Illumination and Acoustics

Electrical Lighting design

BY-
Dr. Abdultawab Qahtan

ELECTRIC LIGHTING DESIGN

1) Lighting Design Process
2) LUMINAIRES- Lighting Fixtures- light fitting
3) Lighting system.
4) Visualizing light distribution
5) Lighting Control
6) Rules for the design of efficient electric lighting.
7) Detailed Design Procedures:
   - Calculation of average Illuminance

1) Computer-Aided Lighting Design.

Quality of light is how good it is, and quantity is how much or how many.

1- LIGHTING DESIGN PROCESS

Lighting design is a combination of applied art and applied science. There can be many solutions to the same lighting problem.

Some lighting design fundamentals:

1) Illuminance **levels** should be satisfactory for effective viewing of the particular task involved.
2) **Variations** (within acceptable luminance ratios) in a given field of view are desirable to avoid monotonyرتابة and to create perspective effects.
3) Lighting equipment should be unobtrusive غير بارز but not necessarily invisible. Fixtures may also be decorative and thus enhance the interior design.
4) Lighting must have the proper **quality**.
5) The entire lighting design must be accomplished **efficiently** in terms of **cost** and **energy**

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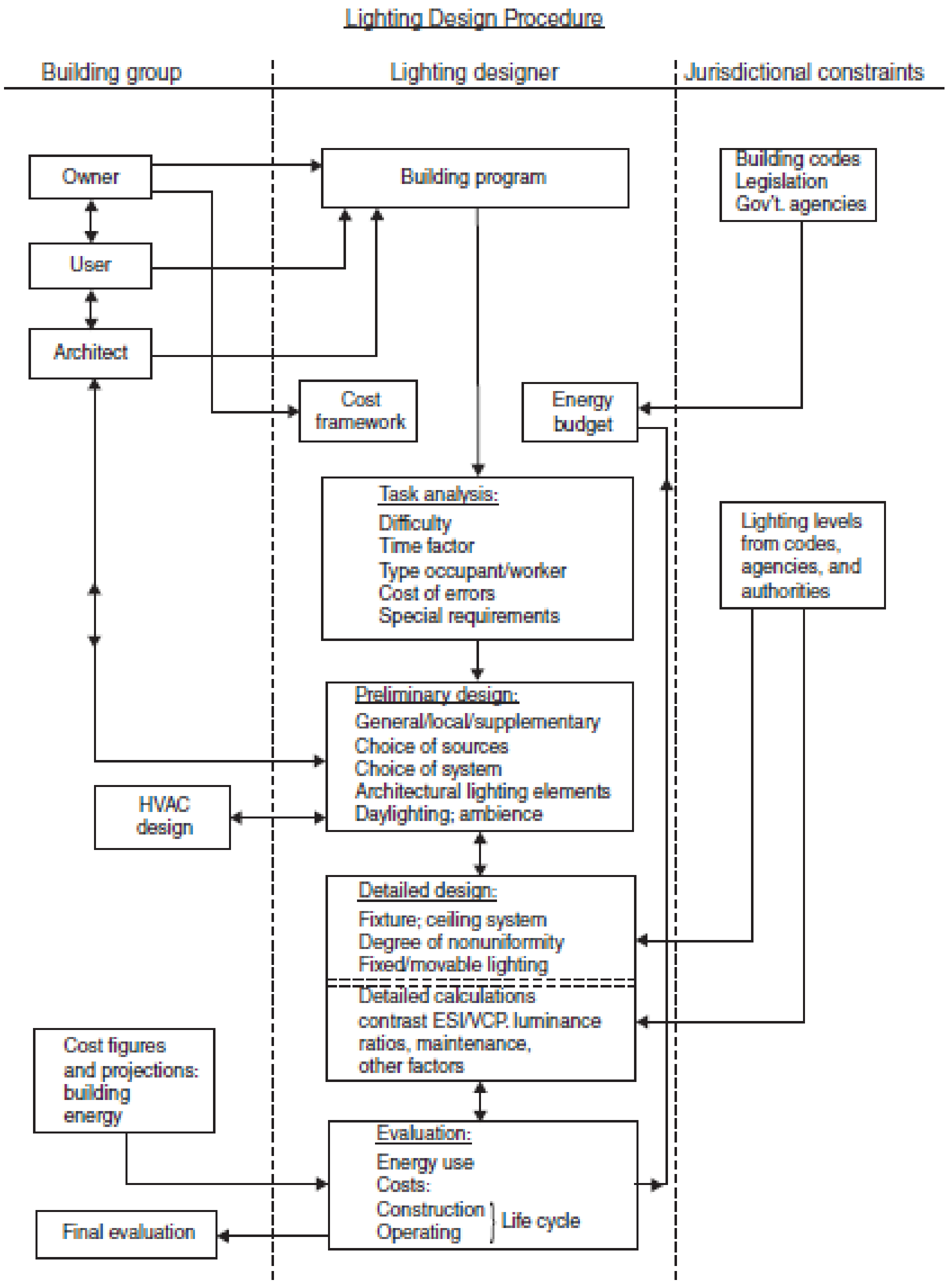
LIGHTING DESIGN PROCEDURE CHART. ***Fig. 15.1*** *Lighting design procedure chart.* ***Textbook p673***



2- LUMINAIRES-

Lighting Fixtures- light fitting

- Why.. lighting fixtures?
- Luminaires- distribution curve
- Luminaires- distribution characteristics.
- Luminaires- type.
- Some luminaire light control

2- LUMINAIRES-
Lighting Fixtures- light fitting

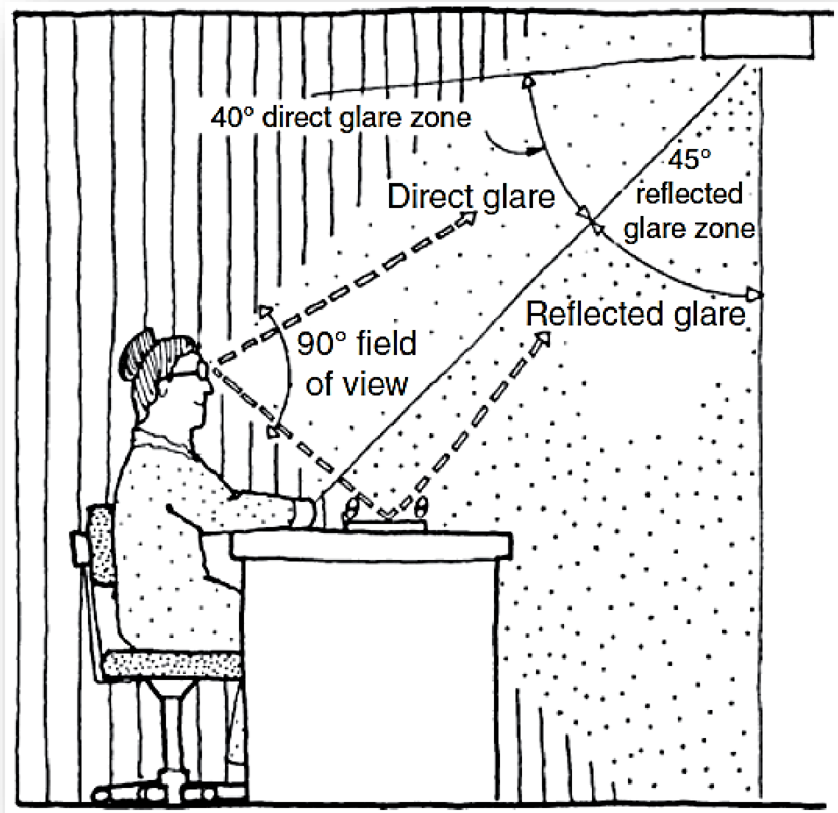
Use not only high **efficacy lamps** but also **high-efficiency luminaires**!

Define the efficacy of the lamps?

Why.. lighting fixtures?

✓ **Physically**: To hold, protect, and electrify the light source ; and

✓ **Photometrically**, to control the lamp output:
- Direct glare, veiling reflections, and unwanted shadows are all reduced or eliminated by the fixtures with a large indirect component.
- The quality of the lighting from direct fixtures can be significantly improved by the design of the fixtures.



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LUMINAIRES- Lighting Fixtures- light fitting

LUMINAIRES- DISTRIBUTION CURVE

✓ The distribution of light from a luminaire (in a vertical plane) is often defined by a curve on a polar-coordinate graph, where the distance from the center represents the **candlepower** (candelas) in that direction.

Luminous intensity (**candlepower**) - characteristic of the a source only

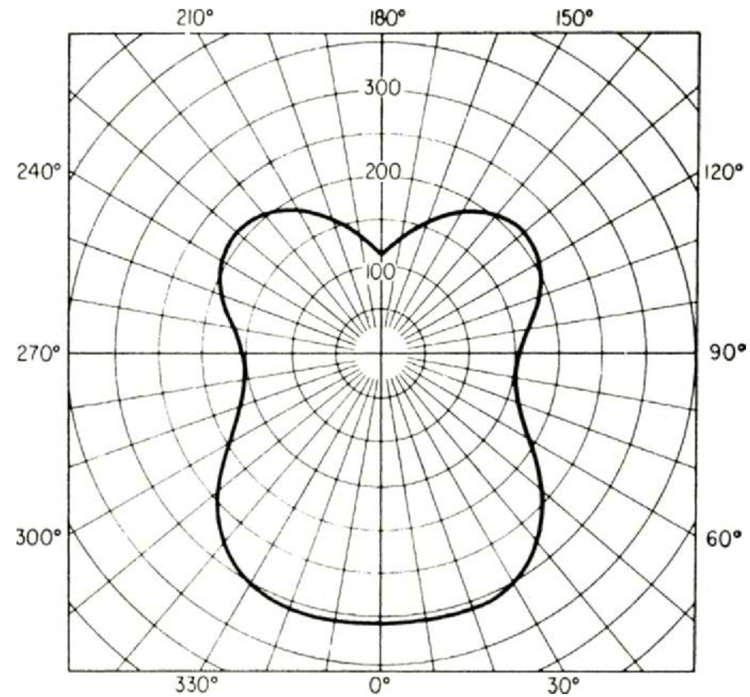

Figure 14.10a. Manufacturers generally supply candlepower (candela) distribution curves for their lighting fixtures. In this vertical section, the distance from the center determines the intensity of the light in that direction. This curve is for a semi-direct lighting fixture

Low-voltage light sources

Veiling Reflection is the **reflection** of a large luminance area on a task. This results in a loss of contrast between the task and the background.

خصائص أجهزة الإضاءة الفعالة

LUMINAIRES- DISTRIBUTION CHARACTERISTICS *text-book P698*

Lighting Fixtures- light fitting

The straight sides of the curve in Fig. 16.1*a* show a fairly sharp cutoff, and the small amount of light above 45° means: high efficiency, probably insufficient wall lighting, barely adequate diffuseness, and very little direct glare potential but a distinct possibility of veiling reflections.

Is it True?
- *High efficiency* is achieved by directing the luminaire output to the work plane (i.e., from 0° to 45° from the vertical).
- Light above 45° is directed to the walls and reaches the working plane only after multiple inter-refelctions.

