21
4.4	76	61	56	49	42	36	31	27	23	20
4.6	76	60	55	47	40	35	30	26	22	19
4.8	75	59	54	46	38	34	28	25	21	18
5	75	59	53	45	38	33	28	24	20	16
6	73	61	48	41	34	28	24	20	16	11
7	70	58	45	38	30	27	21	18	14	8
8	68	55	42	35	27	23	18	15	12	6
9	66	52	38	31	25	21	16	14	11	5
10	65	51	36	29	22	19	15	11	9	4

BASE REFLECTANCE PER CENT	80									
WALL REFLECTANCE PER CENT	90	80	70	60	50	40	30	20	10	0
ROOM CAVITY RATIO										
0.2	79	78	78	77	77	76	76	75	74	72
0.4	79	77	76	75	74	73	72	71	70	68
0.6	78	76	75	73	71	70	68	66	65	63
0.8	78	75	73	71	69	67	65	63	61	57
1	77	74	72	69	67	65	62	60	57	55
1.2	76	73	70	67	64	61	58	55	53	51
1.4	76	72	68	65	62	59	55	53	50	48
1.6	75	71	67	63	60	57	53	50	47	44
1.8	75	70	66	62	58	54	50	47	44	41
2	74	69	64	60	56	52	48	45	41	38
2.2	74	68	63	58	54	49	45	42	38	35
2.4	73	67	61	56	52	47	43	40	36	33
2.6	73	66	60	55	50	45	41	38	34	31
2.8	73	65	59	53	48	43	39	36	32	29
3	72	65	58	52	47	42	37	34	30	27
3.2	72	65	37	51	45	40	35	33	28	25
3.4	71	64	56	49	44	38	34	32	27	24
3.6	71	63	54	48	43	38	32	30	25	23
3.8	70	62	53	47	41	36	31	28	24	22
4	70	61	53	46	40	35	30	26	22	20
4.2	69	60	52	45	39	34	29	25	21	18
4.4	69	60	51	44	38	33	28	24	20	17
4.6	69	59	50	43	37	32	27	23	19	15
4.8	68	58	49	42	36	31	26	22	18	14
5	68	58	48	41	35	30	25	21	18	14
6	66	55	44	38	31	27	22	19	15	10
7	64	53	41	35	28	24	19	16	12	7
8	62	50	38	32	25	21	17	14	11	5
9	61	48	36	30	23	19	15	13	10	4
10	59	46	33	27	21	18	14	11	8	3

BASE REFLECTANCE PER CENT	70									
WALL REFLECTANCE PER CENT	90	80	70	60	50	40	30	20	10	0
ROOM CAVITY RATIO										
0.2	70	69	68	68	67	67	66	66	65	64
0.4	69	68	67	66	65	64	63	62	61	58
0.6	69	67	65	64	63	61	59	58	57	54
0.8	68	66	64	62	60	58	56	55	53	50
1	68	65	62	60	58	55	53	52	50	47
1.2	67	64	61	59	57	54	50	48	46	44
1.4	67	63	60	58	55	51	47	45	44	41
1.6	67	62	59	56	53	47	45	43	41	38
1.8	66	61	58	54	51	46	42	40	38	35
2	66	60	56	52	49	45	40	38	36	33
2.2	65	60	55	51	48	43	38	36	34	32
2.4	65	60	54	50	46	41	37	35	32	30
2.6	65	59	54	49	45	40	35	33	30	28
2.8	65	59	53	48	43	38	33	30	28	26
3	66	58	52	47	42	37	32	29	27	24
3.2	64	58	51	46	40	36	31	28	25	23
3.4	64	57	50	45	39	35	29	27	24	22
3.6	63	56	49	44	38	33	28	25	22	20
3.8	63	56	49	43	37	32	27	24	21	19
4	63	55	48	42	36	31	26	23	20	17
4.2	62	55	47	41	35	30	25	22	19	16
4.4	62	54	46	40	34	29	24	21	18	15
4.6	62	53	45	39	33	28	24	21	17	14
4.8	62	53	45	38	32	27	23	20	16	13
5	61	52	44	36	31	26	22	19	16	12
6	60	51	41	35	28	24	19	16	13	9
7	58	48	38	32	26	22	17	14	11	6
8	57	46	35	29	23	19	15	13	10	5
9	56	45	33	27	21	18	14	12	9	4
10	55	43	31	25	19	16	12	10	8	3

BASE REFLECTANCE PER CENT	60									
WALL REFLECTANCE PER CENT	90	80	70	60	50	40	30	20	10	0
ROOM CAVITY RATIO										
0.2	60	59	59	59	58	57	56	56	55	53
0.4	60	59	59	58	57	55	54	53	52	50
0.6	60	58	57	56	55	53	51	51	50	46
0.8	59	57	56	55	54	51	48	47	46	43
1	59	57	55	53	51	48	45	44	43	41
1.2	59	56	54	51	49	46	44	42	40	38
1.4	59	56	53	49	47	44	41	39	38	36
1.6	59	55	52	48	45	42	39	37	35	33
1.8	58	55	51	47	44	40	37	35	33	31
2	58	54	50	46	43	39	35	33	31	29
2.2	58	53	49	45	42	37	34	31	29	28
2.4	58	53	48	44	41	36	32	30	27	26
2.6	58	53	48	43	39	35	31	28	26	24
2.8	58	53	47	43	38	34	29	27	24	22
3	57	52	46	42	37	32	28	25	23	20
3.2	57	51	45	41	36	31	27	23	22	18
3.4	57	51	45	40	35	30	26	23	20	17
3.6	57	50	44	39	34	29	25	22	19	16
3.8	57	50	43	38	33	29	24	21	19	15
4	57	49	42	37	32	28	23	20	18	14
4.2	56	49	42	37	32	27	22	19	17	14
4.4	56	49	42	36	31	27	22	19	16	13
4.6	56	49	41	35	30	26	21	18	16	13
4.8	56	48	41	34	29	25	21	18	15	12
5	56	48	40	34	28	24	20	17	14	11
6	55	45	37	31	25	21	17	14	11	7
7	54	43	35	30	24	20	15	12	9	5
8	53	42	33	28	22	18	14	11	8	4
9	52	40	31	26	20	16	12	10	7	3
10	51	39	29	24	18	15	11	9	7	2

BASE REFLECTANCE PER CENT	50									
WALL REFLECTANCE PER CENT	90	80	70	60	50	40	30	20	10	0
ROOM CAVITY RATIO										
0.2	50	50	49	49	48	48	47	46	46	44
0.4	50	49	48	48	47	46	45	45	44	42
0.6	50	48	47	46	45	44	43	42	41	38
0.8	50	48	47	45	44	42	40	38	38	36
1	50	48	46	44	43	41	38	37	36	34
1.2	50	47	45	43	41	39	36	35	34	29
1.4	50	47	45	42	40	38	35	34	32	27
1.6	50	47	44	41	39	36	33	32	30	26
1.8	50	46	43	40	38	35	31	30	28	25
2	50	46	43	40	37	34	30	28	26	24
2.2	50	46	42	38	36	33	29	27	24	22
2.4	50	46	42	37	35	31	27	25	23	21
2.6	50	46	41	37	34	30	26	23	21	20
2.8	50	46	41	36	33	29	25	22	20	19
3	50	45	40	36	32	28	24	21	19	17
3.2	50	44	39	35	31	27	23	20	18	16
3.4	50	44	39	35	30	26	22	19	17	15
3.6	50	44	39	34	29	25	21	18	16	14
3.8	50	44	38	34	29	25	21	17	15	13
4	50	44	38	33	28	24	20	17	15	12
4.2	50	43	37	32	28	24	20	17	14	12
4.4	50	43	37	32	27	23	19	16	13	11
4.6	50	43	36	31	26	22	18	15	13	10
4.8	50	43	36	31	26	22	18	15	12	9
5	50	42	35	30	25	21	17	14	12	9
6	50	42	34	29	23	19	15	13	10	6
7	49	41	32	27	21	18	14	11	8	5
8	49	40	30	25	19	16	12	10	7	3
9	48	39	29	24	18	15	11	9	7	3
10	47	37	27	22	17	14	10	8	6	2

Similarly, with a floor/wall reflectance of 20%/50% and FCR of 1.4, the effective floor reflectance is 18% which can be rounded to 20%

BASE REFLECTANCE PER CENT	40									
WALL REFLECTANCE PER CENT	90	80	70	60	50	40	30	20	10	0
ROOM CAVITY RATIO										
0.2	40	40	39	39	39	38	38	37	36	36
0.4	41	40	39	39	38	37	36	35	34	34
0.6	41	40	39	38	37	36	34	33	32	31
0.8	41	40	38	37	36	35	33	32	31	29
1	42	42	38	37	35	33	32	31	29	27
1.2	42	40	38	36	34	32	30	29	27	25
1.4	42	39	37	35	33	31	29	27	25	23
1.6	42	39	37	35	32	30	27	25	23	22
1.8	42	39	36	34	31	29	26	24	22	21
2	42	39	36	34	31	28	25	23	21	19
2.2	42	39	36	33	30	27	24	22	19	18
2.4	43	39	35	33	29	27	24	21	18	17
2.6	43	39	35	32	29	26	23	20	17	15
2.8	43	39	35	32	28	25	22	19	16	14
3	43	39	35	31	27	24	21	18	16	13
3.2	43	39	35	31	27	23	20	17	15	13
3.4	43	39	34	30	26	23	20	17	14	12
3.6	44	39	34	30	26	22	19	16	14	11
3.8	44	38	33	29	25	22	18	16	13	10
4	44	38	32	29	25	21	18	15	12	10
4.2	44	38	33	29	24	21	17	15	12	10
4.4	46	38	33	28	24	20	17	14	11	9
4.6	44	38	32	28	23	19	16	14	11	8
4.8	44	38	32	27	22	19	16	13	10	8
5	45	38	31	27	22	19	15	13	10	7
6	44	37	30	25	20	17	13	11	8	5
7	44	36	29	24	19	16	12	10	7	4
8	44	35	28	23	18	15	11	9	6	3
9	44	35	26	21	16	13	10	8	5	2
10	43	34	25	20	15	12	8	7	5	2