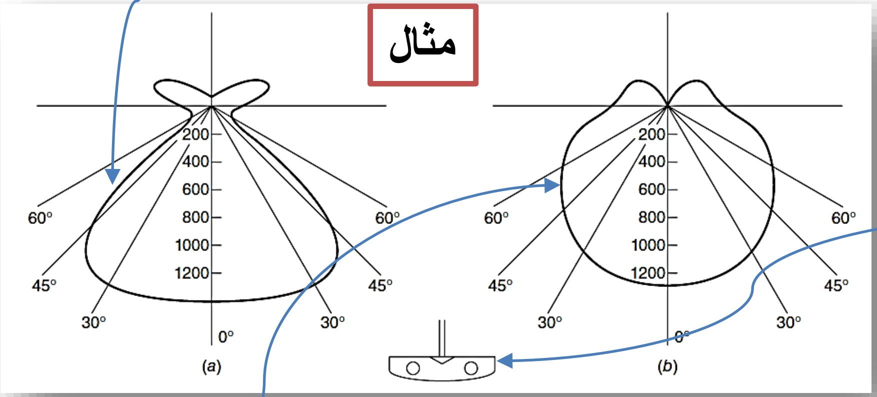

Fig. 16.1 *Semi-direct fluorescent fixture crosswise distribution (**two lamps, 32 W each, prismatic enclosure).***

Conversely, the curve in Fig. 16.1*b* shows a large amount of horizontal illumination (above 45°) with resultant: *direct glare* potential, diffuseness, and relative inefficiency, because *horizontal light output is attenuated by multiple reflections before reaching the horizontal working plane.*

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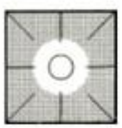
LUMINAIRES- TYPE

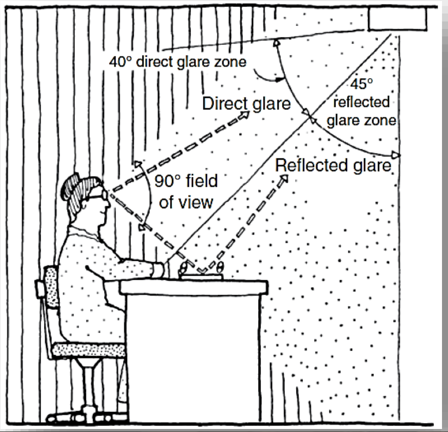
Table 14.9 Lighting Fixtures (Luminaires)

Illustration	Distribution of Light (% directed up/ % directed down)	Type
	0–10 90–100	*Direct:* Direct lighting fixtures send most of the light down to the workplane. Since little light is absorbed by the ceiling or walls, this is an efficient way to achieve high illumination on the work-plane. Direct glare and veiling reflections are often a problem, however. Also, shadows on the task are a problem when the fixture-to-fixture spacing is too large.
	10–40 60–90	*Semidirect:* Semidirect fixtures are very similar to direct luminaires except that a small amount of light is sent up to reflect off the ceiling. Since this creates some diffused light as well as a brighter ceiling, both shadows and the apparent brightness of the fixtures are reduced. Veiling reflections can still be a problem, however.
	40–60 40–60	*General diffuse:* This type of fixture distributes the light more or less equally in all directions. The horizontal component can cause severe direct glare unless the diffusing element is large and a low-wattage lamp is used.
	40–60 40–60	*Direct–indirect:* This luminaire distributes the light about equally up and down. Since there is little light in the horizontal direction, direct glare is not a severe problem. The large indirect component also minimizes shadows and veiling reflections.
	60–90 10–40	*Semi-indirect:* This fixture type reflects much of the light off the ceiling and, thus, yields high-quality lighting. The efficiency is reduced, however, especially when the ceiling and walls are not of a high-reflectance white.
	90–100 0–10	*Indirect:* Almost all of the light is directed up to the ceiling in this fixture type. Therefore, ceiling and wall reflectance factors must be as high as possible. The very diffused lighting eliminates almost all direct glare, veiling reflections, and shadows. The resultant condition is often used for ambient lighting.

SOME LUMINAIRE LIGHT CONTROL

The following describes the various techniques used to improve the types of luminaires:

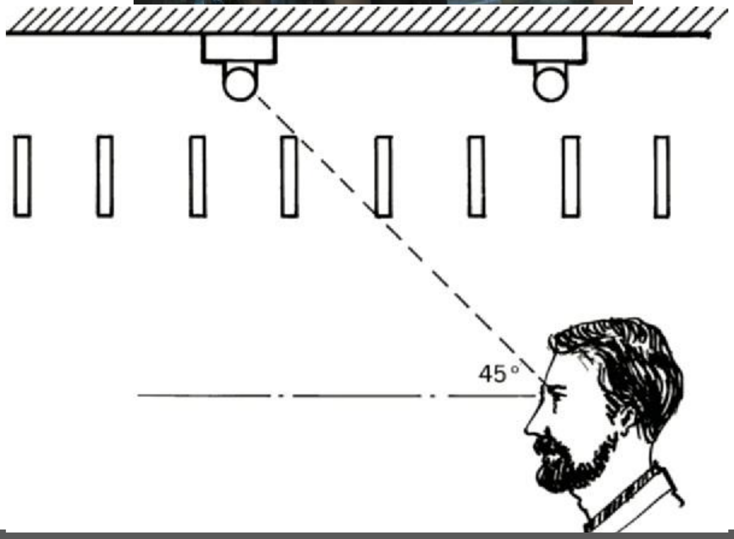
Lenses, prisms, diffusers, baffles, and reflectors are all used in fixtures to control the manner in which light is distributed from the lamps.



1. Baffles, Louvers, and Egg-crate Devices

Baffles, louvers, and egg-crates are **used** to **shield against direct glare.** The direct view of the light sources should be shielded up to at least 45°.

من الأفقي



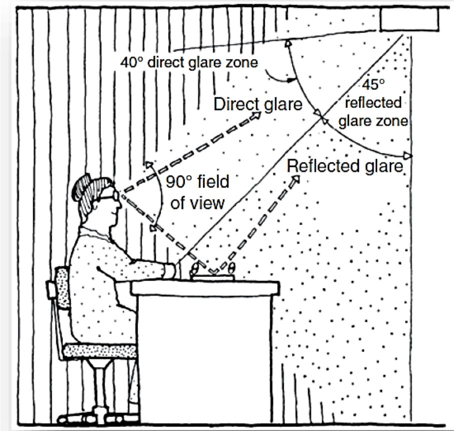
LUMINAIRES- Lighting Fixtures- light fitting

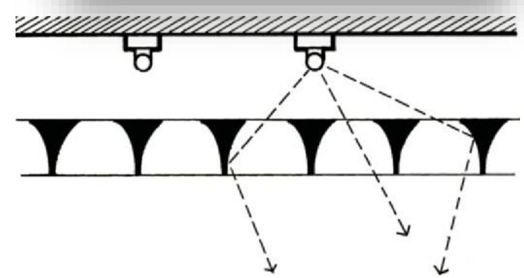
Light in the (…)° to (…)° zone tends to cause direct glare.

2. Parabolic Louvers

قطع مكافئ

- This type of louvers are extremely effective in preventing direct glare because the light distribution is almost straight down.
- Thus, these fixtures have a high visual comfort probability (VCP).
- They are also very good in preventing veiling reflections in computer monitors. **Why?**
- The penalty for having mostly vertical light is that **vertical surfaces such as walls** are not well illuminated.
- This type of louver also does not solve the problem of veiling reflections on horizontal surfaces.





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LUMINAIRES- Lighting Fixtures- light fitting

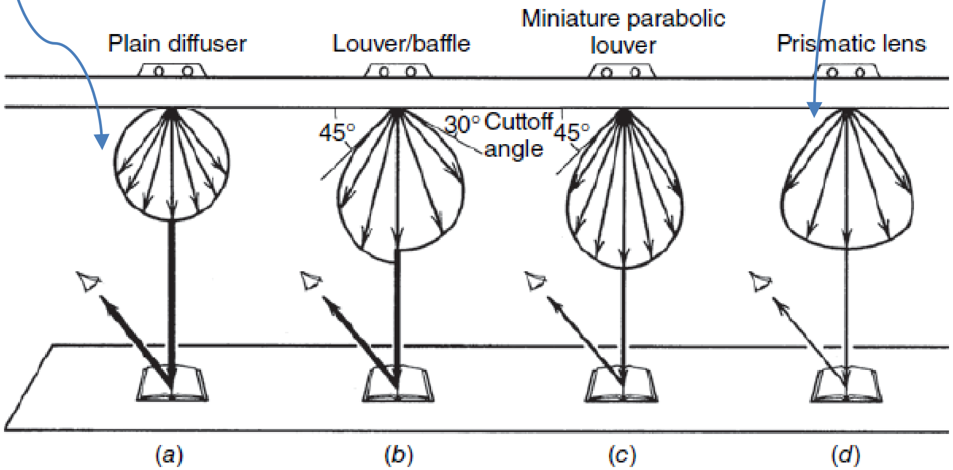
3. Diffusing Glass or Plastic

a. Translucent sheets diffuse the emitted light more or less equally in all directions.
b. The horizontal component of this distributed light is a cause of significant direct glare.
c. Consequently, these devices have limited usefulness.

4. Lenses and Prisms

on Clear Sheets

Refer to page 469-470

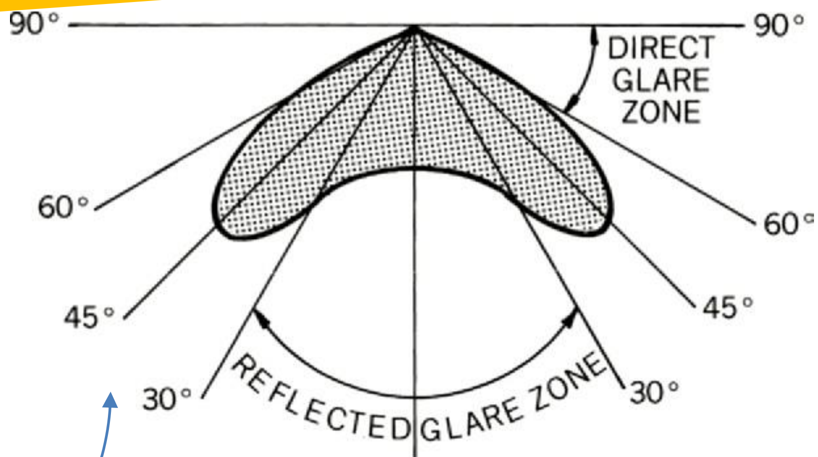


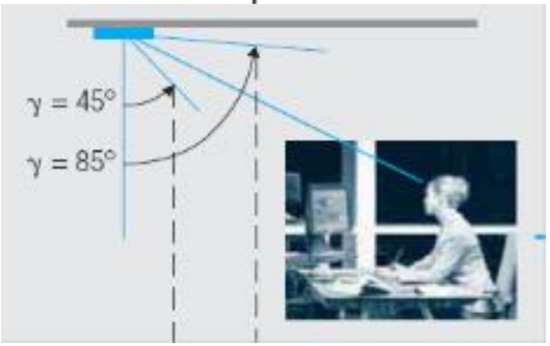
LUMINAIRES- Lighting Fixtures- light fitting

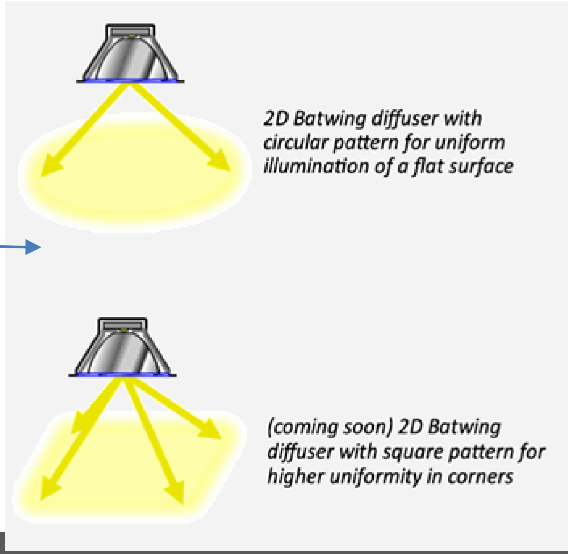
5. Batwing Diffusers

- ✓ For luminaires that have no up-light, only the bottom half of the *polar coordinate graph* is shown. Light that leaves the luminaire from the 0 to 30° zone tends to cause veiling reflections and reflected glare, while light in the 60 to 90° zone tends to cause direct glare.

- ✓ Fixtures with **batwing** light-distribution patterns yield a better-quality light because they minimize the light output in these problematic zones. However, they are not ideal when computers are used.







3- LIGHTING SYSTEMS

Lighting systems can be divided into **six generic types**. In many applications, a combination of these basic systems is used.

1. General Lighting
2. Localized Lighting
3. Ambient Lighting
4. Task Lighting
5. Accent Lighting
6. Decorative Lighting

LIGHTING SYSTEMS

1. General Lighting

- ✓ General lighting usually consists of more or less regularly spaced, ceiling- mounted direct lighting fixtures.
- ✓ It is a very popular system.
- ✓ The illumination is roughly equal everywhere.

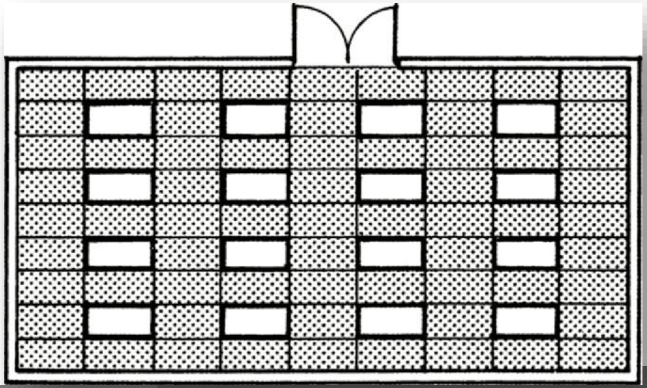
Undesirable:

- ✓ The energy efficiency is usually low
- ✓ work areas receive as much light as task areas.
- ✓ Light quality, especially veiling reflections, is also a problem, since it is hard to find a work area that **does not have** a lighting fixture in the **offending zone**.

Veiling reflections are avoided when light sources are placed outside the offending zone.

Example- whiteboard : The **offending zone** is the area behind user that the user would see if the screen were a mirror.

This reflected-ceiling plan shows the regular layout of direct luminaires, which is typical of general lighting systems. This approach is very flexible but not very energy efficient or interesting.



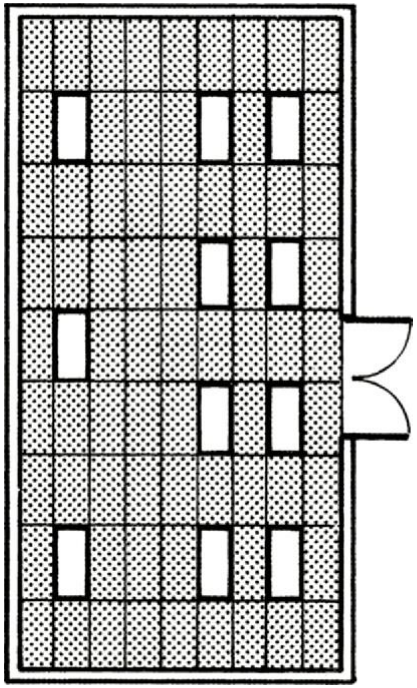
LIGHTING SYSTEMS

2. Localized Lighting

Localized lighting is a **non-uniform arrangement** in which the lighting fixtures are concentrated over the work areas.

- ✓ High efficiency is possible since non-work areas are not illuminated to the same degree as work areas.
- ✓ Veiling reflections and direct glare can be reduced because this system affords some freedom in fixture placement.

Negative:
Reduce the flexibility in rearranging the furniture.



This reflected-ceiling plan illustrates localized lighting. In this system, direct fixtures are placed only where they are needed. Veiling reflections and direct glare are reduced. It is also efficient but is not very flexible.

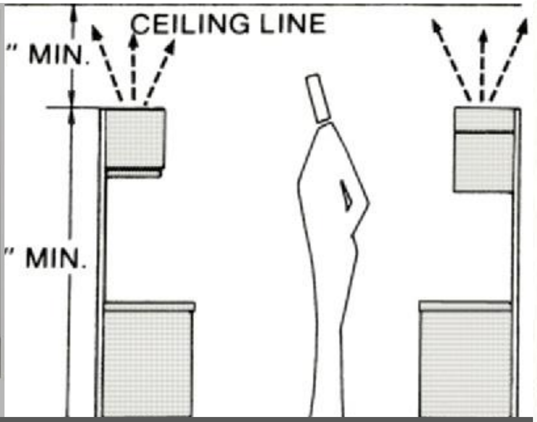
LIGHTING SYSTEMS

3. Ambient Lighting

- ✓ Ambient lighting is **indirect** lighting reflected off the ceiling and walls.
- ✓ It is a diffused, low-illumination, level lighting that is sufficient for easy visual tasks and circulation.
- ✓ It is usually used in conjunction with task lighting and is then known as **task/ambient** lighting.
- ✓ Direct glare and veiling reflections can be almost completely avoided with this approach.
- ✓ The luminaires creating the ambient lighting can be suspended from the ceiling, mounted on walls, supported by stands, or integrated into the furniture.
- ✓ To prevent hot spots, the indirect fixtures should be at least (30 cm) below the ceiling, and to prevent direct glare, they should be above eye level.
- ✓ The ambient illumination level **should be about one-third of the task light level**.

Accent lighting with Ambient lighting

Only Ambient lighting

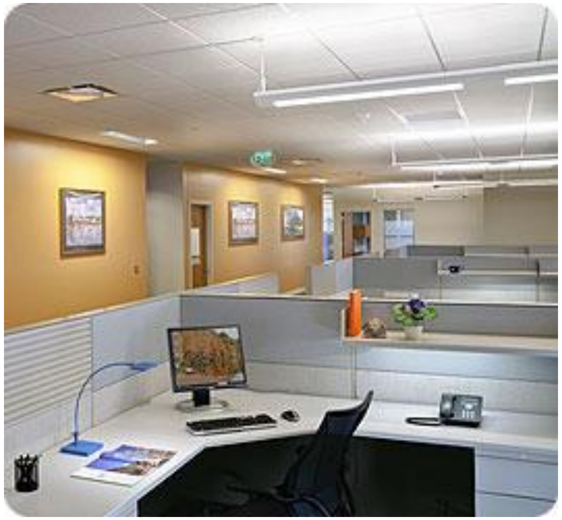


LIGHTING SYSTEMS

4. Task Lighting

- ✓ The greatest flexibility, quality, and energy efficiency.
- ✓ Direct glare and veiling reflections can be completely prevented when the fixtures are placed properly.
- ✓ The individual control possible with this personal lighting system can have significant psychological benefits for workers, who traditionally have little influence over their environment.

- ✓ To avoid dark surrounding areas and excessive brightness ratios, some background illumination is required.
- ✓ Since indirect luminaires are often used to complement the task lighting, this combination is known as **task/ambient lighting**.
- ✓ Task/ambient lighting is the **most sustainable** by using less energy than standard lighting, it is also the highest- quality lighting.



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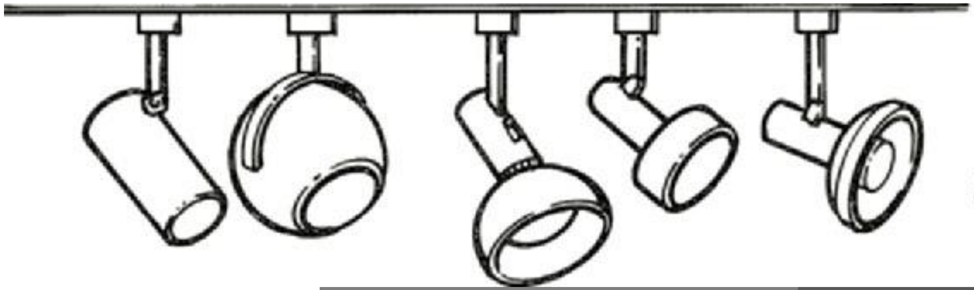
LIGHTING SYSTEMS

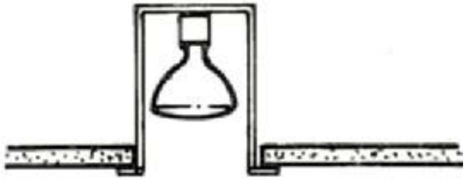
5. Accent Lighting

Accent lighting is used whenever an object or a part of the building is to be highlighted. Accent illumination should be about **ten times higher** than the surrounding light level.

Since this type of lighting is very variable and is a very powerful generator of the visual experience, designers should give it careful attention.

Accent lighting is usually achieved with track lighting or canned downlights. To highlight only small areas or objects, LED or low-voltage fixtures with narrow beams of light are especially appropriate.





LIGHTING SYSTEMS

6. Decorative Lighting

With a decorative-lighting system, unlike all of the others, the lamps and fixtures themselves are the object to be viewed (e.g., **chandeliers**).

Although glare is in this case called “sparkle,” it can still be annoying if it is too bright or if a difficult visual task has to be performed. In most cases, the decorative lighting also supplies some of the functional lighting.

4. VISUALIZING LIGHT DISTRIBUTION

Understanding of the light distribution from various sources.

1- Effect of distance on Illuminance: as discussed previously

2- Effect of Incidence angle on illuminance: cosign law. as discussed previously

In most applications, incandescent and high intensity discharge lamps can be treated as point sources.

4. VISUALIZING LIGHT DISTRIBUTION

How illumination varies with distance from the source?

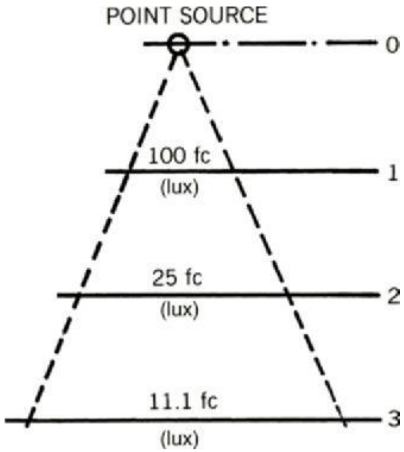
I. For a **point light source**, the illumination (footcandles [lux]) is **inversely proportional to the square of the distance.**

Example:

What is the illumination on the ground directly under a streetlight that is 7 m high and has a light intensity of 15,000 cd straight down?

Lux = cd/m^2 =

15,000/ (7)^2=306 lux

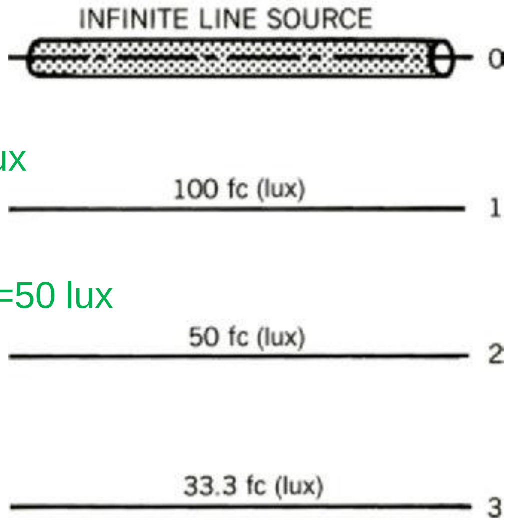


The illumination from a point source is inversely proportional to the square of the distance (feet, meters, or any other unit).

4. VISUALIZING LIGHT DISTRIBUTION

Lux = cd/m =
Lux = 100/ 1=100 lux

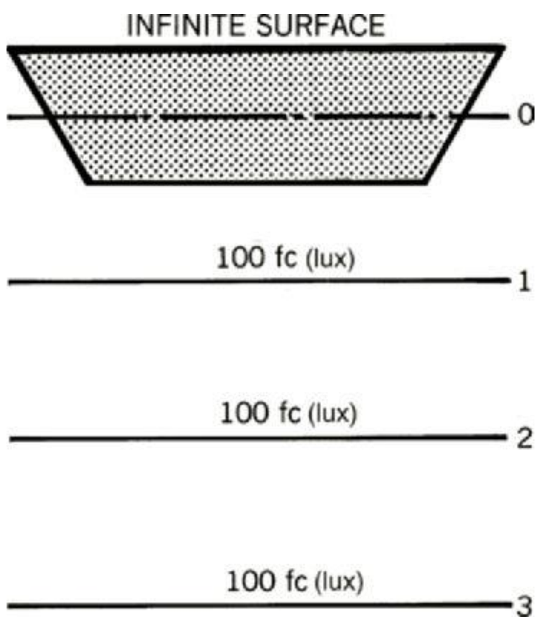
Lux = 100/ 2=50 lux



II. Infinite line source

Infinite line source
The illumination from a line source of infinite length is **inversely proportional to the distance.**

A long string of fluorescent lamps would create such a situation.



III. Infinite surface

The illumination from a surface of infinite area is **constant with distance**.

A typical example of this kind of light source would be well-distributed indirect lighting in a large room.
only direct sunlight acts as a beam of parallel light.(luminaire optics also will)

4. VISUALIZING LIGHT DISTRIBUTION

How the light from a fixed source is distributed over the workplane?

Two major ways exist to graphically display the illumination at the workplane:

1. Graphic method uses points of equal illumination
2. Graphic method shows a graph of the light distribution overlaid on a section of the room.