BASE REFLECTANCE PER CENT	30									
WALL REFLECTANCE PER CENT	90	80	70	60	50	40	30	20	10	0
ROOM CAVITY RATIO										
0.2	31	31	30	30	29	29	29	28	28	27
0.4	31	31	30	30	29	28	28	27	26	25
0.6	32	31	30	29	28	27	26	26	25	23
0.8	32	31	30	29	28	26	25	25	23	22
1	33	32	30	29	27	25	24	23	22	20
1.2	33	32	30	28	27	25	23	22	21	19
1.4	34	32	30	28	26	24	22	21	19	18
1.6	34	33	29	27	25	23	22	20	18	17
1.8	35	33	29	27	25	23	21	19	17	16
2	35	33	29	26	24	22	20	18	16	14
2.2	36	32	29	26	24	22	19	17	15	13
2.4	36	32	29	26	24	22	19	16	14	12
2.6	36	32	29	25	23	21	18	16	14	12
2.8	37	33	29	25	23	21	17	15	13	11
3	37	33	29	25	22	20	17	15	12	10
3.2	37	33	29	25	22	19	16	14	12	10
3.4	37	33	29	25	22	19	16	14	11	9
3.6	38	33	29	24	21	18	15	13	10	9
3.8	38	33	28	24	21	18	15	13	10	8
4	38	33	28	24	21	18	14	12	9	7
4.2	38	33	28	24	20	17	14	12	9	7
4.4	39	33	28	24	20	17	14	11	9	6
4.6	39	33	28	24	20	17	13	10	8	6
4.8	39	33	28	24	20	17	13	10	8	5
5	39	33	28	24	19	16	13	10	8	5
6	39	33	27	23	18	15	11	9	6	4
7	40	33	26	22	17	14	10	8	5	3
8	40	33	26	21	16	13	9	7	4	2
9	40	33	25	20	15	12	9	7	4	2
10	40	32	24	19	14	11	8	6	3	1

BASE REFLECTANCE PER CENT	20									
WALL REFLECTANCE PER CENT	90	80	70	60	50	40	30	20	10	0
ROOM CAVITY RATIO										
0.2	21	20	20	20	20	20	19	19	19	17
0.4	22	21	20	20	20	19	19	18	18	16
0.6	23	21	21	20	19	19	18	18	17	15
0.8	24	22	21	20	19	19	18	17	16	14
1	25	23	22	20	19	18	17	16	15	13
1.2	25	23	22	20	19	17	17	16	14	12
1.4	26	24	22	20	18	17	16	15	13	12
1.6	26	24	22	20	18	17	16	15	13	11
1.8	27	25	23	20	18	17	15	14	12	10
2	28	25	23	20	18	16	15	13	11	9
2.2	28	25	23	20	18	16	14	12	10	9
2.4	29	26	23	20	18	16	14	12	10	8
2.6	29	26	23	20	18	16	14	11	9	8
2.8	30	27	23	20	18	15	13	11	9	7
3	30	27	23	20	17	15	13	11	9	7
3.2	31	27	23	20	17	15	12	11	9	6
3.4	31	27	23	20	17	15	12	10	8	6
3.6	32	27	23	20	17	15	12	10	8	5
3.8	32	28	23	20	17	15	12	10	7	5
4	33	28	22	20	17	14	11	9	7	5
4.2	33	28	23	20	17	14	11	9	7	4
4.4	34	28	24	20	17	14	11	9	7	4
4.6	34	29	24	20	17	14	11	9	7	4
4.8	35	29	24	20	17	13	10	8	6	4
5	35	29	24	20	16	13	10	8	6	4
6	36	30	24	20	16	13	10	8	5	2
7	36	30	24	20	15	12	9	7	4	2
8	37	30	23	19	15	12	8	6	3	1
9	37	29	23	19	14	11	8	6	3	1
10	37	29	23	18	13	10	7	5	3	1

BASE REFLECTANCE PER CENT	10									
WALL REFLECTANCE PER CENT	90	80	70	60	50	40	30	20	10	0
ROOM CAVITY RATIO										
0.2	11	11	11	10	10	10	10	9	9	9
0.4	12	11	11	11	11	10	10	9	9	8
0.6	13	13	12	11	11	10	10	9	8	8
0.8	15	14	13	12	11	10	10	9	8	7
1	16	14	13	12	12	11	10	9	8	7
1.2	17	15	14	13	12	11	10	9	7	6
1.4	18	16	14	13	12	11	10	9	7	6
1.6	19	17	15	14	12	11	9	8	7	6
1.8	19	17	15	14	13	11	9	8	6	5
2	20	18	16	14	13	11	9	8	6	5
2.2	21	19	16	14	13	11	9	7	6	5
2.4	22	19	17	15	13	11	9	7	6	5
2.6	23	20	17	15	13	11	9	7	6	4
2.8	23	20	18	16	13	11	9	7	5	3
3	24	21	18	16	13	11	9	7	5	3
3.2	25	21	18	16	13	11	9	7	5	3
3.4	26	22	18	16	13	11	9	7	5	3
3.6	26	22	19	16	13	11	9	6	4	3
3.8	27	23	19	17	14	11	9	6	4	2
4	27	23	20	17	14	11	9	6	4	2
4.2	28	24	20	17	14	11	8	6	4	2
4.4	28	24	20	17	14	11	8	6	4	2
4.6	29	25	20	17	14	11	8	6	4	2
4.8	29	25	20	17	14	11	8	6	4	2
5	30	25	20	17	14	11	8	6	4	2
6	31	26	21	18	14	11	8	6	3	1
7	32	27	21	17	13	11	8	6	3	1
8	33	27	21	17	13	10	7	5	3	1
9	34	28	21	17	13	10	7	5	2	1
10	34	28	21	17	12	10	7	5	2	1

Step 4:

From the Coefficient of Utilization table of the light fixture, corresponding to a RCR of 4 & 3, we get the CU values as shown below

RCR	CU value 80%/50%/20%	CU value 50%/50%/20%
4	0.77	0.71
3	0.82	0.74

Coefficient of utilisation
(20% effective floor cavity reflectance)

Effective ceiling cavity reflectance	80%			50%		
Wall reflectance	50	30	10	50	30	10
RCR						
10	0.33	0.26	0.22	0.31	0.26	0.22
9	0.43	0.35	0.27	0.40	0.35	0.29
8	0.58	0.42	0.35	0.48	0.42	0.36
7	0.58	0.50	0.42	0.55	0.48	0.42
6	0.64	0.57	0.49	0.61	0.54	0.47
5	0.72	0.65	0.59	0.65	0.60	0.56
4	0.77	0.71	0.64	0.71	0.65	0.60
3	0.82	0.76	0.70	0.74	0.69	0.63
2	0.87	0.82	0.77	0.78	0.74	0.70
1	0.91	0.87	0.83	0.81	0.78	0.75

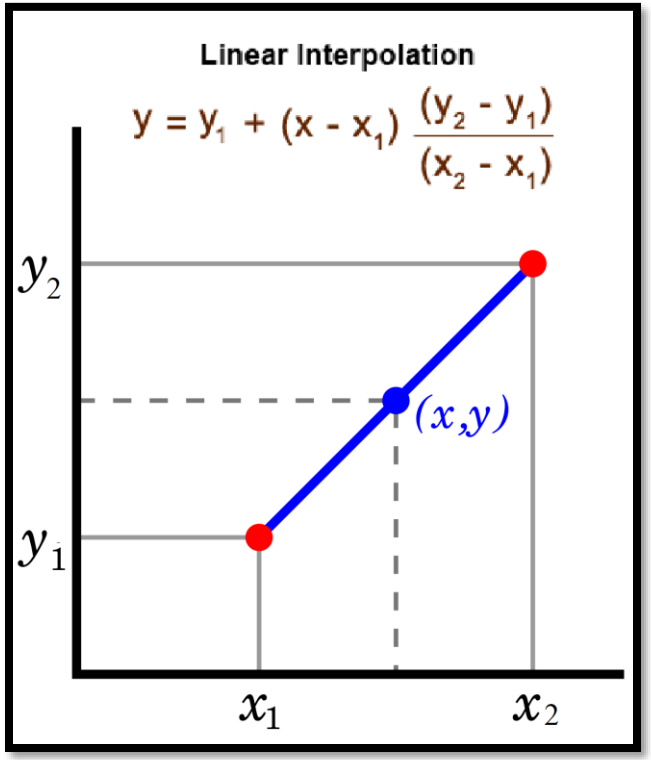
Coefficient of utilisation
(20% effective floor cavity reflectance)

Effective ceiling cavity reflectance	80%			50%		
Wall reflectance	50	30	10	50	30	10
RCR						
10	0.33	0.26	0.22	0.31	0.26	0.22
9	0.43	0.35	0.27	0.40	0.35	0.29
8	0.58	0.42	0.35	0.48	0.42	0.36
7	0.58	0.50	0.42	0.55	0.48	0.42
6	0.64	0.57	0.49	0.61	0.54	0.47
5	0.72	0.65	0.59	0.65	0.60	0.56
4	0.77	0.71	0.64	0.71	0.65	0.60
3	0.82	0.76	0.70	0.74	0.69	0.63
2	0.87	0.82	0.77	0.78	0.74	0.70
1	0.91	0.87	0.83	0.81	0.78	0.75