4. VISUALIZING LIGHT DISTRIBUTION

1. Graphic method uses points of equal illumination to plot the contour lines of the light pattern in plan.

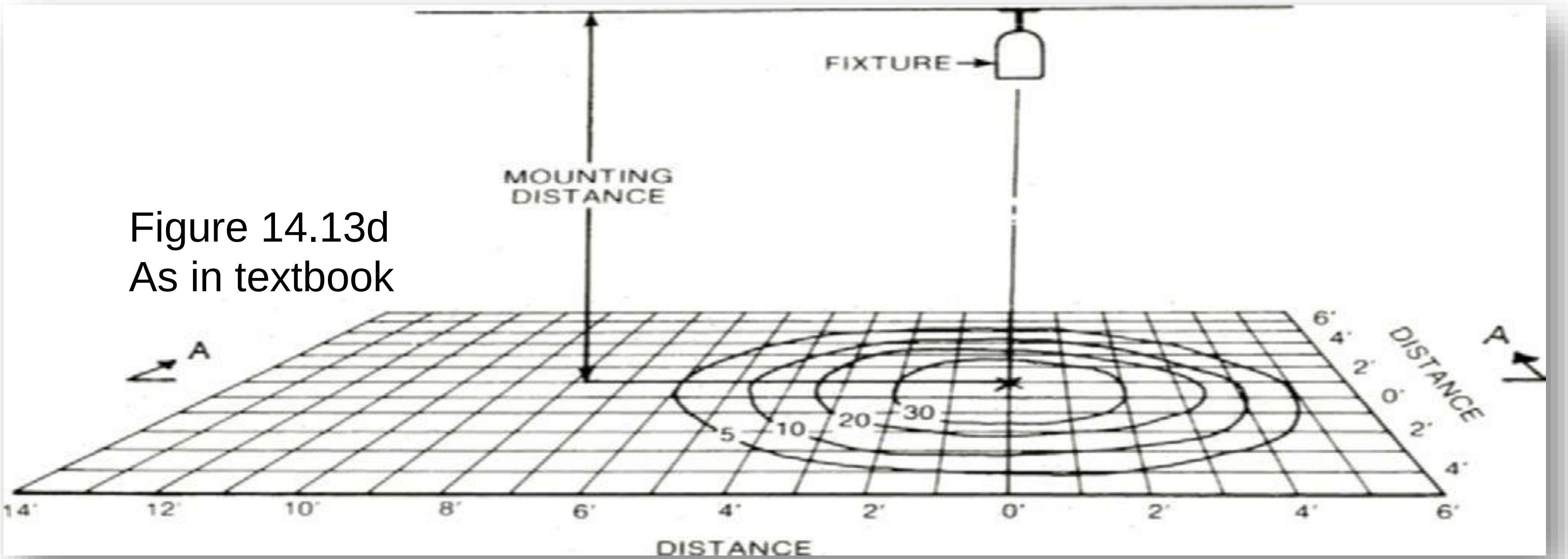
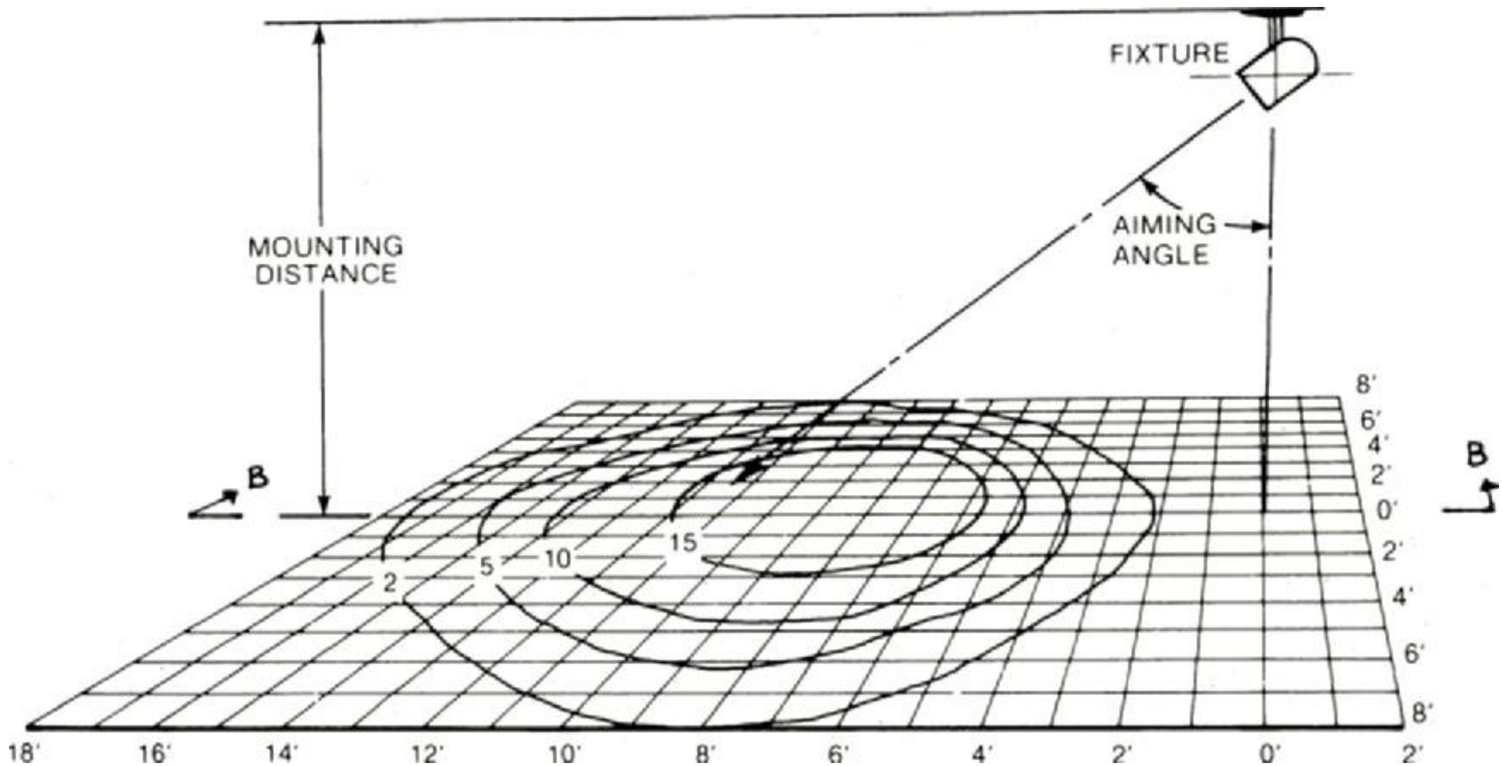


Figure 14.13d
As in textbook

4. VISUALIZING LIGHT DISTRIBUTION

When light is not aimed straight at a surface, the isofootcandle (isolux) lines are extended. The lines are now of **reduced intensity** and cover a larger area.



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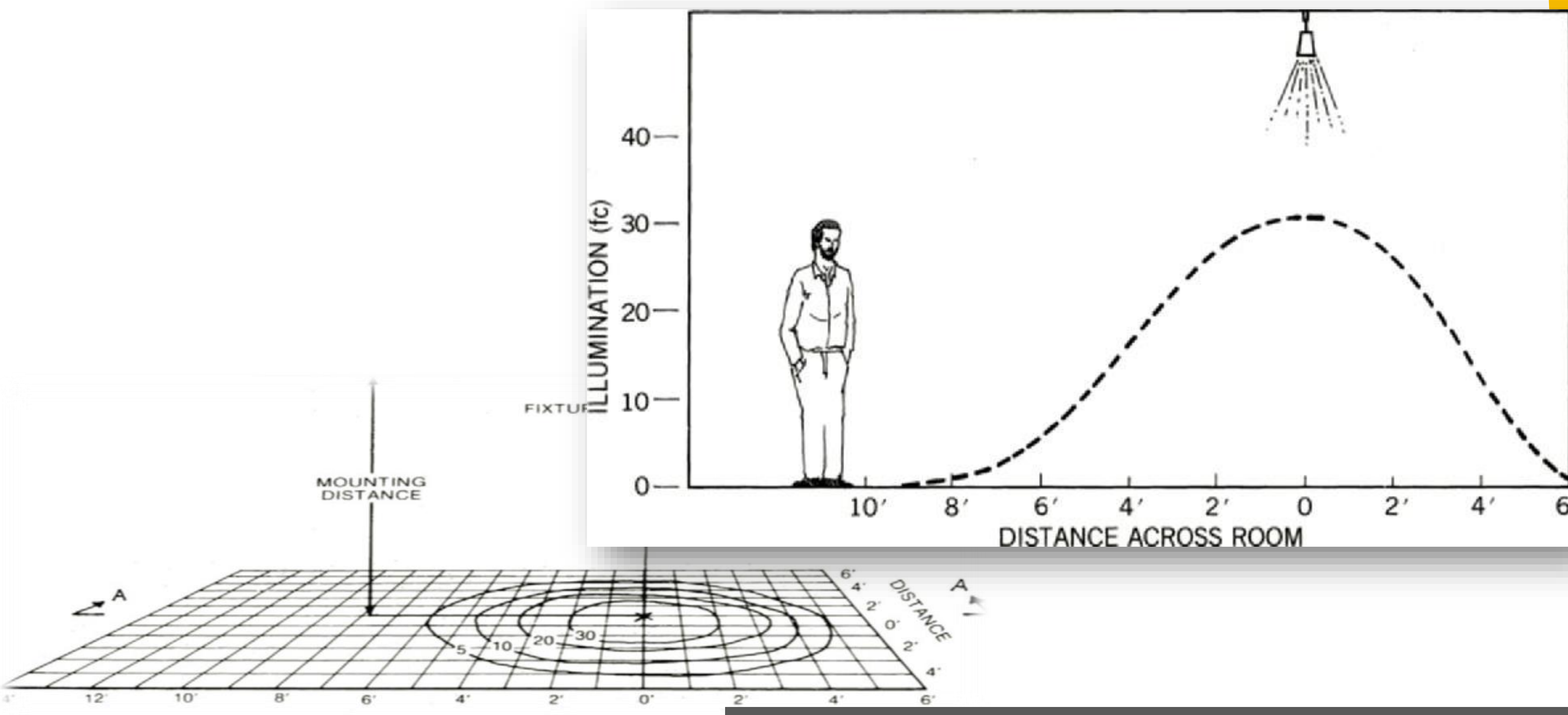
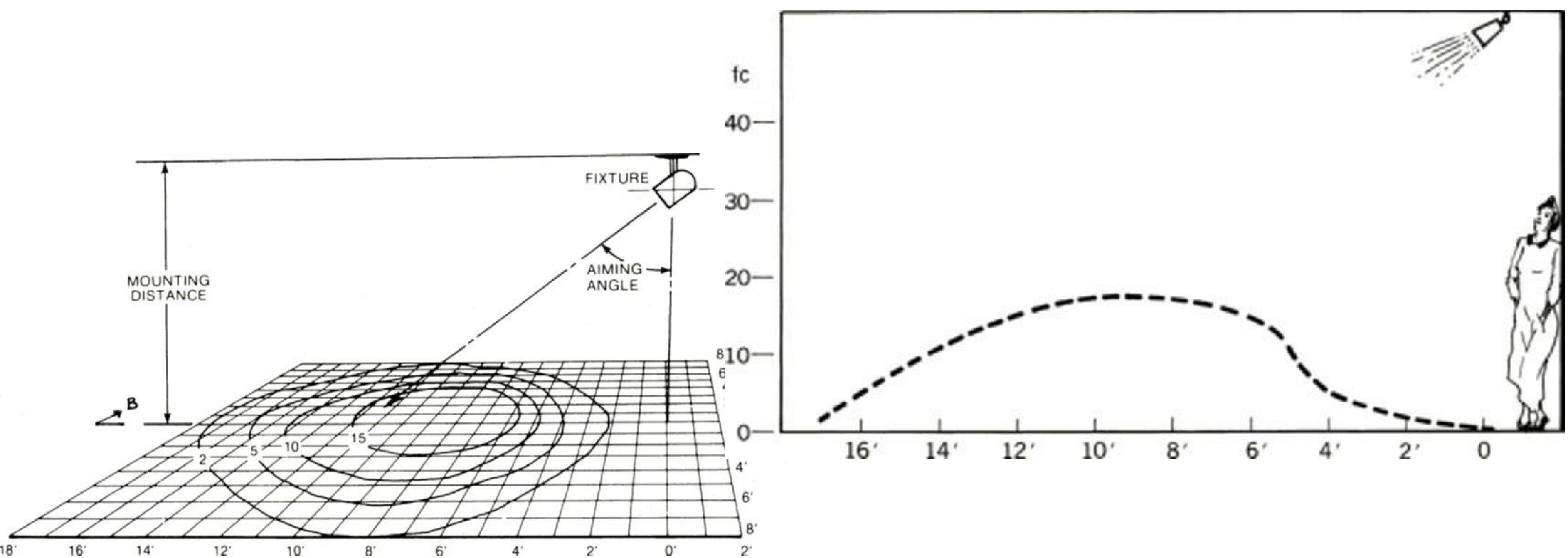
4. VISUALIZING LIGHT DISTRIBUTION