- We have to calculate the required CU value for an effective ceiling reflectance of 55% & an RCR = 3.5.
- For **RCR = 3**, the CU value for 55% effective ceiling reflectance can be calculated as,

$$CU = \frac{0.82-0.74}{80-50} \, x \, (55 - 50) + 0.74 = 0.753$$

(here, y = CU, y1 = CU at 50% ceiling reflectance, y2 = CU at 80% ceiling reflectance, x = % effective ceiling reflectance corresponding to y = 55%, x1 = % effective ceiling reflectance corresponding to y1 = 50%, x2 = % effective ceiling reflectance corresponding to y2 = 80%)



- Similarly, for RCR = 4, the CU value for 55% effective ceiling reflectance can be calculated as

$$CU = \frac{0.77-0.71}{80-50} \, x \, (55 - 50) + 0.71 = 0.72$$

- Now we have the CU values as,

RCR	Ceiling/Wall/floor reflectance 55%/50%/20%
4	0.72
3	0.753

- Hence the value of CU for an RCR = 3.5 can be interpolated from the table as

$$CU = \frac{0.753-0.72}{4-3} \, x \, (3.5 - 3) + 0.72 = 0.7365$$

Step 5:

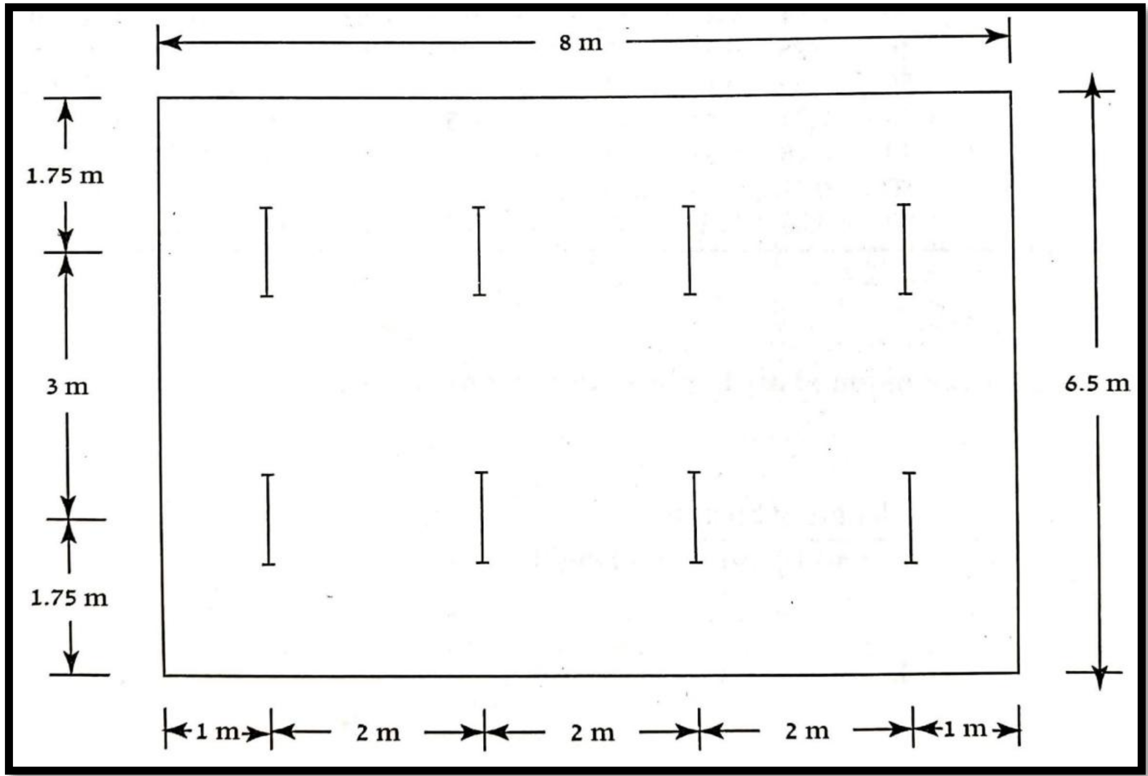
The number of luminaires required = $N = \dfrac{Area\ x\ E}{L_n\ x\ CU\ x\ LLF} = \dfrac{6.5\ x\ 8\ x\ 300}{4000\ x\ 0.7365\ x\ 0.7}$ = 7.56 ≈ 8 nos.

Area per luminaire = Room area/number of fixtures = (6.5 x 8)/ 8 = 6.5m^2

Therefore, spacing between fixtures = √(6.5) = 2.55m

Check

For low bay fixtures (mounting height less than 6m), spacing can be up to 1.5 times the mounting height. Here, mounting height = 2.5m & therefore the spacing should be below 1.5 x 2.5 = 3.75m. As per our design, the spacing is 2.55. Hence the design is satisfactory. The layout of lamps is shown in figure.



Q10. An industrial work shop measuring 12m x 6m is to be provided with an illumination level of 200lux. Design the lighting layout giving due consideration for spacing. The following data pertains to the work shop.

1. Wall reflectance = 50%
2. Ceiling reflectance = 70%
3. Floor reflectance = 10%
4. Height of floor cavity = 1m
5. Height of ceiling cavity = 2.5m
6. Height of room cavity = 3m

Coefficient of utilisation chart

Room reflectance			Room index									
Floor	Ceiling	Wall	0.6	0.8	1.0	1.25	1.50	2.0	2.5	3.0	4.0	5.0
		50	0.36	0.46	0.51	0.57	0.61	0.66	0.70	0.72	0.75	0.77
10	70	30	0.51	0.40	0.47	0.52	0.56	0.62	0.66	0.68	0.72	0.74
		10	0.28	0.36	0.42	0.48	0.52	0.58	0.62	0.65	0.70	0.72
10	50	50	0.35	0.45	0.50	0.56	0.60	0.64	0.68	0.70	0.73	0.75
		30	0.31	0.40	0.46	0.52	0.55	0.61	0.64	0.67	0.71	0.73
		10	0.28	0.36	0.42	0.48	0.52	0.58	0.62	0.64	0.68	0.71
10	30	30	0.31	0.40	0.45	0.51	0.54	0.59	0.64	0.66	0.69	0.71
		10	0.28	0.36	0.42	0.47	0.51	0.57	0.61	0.63	0.68	0.70

Use 2x40W industrial fluorescent fixture with vitreous enamel reflectors whose coefficient of utilization chart is given below.

Lamp rating = 2 x 40W

Initial lamp lumens = 4500

Maximum ratio of spacing to mounting height = 1.5. Coefficient of utilization chart is given above.

Ans: Since Room index values are given, we can use simplified design procedure

Step 1:

Room index, RI = (Length x Breadth)/((length + breadth)x mounting height)

= (2 x 12)/((6 x 12) x 4) = 1

Step 2:

From the table for coefficient of utilization, corresponding a value of RI = 1 & ceiling/wall/floor reflectance of 70%/50%/10%, the value of coefficient of utilization can be obtained as, CU = 0.51

Coefficient of utilisation chart

Room reflectance			Room index									
Floor	Ceiling	Wall	0.6	0.8	1.0	1.25	1.50	2.0	2.5	3.0	4.0	5.0
		50	0.36	0.46	0.51	0.57	0.61	0.66	0.70	0.72	0.75	0.77
10	70	30	0.51	0.40	0.47	0.52	0.56	0.62	0.66	0.68	0.72	0.74
		10	0.28	0.36	0.42	0.48	0.52	0.58	0.62	0.65	0.70	0.72
10	50	50	0.35	0.45	0.50	0.56	0.60	0.64	0.68	0.70	0.73	0.75
		30	0.31	0.40	0.46	0.52	0.55	0.61	0.64	0.67	0.71	0.73
		10	0.28	0.36	0.42	0.48	0.52	0.58	0.62	0.64	0.68	0.71
10	30	30	0.31	0.40	0.45	0.51	0.54	0.59	0.64	0.66	0.69	0.71
		10	0.28	0.36	0.42	0.47	0.51	0.57	0.61	0.63	0.68	0.70

Step 3:

Since the lighting is for an industrial area, the light loss factor may be assumed to be 70%.

i.e, LLF = 0.7

Step 4:

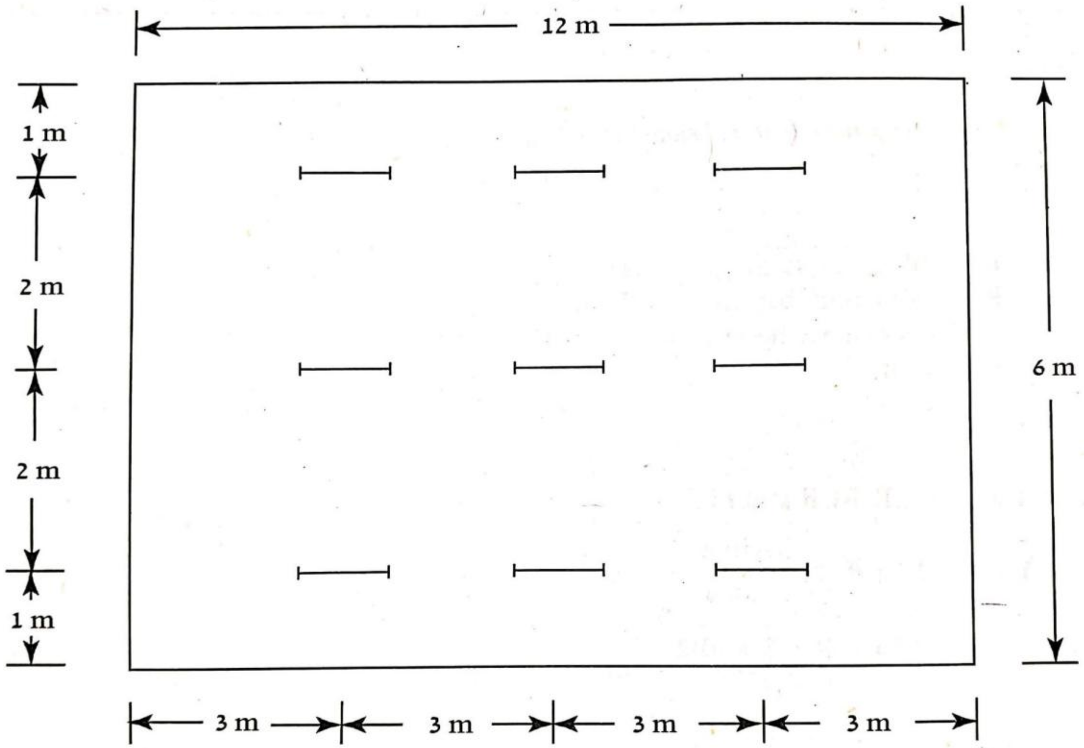
Number of luminaires required, $N = \frac{Area\ x\ E}{L_n\ x\ CU\ x\ LLF} = \frac{6\ x\ 12\ x\ 200}{4500\ x\ 0.51x\ 0.7}$ = 8.963 ≈ 9 nos.

Area per luminaire = Room area/number of fixtures = (6 x 12)/ 9 = 8m^2

Therefore, spacing between fixtures = √(8) = 2.828m ≈ 3m

Check

For low bay fixtures (mounting height less than 6m), spacing can be up to 1.5 times the mounting height. Here, mounting height = 3m & therefore the spacing should be below 1.5 x 3 = 4.5m. As per our design, the spacing is 3m. Hence the design is satisfactory. The layout of lamps is shown in figure.

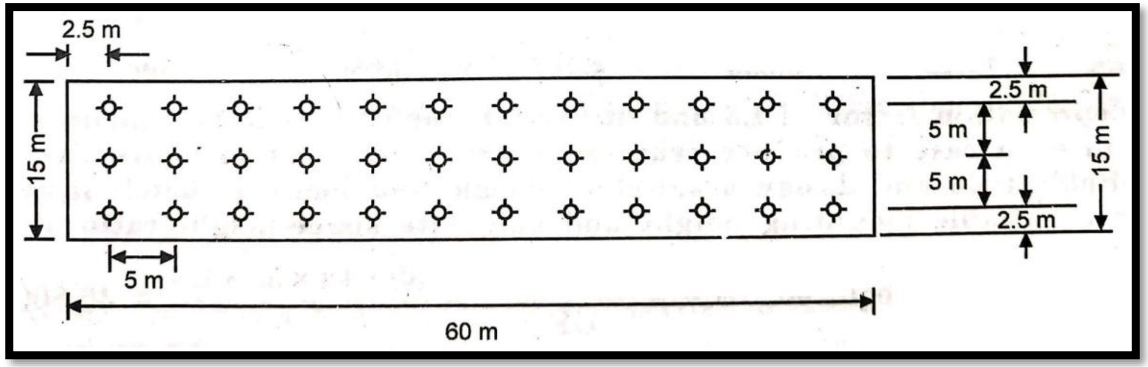


Q11. Estimate the number & wattage of lamps which would be required to illuminate a workshop space 60 x 15 m by means of lamps mounted 5m above the working plane. The average illumination required is about 100 lux, coefficient of utilization = 0.4, luminous efficiency 16 lumens/watt. Assume a space height ratio of unity & a candle power depreciation of 20%?

Ans: Total lumen required, Φ = $\frac{Area\ (A)\ x\ Average\ illumination\ required\ (E)}{CU\ x\ LLF}$

Maintenance factor = LLF = (1 – candle power depreciation) = (1 - 0.2) = 0.8

Area, A = 60 x 15 = 900 m^2



Average illumination required, E = 100 lux

Total lumen required, Φ = $\frac{900\ x\ 100}{0.4\ x\ 0.8}$ = 281250 lumen

Total wattage required, W = (Total lumen required)/

(Luminous efficiency in Lumen/Watts) = 281250/16 = 17578 W

For a space height ratio (Distance between luminaire centres, in a regular square array of luminaires, divided by their height above the working plane) of unity, only 3 lamps can be mounted along the width of the room & 12 lamps can be arranged along the length of the room.

Thus total number of lamps required = 12 x 3 = 36

Wattage of each lamp = total wattage required/number of lamps = 17578/36 = 488.3 ≈ 500W

Q12. A room 8 m x 12 m is lighted by 15 lamps to a fairly uniform illumination of 100 lm/m^2. Calculate the utilization coefficient of the room. Given that the output of each lamp is 1600 lumens

Ans: Total Lumens emitted by the lamps = 15 x 1600 = 24,000 lm

Lumens received by the working plane of the room = area x illumination level

= 8 x 12 x 100 = 9600 lm

Utilization coefficient = lumen received by working plane/total lumen emitted by lamps

= 9600/24000 = 0.4 or 40%

Q13. The illumination in a drawing office 30 m x 10 m to have a value of 250 Lux and is to be provided by a number of 300 W filament lamps. If the coefficient of utilization is 0.4 and the depreciation factor 0.9, determine the number of lamps required. The luminous efficiency of each lamp is 14 ln/W

Ans: Area, A = 30 x 10 = 300m^2, Illumination, E = 250 Lux, CU = 0.4, LLF = 0.9

Total lumen required = (E x A)/(CU x LLF) = (250 x 300)/(0.4 x 0.9) = 208333.3 lm

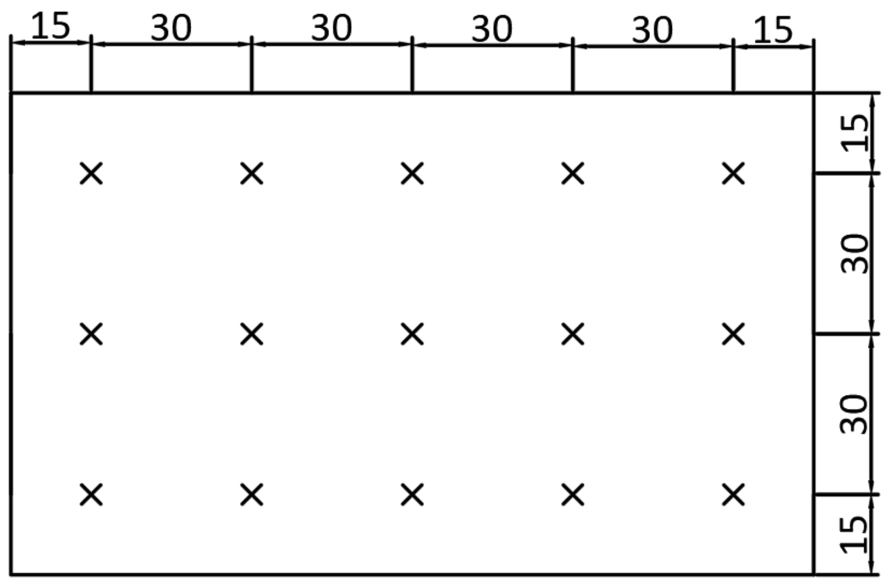
Lumen output of one lamp = 300 x 14 = 4200 lm

Number of lamps required = total lumen required/ lumen output of one lamp

= 208333.3/4200 = 49.6 ≈ 50 lamps

Q14. An office room of size 9m X 15m is to be illuminated by 2x18W LED luminaire. The lamps are being mounted at a height of 3m from the work plane. The average illumination required is 240 lux. Calculate the number of lamps required to be fitted, assuming a CU of 0.75 and a LLF of 0.8. Assume the ceiling height of the room as 5m. Draw the layout of the luminaire arrangement. The lumen output of 2x18W LED may be taken as 4000 lumens.

Ans:



Area, A = 9 x 15 = 135m^2

Height of luminary, H = 3m

Illumination required, E = 240 lux

CU = 0.75, LLF = 0.8

Lumen output of each lamp, L = 4000 lm

$$\text{Number of lamps, } N = \frac{Area\ x\ E}{L_n\ x\ CU\ x\ LLF}$$

$$= \frac{135\ x\ 240}{4000\ x\ 0.75 x\ 0.8} = 13.5 \approx 14 \text{ lamps}$$

Here, Length : Breadth = 15:9 = 5:3

So we can arrange 15 lamps total in 3 rows and 5 columns. Also, the space to height ratio is 1.

Q15. A drawing hall in an engineering college is to be provided with a lighting installation. The hall is 30m x 20m x 8m (high). The mounting height is 5m and the required level of illumination is 144 lm/m^2. Using metal filament lamps, estimate the size and number of single lamp luminaries and also draw their spacing layout. Assume utilization coefficient = 0.6, maintenance factor = 0.75, space height ratio-1. Lumens/watt for 300 W lamp -13, Lumens/watt for 500 W lamp – 16.