In this alternate graphic method of defining the lighting pattern, a curve of the illumination across a room is plotted on top of a section of the space. This diagram, in fact, is section A–A of the room in Figure 14.13d, textbook. *(see previous slide)*



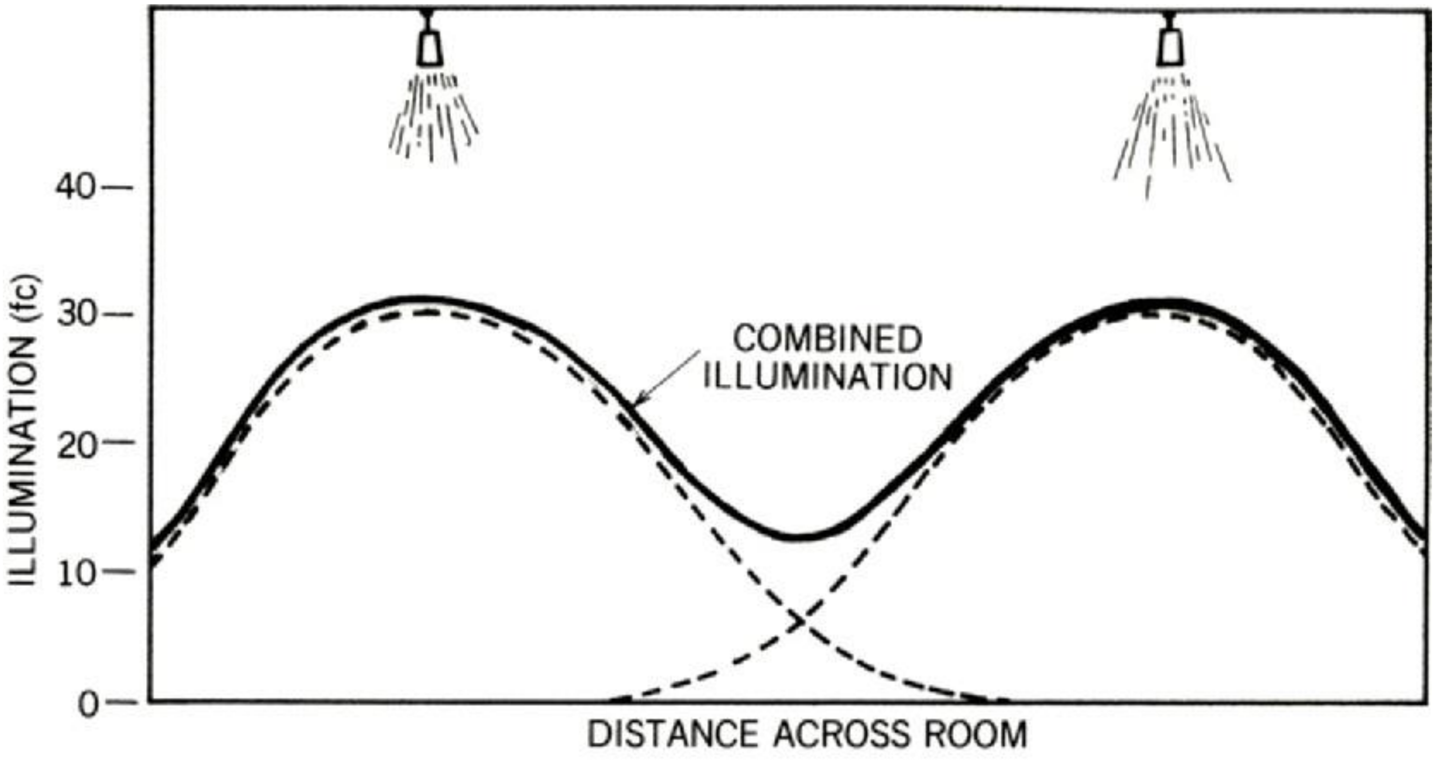
4. VISUALIZING LIGHT DISTRIBUTION

This diagram plots the illumination across the room [at section B–B of](#) Figure 14.13e(as in textbook). Again, we can see that when the light source is not aimed normal (perpendicular) to the work-plane, the maximum illumination is reduced and the light is spread over a larger area.



4. VISUALIZING LIGHT DISTRIBUTION

When more than one light source is present, the curve defining the combined effect is the sum of the individual curves.



5. LIGHTING CONTROL

Automatic lighting controls can reduce lighting energy consumption **as much as 70 percent** by using the following strategies:

1. Dimming
2. Occupancy sensing
3. Scheduling
4. Daylight harvesting
5. task/ambient lighting
6. Personal (manual) control of workstations

من اهم المواضيع
المرتبطة بالاستدامة
في العمارة والاضاءة

6. SOME RULES FOR THE DESIGN OF EFFICIENT ELECTRIC LIGHTING

1. Use light-colored surfaces for ceilings, walls, floors, and furniture.
2. Use local or task lighting to prevent the unnecessary high illumination of non-work areas.
3. Use task/ambient lighting for most work areas.
4. Use electric lighting to complement daylighting.
5. Use the lowest recommended light level for electric lighting.
6. Carefully control the direction of the light source to prevent glare and veiling reflections.
7. Use high-efficacy lamps (e.g., metal halide, fluorescent, and LED).
8. Use the full potential of manual and automatic switching and dimming to save energy and the environment. Use occupancy sensors, photosensors, timers, and central energy-management systems whenever possible.
9. Use Energy Star–labeled lamps.

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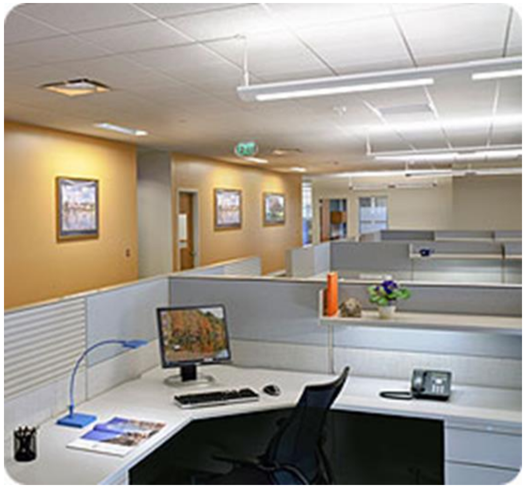
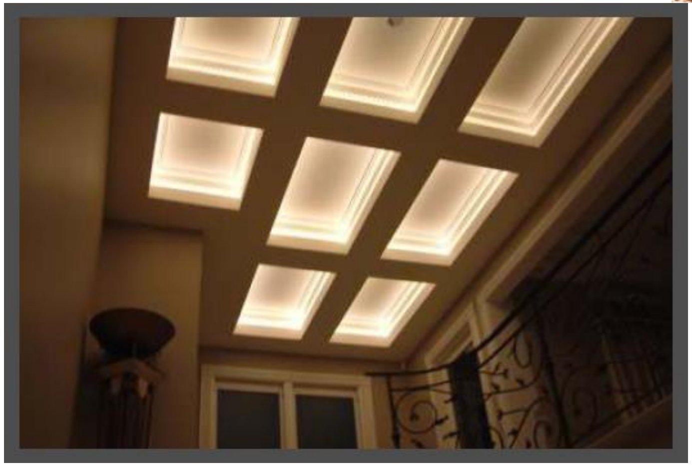
Make a discussion





7. DETAILED DESIGN PROCEDURES:

CALCULATION OF AVERAGE ILLUMINANCE

Next Lecture

Lecture 4: Electrical Lighting design- DETAILED DESIGN PROCEDURES:

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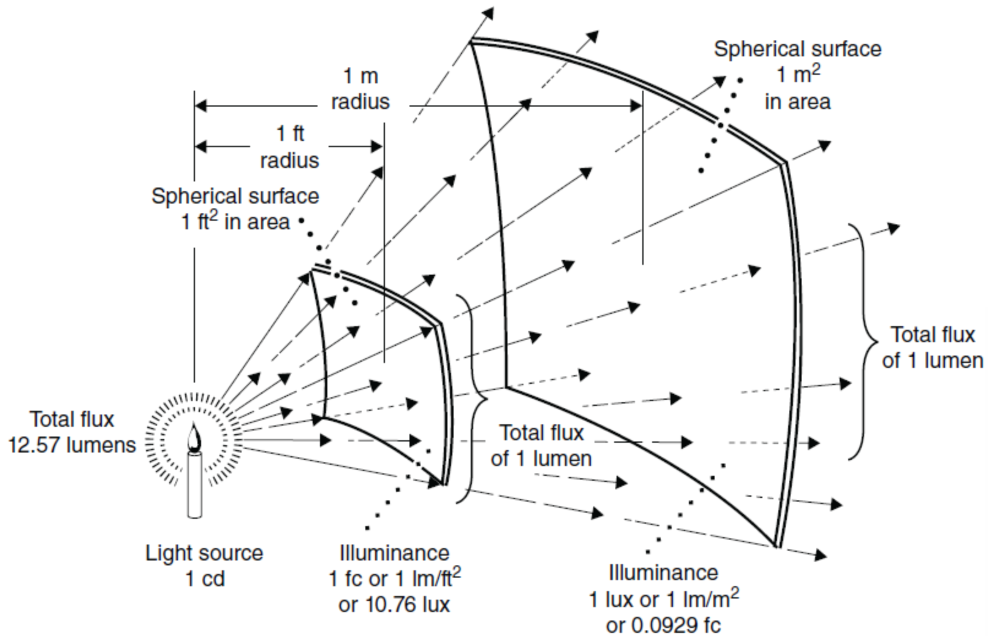
Revision:
Do you remember the terms:
ILLUMINANCE, lumen, luminaire, etc



$$\text{lux} = \frac{\text{lumens}}{\text{square meter area}} \qquad (13.1)$$

$$\text{lx} = \frac{\text{lm}}{\text{m}^2}$$

and

$$\text{footcandles} = \frac{\text{lumens}}{\text{square foot area}} \qquad (13.2)$$

$$\text{fc} = \frac{\text{lm}}{\text{ft}^2}$$

As an *approximation* (with 8% error)

$$10 \text{ lx} \approx 1 \text{ fc} \qquad (13.3)$$

7. DETAILED DESIGN PROCEDURES:

Refer to the Textbook-
Chapter 16, p728

1- CALCULATION OF AVERAGE HORIZONTAL ILLUMINANCE
2- CALCULATING ILLUMINANCE AT A POINT

I. Select a proper luminaire
II. Calculate the number of such fixtures required in each space for uniform *general* illuminance, and to arrange them properly.

Calculation methods:

The lumen (flux) method is simplest and most applicable to our need for **area-lighting** calculations.

7. DETAILED DESIGN PROCEDURES:

1- CALCULATION OF AVERAGE HORIZONTAL ILLUMINANCE

I. Select a proper luminaire
II. Calculate the number of such fixtures required in each space for uniform *general* illuminance, and to arrange them properly.

Calculation methods:

The lumen (flux) method is simplest and most applicable to our need for **area-lighting** calculations.

The Lumen Method- CALCULATION OF AVERAGE HORIZONTAL ILLUMINANCE

Lumen method (also called **zonal cavity method**): is a procedure for determining the *average* maintained illuminance (in footcandles or lux) on the working plane in a room.