Ans:

Area, A = 30 x 20 = 600m^2, Illumination, E = 144 lm/m^2, CU = 0.6, LLF = 0.75

Total lumen required = (E x A)/(CU x LLF) = (144 x 600)/(0.6 x 0.75) = 192000 lm

<u>With 300W lamp</u>

Lumen output of one lamp = 300 x 13 = 3900 lm

Number of lamps required = total lumen required/ lumen output of one lamp

= 192000/3900 = 49.2 ≈ 49

<u>With 500W lamp</u>

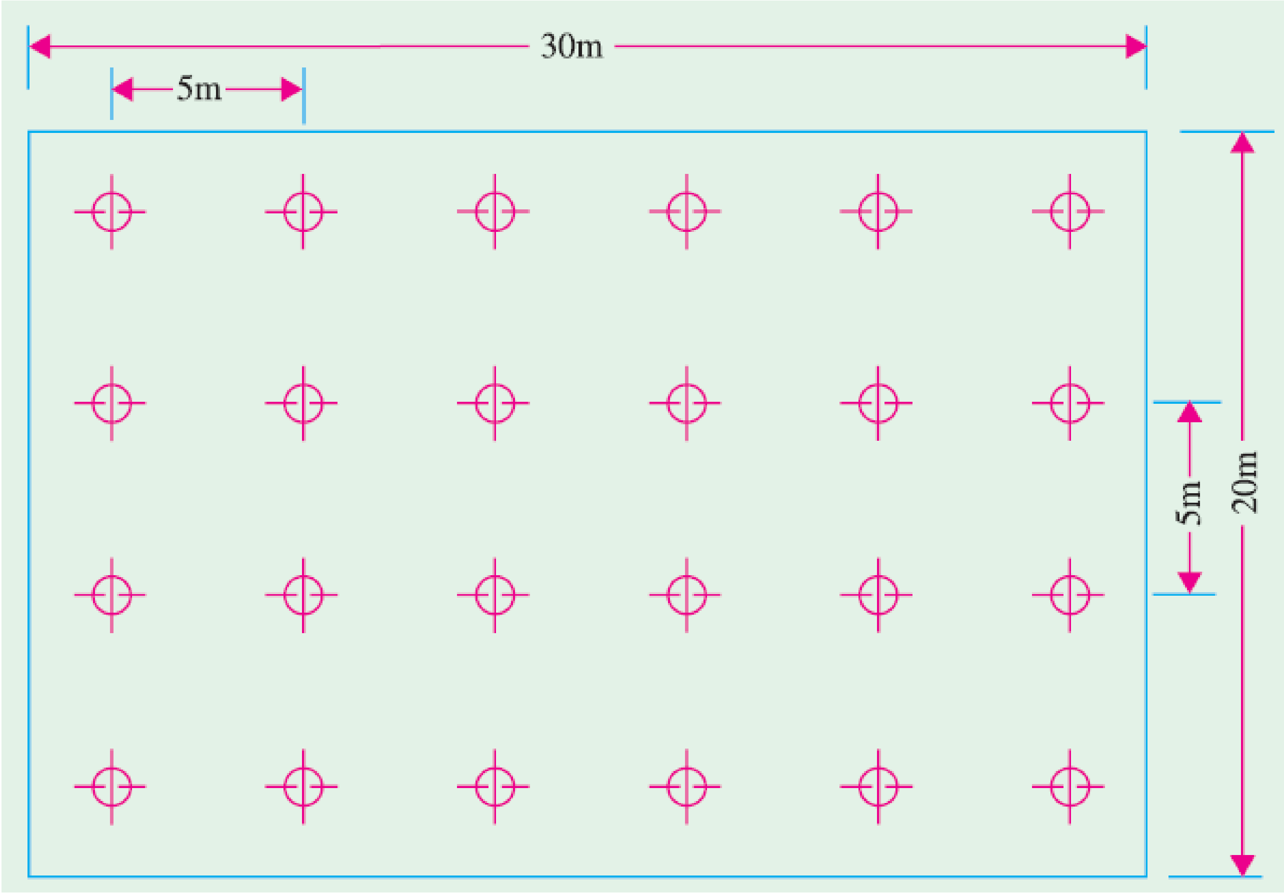
Lumen output of one lamp = 500 x 16 = 8000 lm

Number of lamps required = total lumen required/ lumen output of one lamp

= 192000/8000 = 24

Arrangement

- 300W lamps cannot be used because their number cannot be arranged in a hall of 30m x 20m with a space to height ratio of unity.
- 500W lamps can be arranged in 4 rows of 6 lamp each with a spacing of 5m both in the width and length as shown in figure.



Q16. Two lamps are hung at a height of 9m from the floor level. The distance between the lamps is 1 metre. Lamp one is of 500 candela. It the illumination on the floor vertically below this lamp is 20 lux, find the candle power of the lamp number two.

Ans:

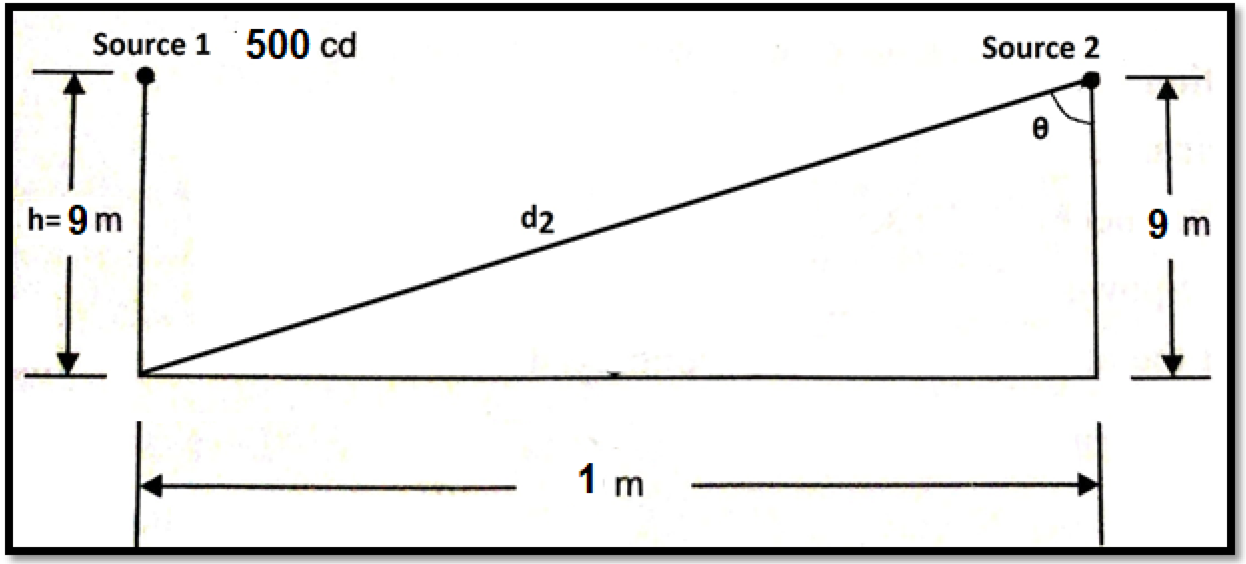
I_1 = 500 candela, h = 9 m, E = 20 lux

Illumination at the point vertically below the lamp one = illumination due to lamp 1 (E_1) + Illumination due to lamp 2 (E_2)

i.e, $E = E_1 + E_2 = \frac{I_1}{d_1^2} + \frac{I_2}{d_2^2} Cos\theta$

i.e, $20 = \frac{500}{9^2} + \frac{I_2}{9.055^2}\ Cos\ (6.3)$

➔ I_2 = 1140 candela



Q17. It is required to provide an illumination of 100 lux in a factory hall 30m by 15 m. Assume that the depreciation factor is 0.8, coefficient of utilization is 0.4 and efficiency of lamp is 14 lm/W. Suggest the number of lamps and their ratings. The size of the lamps available are 100, 250, 400, and 500W.

Ans:

E = 100 lux, A = 30 x 15 = 450 m2, CU = 0.4, LLF = 0.8

Total lumen required = $\frac{Area\ x\ E}{CU\ x\ LLF}$ = $\frac{450\ x\ 100}{0.4\ x\ 0.8}$ = 140625 lm

Total wattage of lamp required = 140625/14 = 10044.6W

- If 500W lamps are used, total number of lamps = 20 lamps
- If 250W lamps are used, total number of lamps = 40 lamps

(U)Q18. A factory area is 40m long, 20m wide and is 8m high. Point source luminaires are suspended 1.5 metres below ceiling level. The working plane is 1 metre high. Calculate the minimum number of luminaires which must be installed to conform with a recommended SHR of 1.5: 1

Ans:

Height of luminaires from work plane = 8 – 1.5 – 1 = 5.5m

SHR = 1.5

Spacing between luminaires = 5.5 x 1.5 = 8.25m

Number of rows of luminaires = 20/8.25 = 2.42 = 3

Number of luminaires per row = 40/8.25 = 4.85 = 5

Minimum number of luminaires = 5 x 3 = 15

If we place 15 luminaires in the area,

the spacing between two rows = 20/3 =6.67m

the spacing between two columns = 40/5 = 8m

(U)Q19. A factory measures 50m x 30m x 6m high. A general lighting scheme is to illuminate the whole area to 500 lux maintained illuminance using 1000 watt metal halide lamps with an initial efficacy of 90 lumens per watt. Maintenance factor is 0.6 and utilization factor is 0.5. A space height ratio of 1.5: 1 is recommended for the luminaire chosen and a mounting height of 5m over working plane is assumed. Design a suitable lighting scheme.