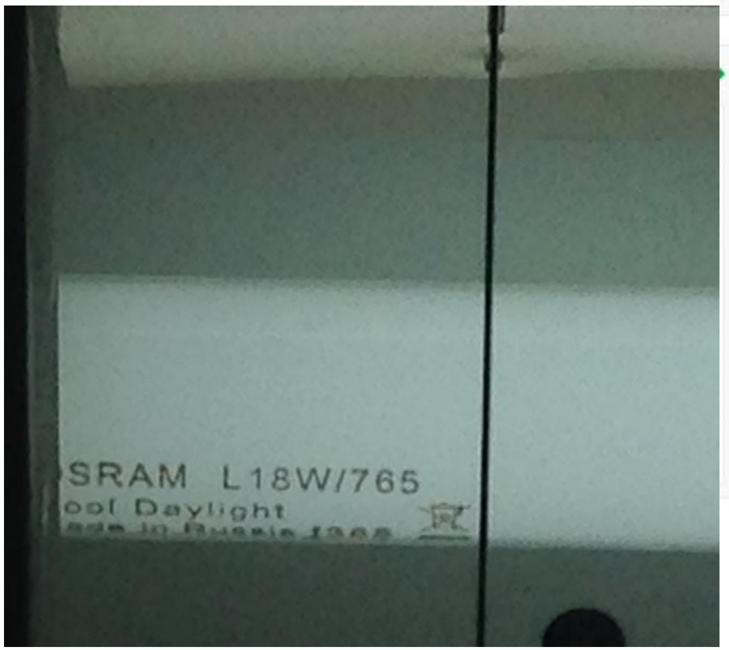
This method is appropriate for spaces in which **illuminance is essentially uniform** throughout.

While Illuminance calculation from point, line, or area sources is covered in other Sections.

Assumptions:

1. It is assumed that the space is empty.
2. It is assumed that all surfaces are perfect diffusers.
3. All surface reflectances are estimates, + - 10%.
4. Maintenance conditions are estimates, at best + - 10%.

Q. Calculate the average Illuminance in your classroom. Use the provided lamp information in figures. Compare the result to the lux value from lux meter.



Fluorescent lamp used in a classroom, College of Engineering, Najran University

View Product
More information on product

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L 18W/765 DAYLIGHT BULB

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ITEM DETAILS
SKU: 2028824

Stock: Stock available

Manufacturer: OSRAM
UOM: PCS
UOM Description: 1 BOX = 25 PIECES
Stock Code: OSR-L18W/10
Manufacturer Part No : L 18W/765

Attachments

- Datasheet/osram-L-18W-765.pdf Size: 58 KB [download]

PRODUCT FEATURES

Average nominal lifespan: 5000
Colour rendering index: 70-79 (class 2A)
Colour temperature: 6500
Energy efficiency class: B
Lamp base: G13
Lamp power: 18
Luminous flux: 1050
Tube diameter: 26

Question:
The Lumen method is a procedure for calculation the average illuminance on the working plane in a room. List the steps of the method. The method based on this formula:

$$lux = \frac{lumens}{m^2}$$

The method is based on this Definition:

$$\text{lux or (fc)} = \frac{\text{lumens}}{\text{area m}^2 \text{ or (ft}^2)}$$

The ratio between the lumens reaching the working plane in a specific space and the lumens generated is the **coefficient of utilization**, CU. Or **lumens on the working plane = lamp lumens × CU**

$$\text{illuminance } E = \frac{\text{lamp lumens} \times \text{CU}}{\text{area}}$$

The **coefficient CU** is selected from tables *-provided by the manufacturer of a selected luminaire-* by a technique known as the zonal cavity method. (explained in the next Section)

CU معامل الاستخدام: سيتم التفصيل فيها لاحقا ضمن هذه المحاضرة

CALCULATION OF AVERAGE HORIZONTAL ILLUMINANCE by The Lumen Method

final expression for maintained illuminance *E* as calculated by the lumen method is, therefore,

$$E = \frac{\text{lamp lumens} \times \text{CU} \times \text{LLF}}{\text{area}} \qquad (16.1)$$

LLF: *Light Loss Factor*
E: lux (footcandles)
Lamp lumens: total within the space and is equal to
number of fixtures × lamps per fixture × initial lumens per lamp

$$E = \frac{\text{number of luminaires} \times \text{lamps/luminaire} \times \text{lumens/lamp} \times \text{CU} \times \text{LLF}}{\text{area}} \qquad (16.2)$$

Number of luminaires =?

CALCULATION OF AVERAGE HORIZONTAL ILLUMINANCE by The Lumen Method

CALCULATION OF LIGHT LOSS FACTOR (LLF)

(a) Luminaire Ambient Temperature

(b) Voltage

(c) Luminaire Surface Reduction

(d) Components

(e) Room Surface Dirt

(f) Lamp Lumen Reduction

(g) Burnouts

(h) Luminaire Dirt Reduction

$$E = \frac{\text{number of luminaires} \times \text{lamps/luminaire} \times \text{lumens/lamp} \times \text{CU} \times \text{LLF}}{\text{area}} \tag{16.2}$$

Refer to the textbook pp729-730

CALCULATION OF AVERAGE HORIZONTAL ILLUMINANCE by The Lumen Method

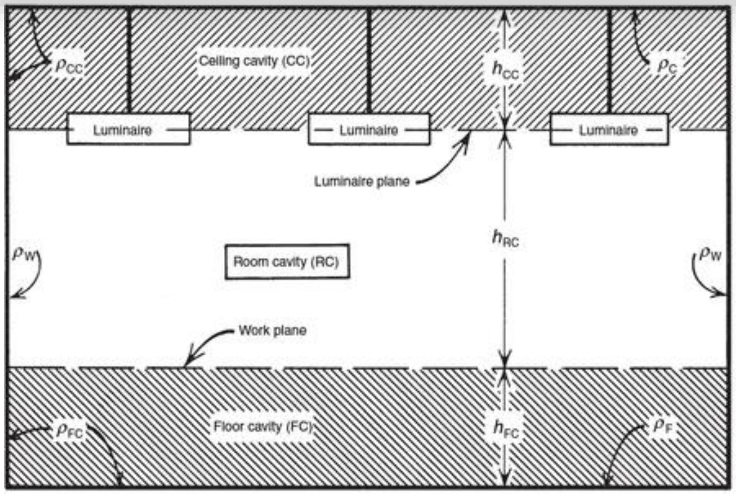
THE COEFFICIENT OF UTILIZATION (CU)

$$E = \frac{\text{number of luminaires} \times \text{lamps/luminaire} \times \text{lumens/lamp} \times \text{CU} \times \text{LLF}}{\text{area}} \qquad (16.2)$$

Definition: A coefficient of utilization (CU) is the ratio between the lumens reaching the working plane in a specific space and the lumens generated.

The space is divided into three cavities:

- ✓ a ceiling cavity above the fixture,
- ✓ a floor cavity below the working plane, and
- ✓ a room cavity between the two



Legend:
ρ_C = ceiling reflectance
ρ_{CC} = ceiling cavity reflectance
ρ_W = wall reflectance
ρ_F = floor reflectance
ρ_{FC} = floor cavity reflectance
h = height in feet or meters
h_{RC} = height of room cavity (etc.)

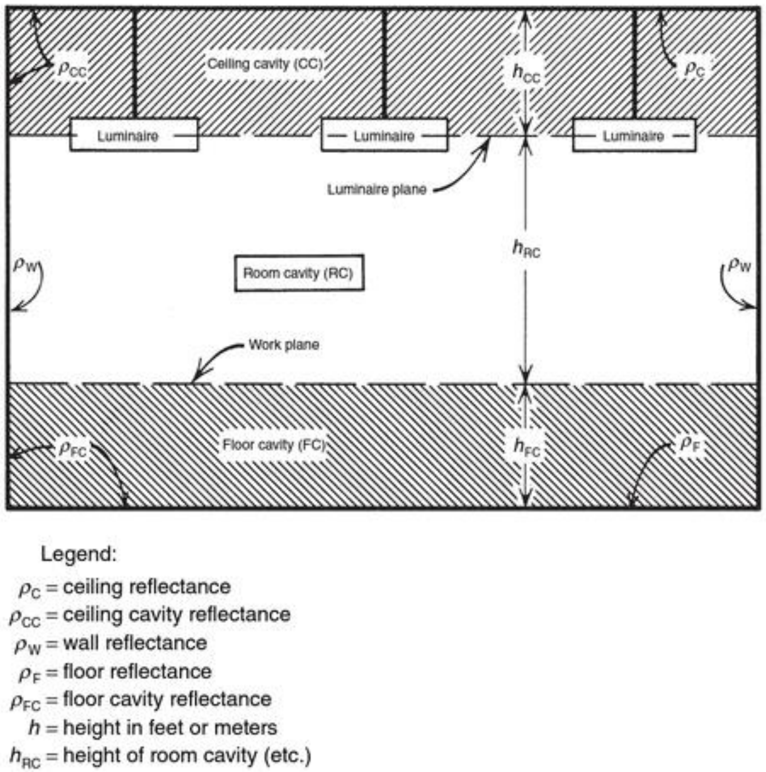
ties as used in the zonal cavity method.

DETERMINATION OF THE COEFFICIENT OF UTILIZATION (CU) BY THE ZONAL CAVITY METHOD

STEP 1. **Dimensional data**

First, dimensional data are established. In offices, schools, and many other occupancies, the **work plane** is (760 mm) above the finished floor (AFF). In **drafting** rooms it is (915 to 965 mm); in **shops**, (1066 to 1220 mm); in **carpet stores** and sail-cutting rooms at floor level. The three *h* terms are the heights of the various cavities.

The working plane for a corridor is 0.2



cavities as used in the zonal cavity method.

Activity:

Draw a sketch of your classroom. Show the dimensions of ceiling cavity, room cavity & floor cavity?

CALCULATION OF AVERAGE ILLUMINANCE

DETERMINATION OF THE COEFFICIENT OF UTILIZATION (CU)

STEP 2. Cavity Ratios

This step involves determining the cavity ratios **of the room** by calculation. The basic expression for a cavity ratio (CR) is

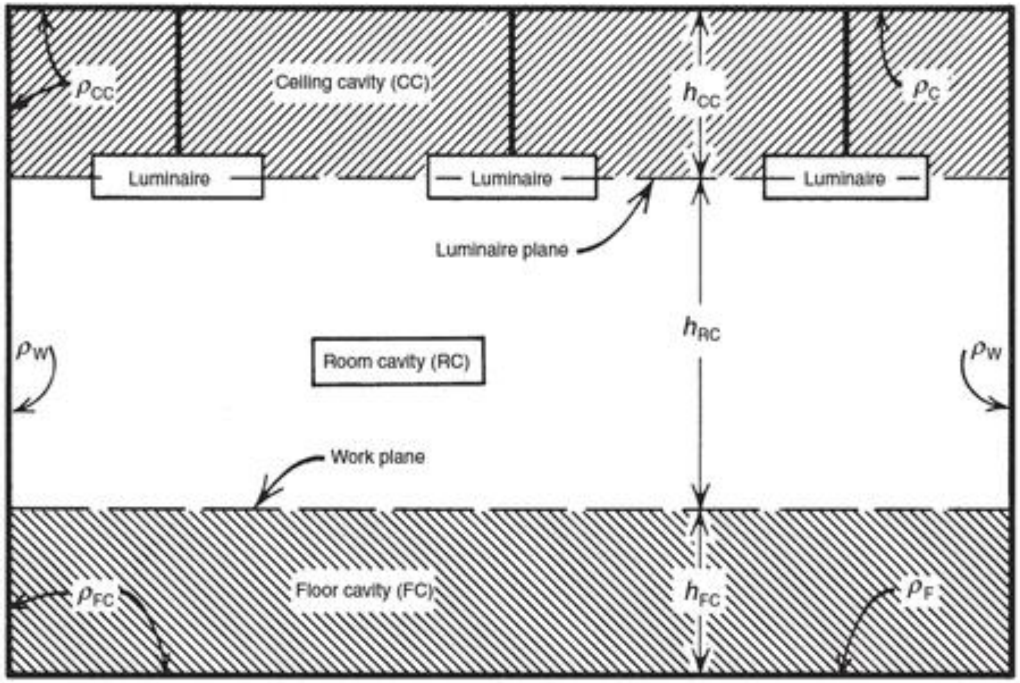
$$\mathrm{CR} = 2.5 \times \frac{\text{area of cavity wall}}{\text{area of work plane}}$$

In a rectangular space, the area of the cavity wall is $h \times (2l \times 2w)$ or $2h(l+w)$; therefore,

$$\mathrm{CR} = \frac{2.5 \times 2h(l+w)}{\text{area of work plane}}$$

or

$$\mathrm{CR} = 5h \times \frac{l+w}{l \times w} \qquad (16.6)$$



For each of the cavities in a rectangular room we have:

Room cavity ratio

$$\mathrm{RCR} = 5h_{RC}\frac{l+w}{l \times w} \qquad (16.8)$$

Ceiling cavity ratio

$$\mathrm{CCR} = 5h_{CC}\frac{l+w}{l \times w} \qquad (16.9)$$

Floor cavity ratio

$$\mathrm{FCR} = 5h_{FC}\frac{l+w}{l \times w} \qquad (16.10)$$

CALCULATION OF AVERAGE ILLUMINANCE

DETERMINATION OF THE COEFFICIENT OF UTILIZATION (CU)

STEP 3. ceiling cavity reflectance

This step involves obtaining the effective ceiling cavity reflectance (ρCC) from the Table, note that the **wall reflectance** remains as selected in step 1.
If the fixtures are surface-mounted or recessed, then CCR = 0 and ρCC = selected ceiling surface reflectance.

Refer to pages 731-733

TABLE 16.2 Percent Effective Ceiling or Floor Cavity Reflectance (ρ_{CC}, ρ_{FC}) for Various Reflectance Combinations

Percent Ceiling ρ_C or Floor Reflectance ρ_F:	90				80				70			50			30				10		
Percent Wall Reflectance ρ_W:	90	70	50	30	80	70	50	30	70	50	30	70	50	30	65	50	30	10	50	30	10
Ceiling or Floor Cavity Ratios—CCR or FCR 0	90	90	90	90	80	80	80	80	70	70	70	50	50	50	30	30	30	30	10	10	10
0.2	89	88	86	85	79	78	77	76	68	67	66	49	48	47	30	29	29	28	10	10	9
0.4	88	86	83	81	78	76	74	72	67	65	63	48	46	45	30	29	27	26	11	10	9
0.6	88	84	80	76	77	75	71	68	65	62	59	47	45	43	29	28	26	25	11	10	9
0.8	87	82	77	73	75	73	69	65	64	60	56	47	43	41	29	27	25	23	11	10	8
1.0	86	80	74	69	74	71	66	61	63	58	53	46	42	39	29	27	24	22	11	9	8
1.2	86	78	72	65	73	70	64	58	61	56	50	45	41	37	29	26	23	20	12	9	7
1.4	85	77	69	62	72	68	62	55	60	54	48	45	40	35	28	26	22	19	12	9	7
1.6	85	75	66	59	71	67	60	53	59	52	45	44	39	33	28	25	21	18	12	9	7
1.8	84	73	64	56	70	65	58	50	57	50	43	43	37	32	28	25	21	17	12	9	6
2.0	83	72	62	53	69	64	56	48	56	48	41	43	37	30	28	24	20	16	12	9	6
2.2	83	70	60	51	68	63	54	45	55	46	39	42	36	29	28	24	19	15	13	9	6
2.4	82	68	58	48	67	61	52	43	54	45	37	42	35	27	28	24	19	14	13	9	6
2.6	82	67	56	46	66	60	50	41	53	43	35	41	34	26	27	23	18	13	13	9	5
2.8	81	66	54	44	66	59	48	39	52	42	33	41	33	25	27	23	18	13	13	9	5
3.0	81	64	52	42	65	58	47	38	51	40	32	40	32	24	27	22	17	12	13	8	5
3.5	79	61	48	37	63	55	43	33	48	38	29	39	30	22	26	22	16	11	13	8	5
4.0	78	58	44	33	61	52	40	30	46	35	26	38	29	20	26	21	15	9	13	8	4
4.5	77	55	41	30	59	50	37	27	45	33	24	37	27	19	25	20	14	8	14	8	4
5.0	76	53	38	27	57	48	35	25	43	32	22	36	26	17	25	19	13	7	14	8	4

Source: Extracted from the *IESNA Lighting Handbook* (1993); reprinted with permission. For more complete data, see the current *IESNA Lighting Handbook*.

CALCULATION OF AVERAGE ILLUMINANCE

DETERMINATION OF THE

COEFFICIENT OF UTILIZATION (CU)

STEP 4. floor cavity reflectance

This step involves obtaining the effective floor cavity reflectance ρFC, as in step 3 for ρCC.

If the floor is the working plane, FCR = 0 and ρFC = selected floor surface reflectance.

TABLE 16.2 Percent Effective Ceiling or Floor Cavity Reflectance (ρ_{CC}, ρ_{FC}) for Various Reflectance Combinations

Percent Ceiling ρ_C or Floor Reflectance ρ_F:		90				80				70			50			30				10		
Percent Wall Reflectance ρ_W:		90	70	50	30	80	70	50	30	70	50	30	70	50	30	65	50	30	10	50	30	10
Ceiling or Floor Cavity Ratios—CCR or FCR	0	90	90	90	90	80	80	80	80	70	70	70	50	50	50	30	30	30	30	10	10	10
	0.2	89	88	86	85	79	78	77	76	68	67	66	49	48	47	30	29	29	28	10	10	9
	0.4	88	86	83	81	78	76	74	72	67	65	63	48	46	45	30	29	27	26	11	10	9
	0.6	88	84	80	76	77	75	71	68	65	62	59	47	45	43	29	28	26	25	11	10	9
	0.8	87	82	77	73	75	73	69	65	64	60	56	47	43	41	29	27	25	23	11	10	8
	1.0	86	80	74	69	74	71	66	61	63	58	53	46	42	39	29	27	24	22	11	9	8
	1.2	86	78	72	65	73	70	64	58	61	56	50	45	41	37	29	26	23	20	12	9	7
	1.4	85	77	69	62	72	68	62	55	60	54	48	45	40	35	28	26	22	19	12	9	7
	1.6	85	75	66	59	71	67	60	53	59	52	45	44	39	33	28	25	21	18	12	9	7
	1.8	84	73	64	56	70	65	58	50	57	50	43	43	37	32	28	25	21	17	12	9	6
	2.0	83	72	62	53	69	64	56	48	56	48	41	43	37	30	28	24	20	16	12	9	6
	2.2	83	70	60	51	68	63	54	45	55	46	39	42	36	29	28	24	19	15	13	9	6
	2.4	82	68	58	48	67	61	52	43	54	45	37	42	35	27	28	24	19	14	13	9	6
	2.6	82	67	56	46	66	60	50	41	53	43	35	41	34	26	27	23	18	13	13	9	5
	2.8	81	66	54	44	66	59	48	39	52	42	33	41	33	25	27	23	18	13	13	9	5
	3.0	81	64	52	42	65	58	47	38	51	40	32	40	32	24	27	22	17	12	13	8	5
	3.5	79	61	48	37	63	55	43	33	48	38	29	39	30	22	26	22	16	11	13	8	5
	4.0	78	58	44	33	61	52	40	30	46	35	26	38	29	20	26	21	15	9	13	8	4
	4.5	77	55	41	30	59	50	37	27	45	33	24	37	27	19	25	20	14	8	14	8	4
	5.0	76	53	38	27	57	48	35	25	43	32	22	36	26	17	25	19	13	7	14	8	4

Source: Extracted from the *IESNA Lighting Handbook* (1993); reprinted with permission. For more complete data, see the current *IESNA Lighting Handbook*.

CALCULATION OF AVERAGE ILLUMINANCE

DETERMINATION OF THE COEFFICIENT OF UTILIZATION (CU)

STEP 5. CU (Coefficient of Utilization) from the manufacturer's data.

Select the CU from the manufacturer's data. See Example 16.1 in the next slides.

The coefficient of utilization (CU), is a factor used to determine the efficiency of a lighting fixture in delivering light for a specific application.

The coefficient of utilization is determined as a ratio of light output from the luminaire that reaches the workplane to the light output of the lamps alone

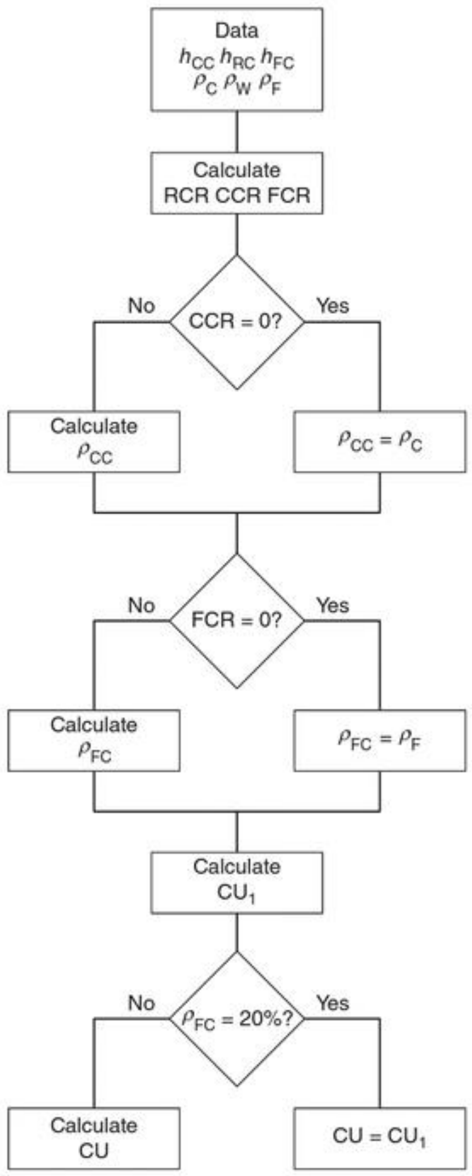


Fig. 16.34 *Zonal cavity method flow chart.*

CALCULATION OF AVERAGE ILLUMINANCE

DETERMINATION OF THE COEFFICIENT OF UTILIZATION (CU)

STEP 6.

Calculate the illuminance and the number of fixtures

Calculate the illuminance and the number of fixtures or area per luminaire as in equation shown. CU coefficients are listed in Table 16.1-textbook- for general luminaire types.

$$\text{lux or (fc)} = \frac{\text{lumens}}{\text{area m}^2 \text{ or } (\text{ft}^2)}$$

As explained previously, the ratio between the lumens reaching the working plane in a specific space and the lumens generated is the coefficient of utilization, CU. Or

$$\text{lumens on the working plane} = \text{lamp lumens} \times \text{CU}$$

Therefore,

$$\text{illuminance } E = \frac{\text{lamp lumens} \times \text{CU}}{\text{area}}$$

$$E = \frac{\text{number of luminaires} \times \text{lamps/luminaire} \times \text{lumens/lamp} \times \text{CU} \times \text{LLF}}{\text{area}} \qquad (16.2)$$

CALCULATION OF AVERAGE ILLUMINANCE
ZONAL CAVITY METHOD

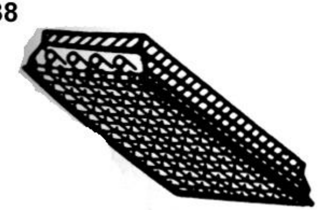
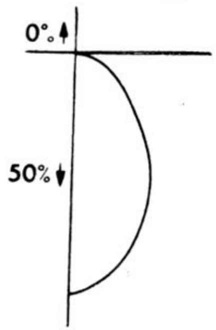
Examples

Example 1

- ✓ Classroom 20’ x 27’ x 12’
- ✓ E=50 fc
- ✓ WP= 2’-6” AFF
- ✓ ρ_c= 80% h_{cc}= 0.0’
- ✓ ρ_w= 50% h_{rc}= 9.5’
- ✓ ρ_f= 20% h_{fc}= 2.5’
- ✓ fixture: fluorescent (#38)
- ✓ maintenance: yearly
- ✓ replacement: on burnout
- ✓ voltages & ballast: normal
- ✓ environment: medium clean