Ans:

Illuminance = 500 lux, CU = 0.5, MF = LLF = 0.6

Initial lumen output of lamp, Ln = 90 x 1000 = 90000 lumen

Number of lamps, $N = \frac{Area\ x\ E}{L_n\ x\ CU\ x\ LLF} = \frac{50\ x\ 30\ x\ 500}{90000\ x\ 0.5 x\ 0.6}$ = 27.78 ≈ 28 lamps

SHR = 1.5:1

H = 5m, S = 7.5m

Number of lamps in a row (50m side) = 50/7.5 = 6.66 = 7

Number of lamps in a column (30m side) = 30/7.5 = 4

Exterior lighting design

- Exterior lighting has 2 aspects Functional lighting & Decorative lighting
- Road lighting, area lighting, flood lighting etc. come under the category of functional lighting
- Monumental lighting, lighting of festival etc. come under decorative lighting
- The primary aim of exterior lighting are safety & security
- The exterior lighting luminaires can be classified into static & adjustable luminaires
- Luminaires permanently fixed on top of a pole to produce light in a predetermined manner are called static luminaires
- Luminaires mounted with adjustable brackets are referred to as adjustable luminaires
- Adjustable luminaires are mostly used for flood lighting
- The mounting height of luminaire is an important factor in external lighting
- For average roads & public areas, the pole height is chosen in such a way that the luminaires can be serviced from the ground
- For highway intersections or large parking areas, high mast lighting systems (pole height > 16m) are preferred
- Maintenance & servicing of high mast lighting system is difficult. Therefore, lamps with very high average life or lowering mechanism for servicing of lamps are used in high mast system.

Road lighting (Street lighting)

- The most important requirement of road lighting is to provide the driver, the exact information from the road continuously & accurately
- *Factors to be considered for good road lighting are*
  - Adequate level of illumination which would cause sufficient luminance
  - Uniformity of illumination on carriageway
  - Limiting the glare to the minimum possible level
  - Optical guidance

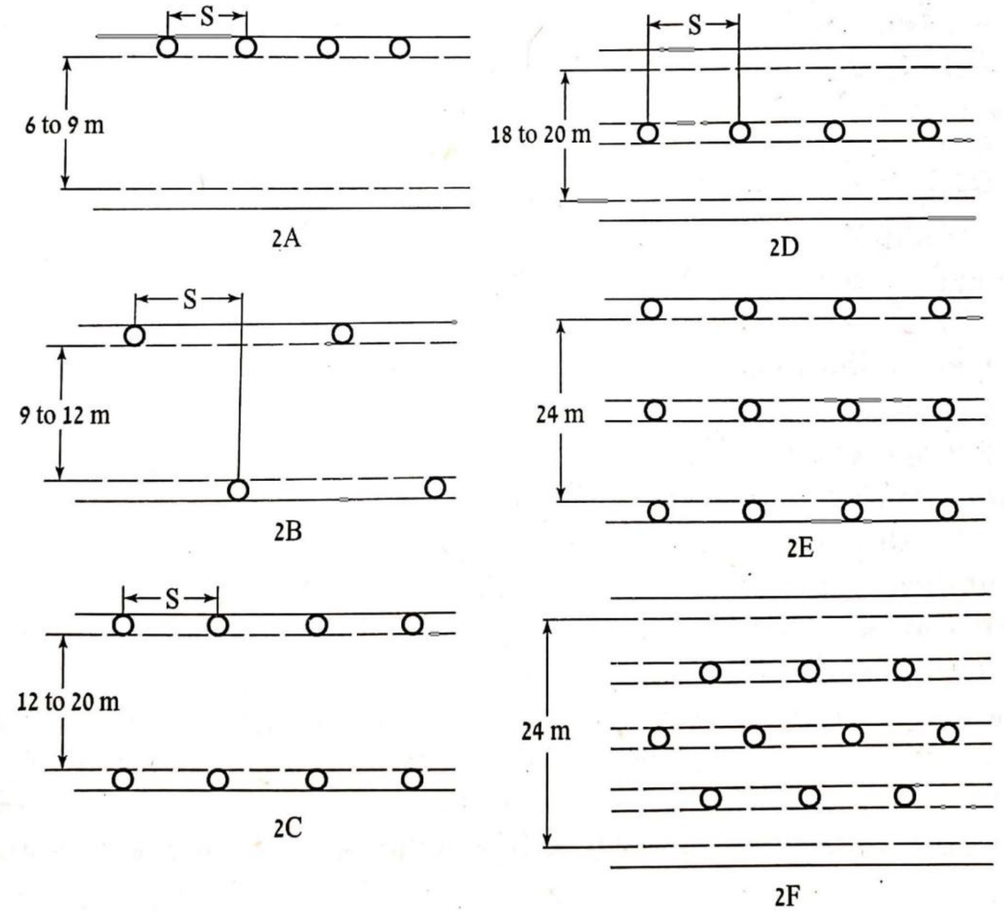
Classification of roads

- Roads are classified based on the volume of composition of the traffic
- The NEC classifies the roads into 7 groups

Classification of roads as per NEC 1985 (as in IS -1944)

Group	Description
A1	Very important roads with rapid and dense traffic, where safety, speed of traffic and comfort to drivers are the only consideration
A2	Other main roads with considerable mixed traffic like main city streets, arterial roads etc.
B1	Secondary roads of considerable traffic such as principal local traffic routes, shopping streets etc.
B2	Secondary roads with comparatively light traffic
C	Residential and unclassified roads not included in group A and B
D	Grade separated junctions, bridges and elevated roads
E	Town and city centres and areas of civic importance
F	Roads with special requirements
G	Road tunnels

- For roads of width ranging from 6 to 9 metres, it is economical to arrange the lamps posts on side of the road
- For roads of width ranging from 9 to 12 metres, zig zag spacing is recommended to get a more or less uniform distribution of light on road surface
- For the roads of width ranging from 12 to 20 metres, face to face spacing of lamp posts on both sides of the road become necessary
- For multi line roads, spacing of the lamp posts on the median, or on the median plus curbs on both sides may have to be chosen, depending on the number of lanes of traffic planned for the road



Details of lamp spacing for different classes of roads (NEC 1985).

Selection of lamps

- The various lamps commonly used for road lighting are

Sl. No.	Lamp type	Advantages & disadvantages
1	Incandescent lamp	• Low initial cost • Low life span, high maintenance cost, low efficacy
2	Fluorescent lamp	• Better efficacy & life span compared to incandescent lamp • Large size & sensitive to temperature
3	Mercury vapor lamp	• Long life • Low efficacy & poor light quality compared to HID lamps
4	Metal halide lamp	• Good color quality & efficacy • Low life span
5	High pressure sodium vapor lamp	• High efficacy among white light sources, long life
6	Low pressure sodium vapor lamp	• High efficacy • Poor color rendering due to monochromatic yellow light
7	LED light sources	• Long life, low power consumption

Road lighting Design considerations

- The spacing between luminaires can be determined using the equations of average lumen method
- illuminance on a surface is given by, $E = \frac{L_n \; x \; CU \; x \; LLF}{A}$

where, E = illuminance in lux

L_n = initial lumen output of the luminaire

CU = Coefficient of Utilization

LLF = Light Loss Factor (Also known as Maintenance factor)

A = Area of road in square meter = W x S

W = width of the road in metre, S = Spacing between lamp poles

LLF = LLD x LDD

LLD = Lamp Lumen Depreciation, LDD = Lamp Dirt Depreciation

Therefore, **S = spacing between poles =** $\frac{L_n \; x \; CU \; x \; LLF}{E \; x \; W}$

- If all the parameters are known, the spacing between poles is directly proportional to the lamp lumen
- Theoretically, the highest wattage lamp will space the lamps farthest apart
- In order to get perfect uniform illumination, the illuminance directly under the luminaire be the same as that midway between the poles
- In reality it is not possible to provide perfect uniformity of light on road
- As a general rule, the maximum light occurs underneath the luminaire & minimum is at the midpoint between the poles
- A measure of acceptance degree of uniformity is expressed as a ratio of the average to minimum illuminance levels
- ***According to IES (Illumination Engineering Society), the ratio of average to minimum illuminance should not be greater than 3 for most of the applications***
- ***For residential areas, this ratio can be as high as 6***
- ***As a general rule for the purpose of energy saving, economy & uniformity of illumination, the ratio of spacing to mounting height should not be less than 3 or larger than 5***
- Closer spacing means higher cost & power consumption, whereas with larger spacing, it is impossible to obtain the specified ratio of average to minimum illumination ratio of 3:1

Q20. Design a roadway lighting scheme with the following data.

Width of the roadway = 12m

Illumination required = 15 lux

Mounting height of poles = 9m

Arm length = 2m

(Assume that the lamps are placed on one side of the road)

Luminaire details are given in table shown.

Lamp type	CU	LLF	Wattage	Lumen output
HPS	0.6	0.7	100 150 250	9500 16,000 26,000
LPS	0.3	0.95	90 135 180	12,500 21,500 33,000

Ans: The spacing between pole, S = $\frac{L_n \, x \, CU \, x \, LLF}{E \, x \, W}$

Here assume that we are using 100W HPS lamps

Now, Ln = 9500 lumen, LLF = 0.7, CU = 0.6

W = 12m, E = 15 lux

The spacing between pole, S = $\frac{9500 \, x \, 0.6 \, x \, 0.7}{15 \, x \, 12}$ = 22.16m

Check : The spacing to mounting height ratio = 22.16/9 = 2.46

This ratio is less than 3 & hence the design is not economical. Choose a higher wattage lamp.

Considering a 150W HPS lamp

Now, Ln = 16000 lumen, LLF = 0.7, CU = 0.6

W = 12m, E = 15 lux

The spacing between pole, S = $\frac{16000\ x\ 0.6\ x\ 0.7}{15\ x\ 12}$ = 37.33m

Check : The spacing to mounting height ratio = 37.33/9 = 4.148

This is within the specified range & hence the design is satisfactory

Q21. Design a road way lighting scheme and determine the spacing between the poles using the given lamps. Which alternative you will choose, from the point of energy conservation?

Width of the road way = 12 m

Illumination required = 15 lux

Mounting height of poles = 9 m

Arm length = 2m

Types of lamps	CU	LLF
HPSV – 150W, 16000 lumens	0.65	0.7
LPSV – 150W, 25500 lumens	0.5	0.9

Ans: The spacing between pole, S = $\frac{L_n\ x\ CU\ x\ LLF}{E\ x\ W}$, W = 12m, E = 15 lux

<u>With HPSV lamps– 150W, 16000 lumens</u> : CU = 0.65, LLF = 0.7

The spacing between pole, S = $\frac{L_n\ x\ CU\ x\ LLF}{E\ x\ W} = \frac{16000\ x\ 0.65\ x\ 0.7}{15\ x\ 12}$ = 40.44m

Space to mounting height ratio = 40.44/9 = 4.49, the design is acceptable

<u>With LPSV lamps – 150W, 25500 lumens</u> : CU = 0.5, LLF = 0.9

The spacing between pole, S = $\frac{L_n\ x\ CU\ x\ LLF}{E\ x\ W} = \frac{22500\ x\ 0.5\ x\ 0.9}{15\ x\ 12}$ = 56.25m

Space to mounting height ratio = 56.25/9 = 6.25, the design is not acceptable

- From the point of energy conservation, we choose *<u>LPSV lamps – 150W, 25500 lumens</u>*

Q22. A road of 500m long is required to be illuminated by providing 150W HPS lamps. The width of the road is 8m. Design a street lighting scheme to obtain a minimum level of illumination of 10 lux. Assume mounting height of the pole is 9m and arm length is 2m. Take CU as 0.6, LLF as 0.7 and lumen output of the lamp as 16000. Sketch the arrangement of the street lighting poles.

Ans:

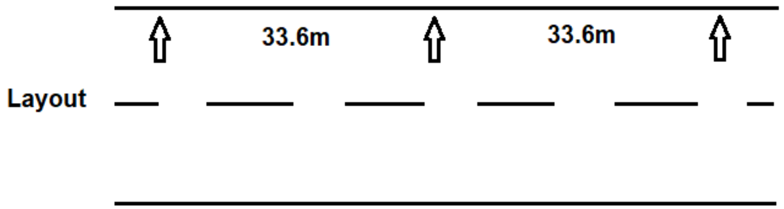
W = 8m, H = 9m, E_{min} = 10 lux, CU = 0.6, LLF = 0.7, L = 16000

- ***The ratio of minimum to average illumination can be taken as 0.4***
- Therefore, $E_{avg} = E_{min}/0.4$ = 25 lux

The spacing between pole, $S = \frac{L_n \; x \; CU \; x \; LLF}{E \; x \; W} = \frac{16000 \; x \; 0.6 \; x \; 0.7}{25 \; x \; 8}$ = 33.6m

Spacing to mounting height ratio = 33.6/9 = 3.73, It is in the acceptable range.

Therefore the design is satisfactory.



Number of street lights = (total length of road/spacing between poles) +1= 500/33.6 = 15 +1=16

Q23. A road 300m long is required to be illuminated by providing 40W fluorescent lamps. The width of the road is 4m. Design a street lighting scheme and estimate the material required if the scheme is to be estimated for obtaining minimum level of illumination of 0.6 lux.

Ans:

- While designing a street lighting scheme, to obtain a uniform level of illumination, the distance between the two street light points should not be more than 35m.

- In the above case, consider the length of span as 30m.

- Given, minimum level of illumination = 0.6

- We can calculate the minimum level of illumination at the mid point between two street light points and see whether it is within the limit

- Assume, the mounting height of lamp, h = 9m, coefficient of utilization = 0.5

- The lumen output of 40W fluorescent lamp = 2700 ln (from data hand book)

- The luminous intensity of 40W lamp = $2700/4\pi = 214.9$ cd

(Luminous intensity of a light source= Total lumen output of lamp/4π)

- Distance between the light source and midpoint of the span, d = $\sqrt{(15^2+9^2)}$ = 17.5m

- Illumination at the point B due to two light points, E = $\frac{2Ih}{d^3}$ x CU = $\frac{2 \times 214.9 \times 9}{17.5^3} \times 0.5$ = 0.36 lux

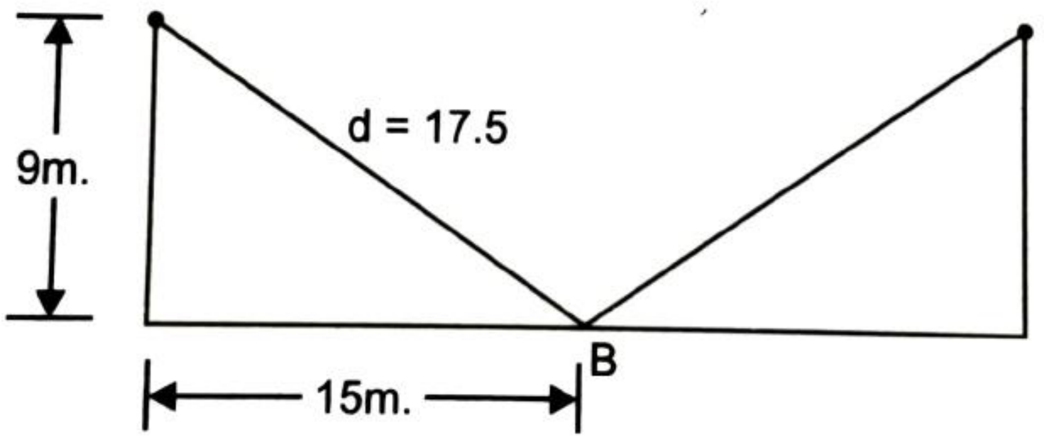
- It is very much less than the limit.

- So choose span as 20m

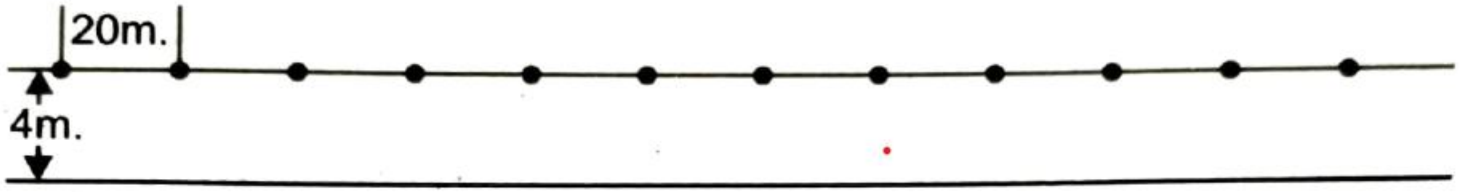
- Now, d = $\sqrt{(10^2+9^2)}$ = 13.45 m

- Illumination at the point B due to two light points,

E = $\frac{2Ih}{d^3}$ x CU = $\frac{2 \times 214.9 \times 9}{13.45^3} \times 0.5$ = 0.795 lux



- This is within the limit. Hence the arrangement is shown in figure.



- Number of poles = 300/20 = 15 + 1 = 16

- Number of street light weather proof fittings = 16

- Total load on line = 40 x 16 = 640W

  Load current = 640/230 = 2.78A

  ACSR conductor (squirrel) is selected

  Length = 2 x 300 + 5% for sagging and wastage = 630m

- Number of shackle insulators = 16 x 2 = 32

Q(U)24. A main road 2km long and 8m wide is required to be illuminated by 85 W sodium vapour lamps. The lamps are mounted on poles 10 m high, so that the minimum level of illumination is 0.8lux. Design a suitable street lighting scheme using underground cable feeder.

Ans:

While designing a street lighting scheme, to obtain a uniform level of illumination, the distance between the two street light points should not be more than 35m.

- In the above case, consider the length of span as 30m.
- Given, minimum level of illumination = 0.8 lux
- We can calculate the minimum level of illumination at the mid point between two street light points and see whether it is within the limit
- The mounting height of lamp, h = 10m and assume, coefficient of utilization = 0.5
- The lumen output of 85W sodium vapour lamp = 9500 ln (from data hand book, data for 100W lamp as data for 85W not available)
- The luminous intensity of 100W lamp = 9500/4π = 756 cd

(Luminous intensity of a light source= Total lumen output of lamp/4π)

- Distance between the light source and midpoint of the span, d = $\sqrt{(15^2+10^2)}$ = 18m

- Illumination at the point B due to two light points, E = $\frac{2Ih}{d^3}$ x CU = $\frac{2 \ x \ 756 \ x \ 10}{18^3} \ x \ 0.5$ = 1.3 lux

- This is within the limit. Hence span can be taken as 30m

- Number of poles = 2000/30 = 67 + 1 = 68

Number of street light weather proof fittings = 68

- Total load on line = 68 x 100 = 6800W

Load current = 6800/230 = 29.6 A

$6mm^2$, 2 core, PVC insulated, aluminium armored cable is selected

Length = 2000m + 4m bend at street light pillar box + 4m bend at each pole = 2276m

Wire for connection from cable end box to lamp = 2 x 10 x 68 = 1360m

Cable end box with necessary fittings = 68 nos

Street light pillar box with ICDP switch and other fittings = 1 nos

Area lighting

- Area lighting means the illumination of a large area of space with an average level of lighting
- This is quite different from that of flood lighting, where the illumination required has to meet a very high level of quality & quantity
- Typical examples of area lighting are
  - Airport parking space
  - Railway yards
  - Vehicle parking space

Important considerations for area lighting design are

- Light distribution and brightness
- Appearance of space and luminaires
- The appearance of color
- Lighting control flexibility
- Cost of implementation
- Conservation of energy
- Glare

- All luminaires designed for road lighting can also be used for area lighting
- Some of the limiting factors of area lighting are
  - Restrictions on mounting height
  - Color rendering property of the lamp source
  - Spacing limitations
- Each situation has its own characteristics that may be different from others
- In order to make a good preliminary selection & to simplify the design procedure, the following factors shall be taken into consideration
  - ***Spacing between poles shall not be more than 4.5 times the height of the poles***
  - Spacing between the edges of the area & the nearest pole shall not be greater than 2.25 times the mounting height
  - A minimum of 2 lights per pole shall be employed in order to achieve even distribution of lighting

Q22. Design a lighting scheme for an area measuring 180m x 80m. The design requirements are

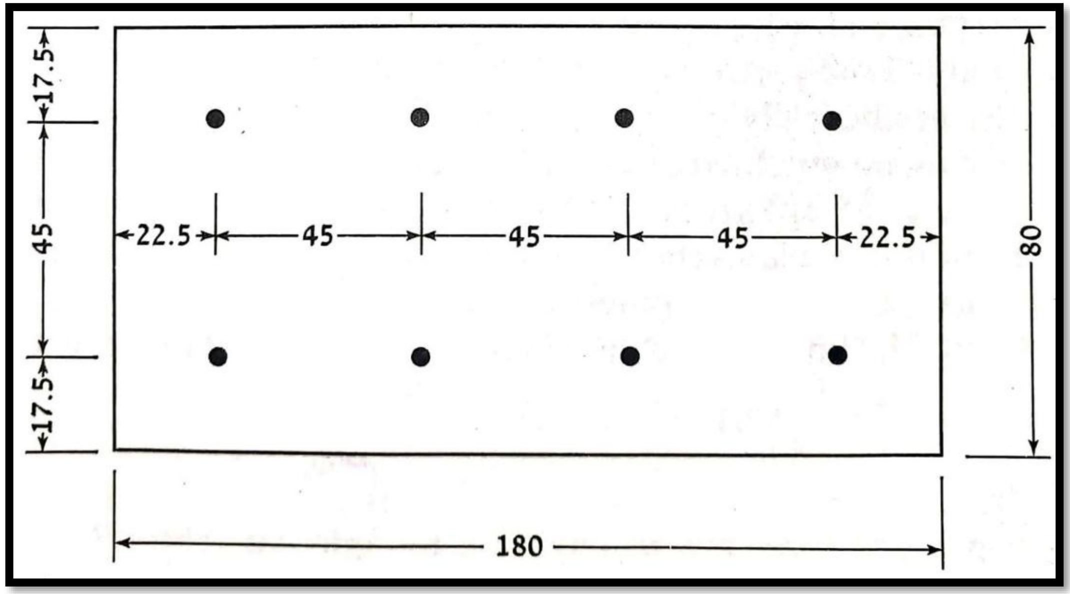
1. Illumination level = 15 lux
2. Mounting height of poles = 10m
3. Luminaires/pole = 2 nos

The details regarding the luminaires available are given in table shown

Type of lamp	CU	LLF	Watts	Lumen output
HPS	0.7	0.75	100	9500
			150	16000
			250	26000
LPS	0.65	0.95	90	12500
			135	21500
			180	33000

Sol: Assume the ratio of spacing to mounting height = 4.5

- Now, the allowable maximum spacing = 4.5 x 10 = 45m
- Therefore, we can accommodate 4 number of poles along the longer side of the area & 2 number of poles along the shorter side as shown in figure
- Since the luminaires/pole is 2, total number of luminaires = 8 x 2 = 16



Case 1 : if HPS lamps are used

- Lumen output of each lamp, Ln = $\frac{A\ x\ E}{N\ x\ CU\ X\ LLF}$ = $\frac{80\ x\ 180\ x\ 15}{16\ x\ 0.7\ x\ 0.75}$ = 22714 lumen
- From the table, 250W HPS lamps with lumen output of 26000 lumen will satisfy the design requirement

Case 2 : if LPS lamps are used

- Lumen output of each lamp, Ln = $\frac{A\ x\ E}{N\ x\ CU\ X\ LLF}$ = $\frac{80\ x\ 180\ x\ 15}{16\ x\ 0.65\ x\ 0.95}$ = 21862 lumen
- From the table, 135W LPS lamps with lumen output of 21500 lumen will satisfy the design requirement

Advantages of LED lamps

- *Long Life span*

- Compared to the lifespan of incandescent bulb, the lifespan of a LED light is far superior.
- The average incandescent bulb lasts about a thousand hours.
- The lifespan of an average LED light is 50,000 hours

- *Energy Efficiency*

- Compared to the energy efficacy of other lamps, LEDs are having higher energy efficacy

- *Improved Environmental Performance*

- It is becoming increasingly important for companies/people to become eco-friendly.
- LEDs become environmental friendly by consuming less energy
- The environmental benefits of LED lighting also extend to their manufacturing process. Many traditional lighting sources, like fluorescent lighting and mercury vapor lights, use mercury internally as part of their construction. Because of this, when they reach the end of their lifespans, they require special handling. There is no such issues with LED lights.

❖ *The Ability to Operate in Cold Conditions*

- Traditional lighting sources don’t like cold weather.
- When the temperature drops, lighting sources, particularly fluorescent lamps, require a higher voltage to start, and the intensity of their light diminishes.
- LED lights, on the other hand, perform better in cold temperatures by about 5%.
- This is why LED lights are a better choice for lighting needed in freezers, meat lockers, cold storage spaces or refrigerated display cases.

❖ *No Heat or UV Emissions*

- Many traditional lighting systems like incandescent bulbs turn more than 90% of the energy they use to heat, allocating only 10% of energy to actual light production.
- LEDs emit almost no heat, and most of the light they emit is within the visible spectrum.

❖ *Design Flexibility*

- LEDs are very small. This means that they can be used in almost any application.
- LED devices can be so small, so that we can use them for illuminating everything from a shop floor to a major league football stadium.

Instant Lighting and the Ability to Withstand Frequent Switching

- LED lights can turn on and off instantly.
- A metal halide lamp need to be prepared for a warm-up period for turning on.
- Since LEDs are unaffected by switching on and off, they can be rapidly cycled for flashing light displays or applications that require sensors that frequently switch from on to off and back again.

Low Voltage Operation

- In many cases LEDs operate on very low voltages.
- This makes them suitable for use in outdoor lighting applications where other lighting might not meet code such as with oceanfront homes where the ground level of the property is in a flood zone.

Dimming Capabilities

- LEDs perform well at almost any power percentage, from about 5% to 100%.
- Some lighting sources, such as metal halide, perform less efficiently when dimmed. Sometimes, we cannot dim them at all.

❖ *Directionality*

- Every conventional lighting technology emits light at 360° around the light source.
- This means that if you want the light to illuminate a specific area, you'll need to purchase accessories to channel or deflect the light in the desired direction.
- An LED light, however, only lights up an area of 180°, which makes LED lighting perfect when you need recessed lighting in an industrial kitchen, hallway or bathroom

Luminous efficacy of LED lamps

- In general the luminous efficiency of LEDs can be as high as 300 lm/W, which is over 18 times more than traditional light bulbs (16.6 lm/IN).
- Although LEDs are a more expensive light source, they are worth choosing due to their high energy efficiency and long life.
- Luminous efficacy of 5 - 16 W LED screw base lamp (230 V) : 75-210 lm/W
- Luminous efficacy of 21.5 W LED retrofit for T8 fluorescent tube (230 V) : 172 lm/W

Previous University Questions

1. Mention the features of good lighting scheme for buildings?
2. Explain the various design parameters taken into consideration while designing street lighting & flood lighting?
3. Explain the laws of illumination with neat diagram?
4. Explain the factors to be considered for an efficient lighting system design?
5. What are the requirements of efficient street lighting?
6. What is the significance of LLF in lighting design? Explain its components?
7. Explain coefficient of utilization and LLF in illumination system.
8. Mention the various types of luminaries in lighting system?
9. List the different types of lamps suitable for street lighting and give their merits and demerits?
10. Briefly explain the working of a LED lamp with circuit diagram?
11. Define the following terms, i. Luminous intensity ii. Luminous Flux iii. Steradian
12. What is Coefficient of utilisation (CoU)? What are the factors affecting CoU?
13. What are the advantages and disadvantages of using LED lamps for household applications?

Previous University Questions

1. A certain incandescent lamp, hangs from the ceiling of a room. The illuminance received on a small horizontal screen lying on a bench 2m vertically below the lamp is 63.5 lux. Calculate illuminance at a point when the screen is moved horizontally a distance of 1.5m along the bench.
2. A factory area is 40m long, 20m wide and is 8m high. Point source luminaires are suspended 1.5 metres below ceiling level. The working plane is 1 metre high. Calculate the minimum number of luminaires which must be installed to conform with a recommended SHR of 1.5: 1
3. A lamp giving out 1200 lm in all directions is suspended 8 m above the working plane. Calculate the illumination at a point on the working plane 6 m away from the foot of the lamp.
4. A factory measures 50m x 30m x 6m high. A general lighting scheme is to illuminate the whole area to 500 lux maintained illuminance using 1000 watt metal halide lamps with an initial efficacy of 90 lumens per watt. Maintenance factor is 0.6 and utilization factor is 0.5. A space height ratio of 1.5: 1 is recommended for the luminaire chosen and a mounting height of 5m over working plane is assumed. Design a suitable lighting scheme.