Example 1

Confirm fixture data

Luminaire	Typical Distribution and Percent Lamp Lumens / Maintenance Category	Maximum S/MH	RCR	ρ_{CC}: 80, ρ_W: 50	80 / 30	80 / 10	70 / 50	70 / 30	70 / 10	50 / 50	50 / 30	50 / 10	0 / 0
38  Four-lamp, 610 mm (2ft)-wide troffer with 45 plastic louver	IV 	1.0	0	.60	.60	.60	.58	.58	.58	.56	.56	.56	.50
			1	.54	.52	.50	.52	.51	.49	.50	.49	.48	.44
			2	.48	.45	.43	.47	.44	.42	.45	.43	.41	.39
			3	.43	.40	.37	.42	.39	.37	.41	.38	.36	.34
			4	.39	.35	.32	.38	.35	.32	.37	.34	.32	.30
			5	.35	.31	.28	.35	.31	.28	.34	.30	.28	.26
			6	.32	.28	.25	.32	.28	.25	.31	.27	.25	.23
			7	.29	.25	.22	.29	.25	.22	.28	.25	.22	.21
			8	.26	.22	.20	.26	.22	.20	.25	.22	.20	.18
			9	.24	.20	.17	.24	.20	.17	.23	.20	.17	.16

Coefficients of Utilization for 20% Effective Floor Cavity Reflectance (ρ_{FC} = 20)

S: T.15.1 p. 641

Example 1

Complete #1-6

1. Project identification: ______________________
   (Give name of area and/or building and room number)

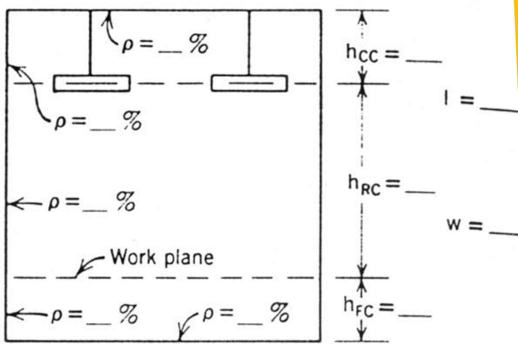
2. Average maintained illumination for design: ______ lux [footcandles]

Luminaire data:
3. Manufacturer: ______________________
4. Catalog number: ______________________

Lamp data:
5. Type and color: ______________________
6. Number per luminaire: ______________________
7. Total lumens per luminaire: ______________________

SELECTION OF COEFFICIENT OF UTILIZATION

8. Step 1: Fill in sketch at right.



9. Step 2: Determine Cavity Ratios by formulas.
   9a. Room cavity ratio, RCR = ______________________
   9b. Ceiling cavity ratio, CCR = ______________________
   9c. Floor cavity ratio, FCR = ______________________

10. Step 3: Obtain effective ceiling cavity reflectance (ρ_{CC}) from Table 20.3. ρ_{CC} = ______
11. Step 4: Obtain effective floor cavity reflectance (ρ_{FC}) from Table 20.3. ρ_{FC} = ______
12. Step 5: Obtain coefficient of utilization (CU) from manufacturer's data. CU = ______

SELECTION OF LIGHT LOSS FACTORS

Unrecoverable
13. Luminaire ambient temperature ______
14. Voltage to luminaire ______
15. Luminaire surface depreciation ______
16. Other factors ______

Recoverable
17. Room surface dirt depreciation ______
18. Lamp lumen depreciation ______
19. Lamp burnouts factor ______
20. Luminaire dirt depreciation LDD ______

21. Total light loss factor, LLF (product of individual factors above): ______

CALCULATIONS
(Average maintained illumination level)

Example 1

7. Determine lumens per luminaire

Obtain lamp lumens from manufacturer's data

TABLE 12.5 Comparative Characteristics of Tubular Fluorescent Lamps[a]

	T12	T8	T5
Initial rated light output	3350 lumens	$\boxed{\text{2950 lumens}}$	2900 lumens
Nominal lamp watts	40W	32 W	28W
Initial lamp efficacy[1]	84 lm/W	92 lm/W	104 lm/W
Initial system efficacy[2]	88 lm/W	90 lm/W	89 lm/W
Lumen maintenance[1]	78%	93%	97%
Maintained system efficacy	69 lm/W	84 lm/W	86 lm/W
Rated life[3]	20,000 hr	20,000 hr	16,000 hr
CRI	80	85	85
Optimum operating temperature	77°F [25°C]	77°F [25°C]	95°F [35°C]

S: T. 12.5 p. 546

Lumen Flux Method

8. Record dimensional data

(Give name of area and/or building and room number)

2. Average maintained illumination for design: ______ lux [footcandles]

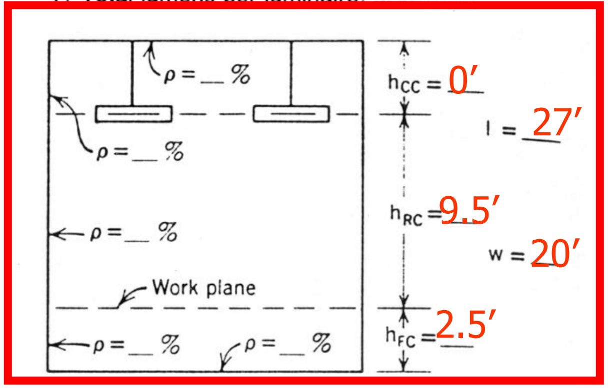
Luminaire data:
3. Manufacturer: ______
4. Catalog number: ______

Lamp data:
5. Type and color: ______
6. Number per luminaire: ______
7. Total lumens per luminaire:

SELECTION OF COEFFICIENT OF UTILIZATION

8. Step 1: Fill in sketch at right.

$\rho_c = 80\%$
$\rho_w = 50\%$
$\rho_f = 20\%$



9. Step 2: Determine Cavity Ratios by formulas.

9a. Room cavity ratio, RCR = ______
9b. Ceiling cavity ratio, CCR = ______
9c. Floor cavity ratio, FCR = ______

10. Step 3: Obtain effective ceiling cavity reflectance (ρ_{CC}) from Table 20.3. ρ_{CC} = ______

11. Step 4: Obtain effective floor cavity reflectance (ρ_{FC}) from Table 20.3. ρ_{FC} = ______

12. Step 5: Obtain coefficient of utilization (CU) from manufacturer's data. CU = ______

SELECTION OF LIGHT LOSS FACTORS

Unrecoverable
13. Luminaire ambient temperature ______
14. Voltage to luminaire ______
15. Luminaire surface depreciation ______
16. Other factors ______

Recoverable
17. Room surface dirt depreciation ______
18. Lamp lumen depreciation ______
19. Lamp burnouts factor ______
20. Luminaire dirt depreciation LDD ______

21. Total light loss factor, LLF (product of individual factors above): ______

CALCULATIONS

(Average maintained illumination level)

$$\text{Number of luminaires} = \frac{(\text{Illuminance}) \times (\text{Area})}{(\text{Lumens per luminaire}) \times (\text{CU}) \times (\text{LLF})}$$

$$\text{Lux [footcandles]} = \frac{(\text{number of luminaires}) \times (\text{lumens per luminaire}) \times (\text{CU}) \times (\text{LLF})}{}$$

Coefficient of Utilization Factor(CU) Calculation

9. Calculate Cavity Ratios

(Give name of area and/or building and room number)

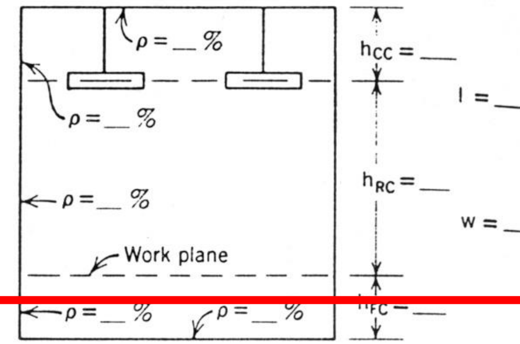
2. Average maintained illumination for design: ______ lux [footcandles]

Luminaire data:
3. Manufacturer: ______
4. Catalog number: ______

Lamp data:
5. Type and color: ______
6. Number per luminaire: ______
7. Total lumens per luminaire: ______

SELECTION OF COEFFICIENT OF UTILIZATION

8. Step 1: Fill in sketch at right.



9. Step 2: Determine Cavity Ratios by formulas.
   - 9a. Room cavity ratio, RCR = ______
   - 9b. Ceiling cavity ratio, CCR = ______
   - 9c. Floor cavity ratio, FCR = ______

10. Step 3: Obtain effective ceiling cavity reflectance (ρ_{CC}) from Table 20.3. ρ_{CC} = ______

11. Step 4: Obtain effective floor cavity reflectance (ρ_{FC}) from Table 20.3. ρ_{FC} = ______

12. Step 5: Obtain coefficient of utilization (CU) from manufacturer's data. CU = ______

SELECTION OF LIGHT LOSS FACTORS

Unrecoverable
13. Luminaire ambient temperature ______
14. Voltage to luminaire ______
15. Luminaire surface depreciation ______
16. Other factors ______

Recoverable
17. Room surface dirt depreciation ______
18. Lamp lumen depreciation ______
19. Lamp burnouts factor ______
20. Luminaire dirt depreciation LDD ______

21. Total light loss factor, LLF (product of individual factors above): ______

CALCULATIONS

(Average maintained illumination level)

$$\text{Number of luminaires} = \frac{(\text{Illuminance}) \times (\text{Area})}{(\text{Lumens per luminaire}) \times (\text{CU}) \times (\text{LLF})}$$

$$\text{Lux [footcandles]} = \frac{(\text{number of luminaires}) \times (\text{lumens per luminaire}) \times (\text{CU}) \times (\text{LLF})}{}$$

Example 1:

Cavity Ratios

$CR = 5\ H \times (L+W)/(L \times W)$

$RCR = 5\ H_{rc} \times (L+W)/(LxW) = 4.1$

$CCR = 5\ H_{cc} \times (L+W)/(LxW) = 0$

$FCR = 5\ H_{fc} \times (L+W)/(LxW) = 1.1$

Remember:

$$CR = 2.5 \times \frac{\text{area of cavity wall}}{\text{area of work plane}}$$

In a rectangular space, the area of the cavity wall is $h \times (2l \times 2w)$ or $2h(l + w)$; therefore,

$$CR = \frac{2.5 \times 2h(l + w)}{\text{area of work plane}}$$

or

$$CR = 5h \times \frac{l + w}{l \times w} \quad (16.6)$$

Coefficient of Utilization Factor(CU) Calculation

10. Calculate Effective Ceiling Reflectance

(Give name of area and/or building and room number)

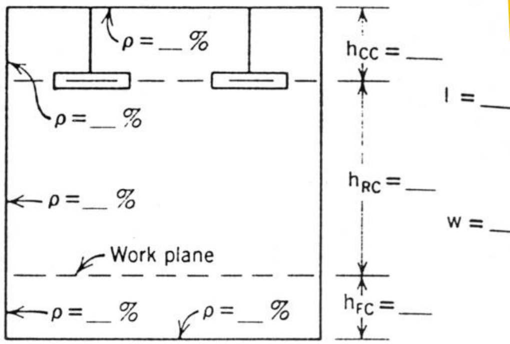
2. Average maintained illumination for design: ______ lux [footcandles]

Luminaire data:
3. Manufacturer: ______
4. Catalog number: ______

Lamp data:
5. Type and color: ______
6. Number per luminaire: ______
7. Total lumens per luminaire: ______

SELECTION OF COEFFICIENT OF UTILIZATION

8. Step 1: Fill in sketch at right.



9. Step 2: Determine Cavity Ratios by formulas.
   - 9a. Room cavity ratio, RCR = ______
   - 9b. Ceiling cavity ratio, CCR = ______
   - 9c. Floor cavity ratio, FCR = ______

10. Step 3: Obtain effective ceiling cavity reflectance (ρ_{CC}) from Table 20.3. ρ_{CC} = ______

11. Step 4: Obtain effective floor cavity reflectance (ρ_{FC}) from Table 20.3. ρ_{FC} = ______

12. Step 5: Obtain coefficient of utilization (CU) from manufacturer's data. CU = ______

SELECTION OF LIGHT LOSS FACTORS

Unrecoverable
13. Luminaire ambient temperature ______
14. Voltage to luminaire ______
15. Luminaire surface depreciation ______
16. Other factors ______

Recoverable
17. Room surface dirt depreciation ______
18. Lamp lumen depreciation ______
19. Lamp burnouts factor ______
20. Luminaire dirt depreciation LDD ______

21. Total light loss factor, LLF (product of individual factors above): ______

CALCULATIONS

(Average maintained illumination level)

$$\text{Number of luminaires} = \frac{(\text{Illuminance}) \times (\text{Area})}{(\text{Lumens per luminaire}) \times (\text{CU}) \times (\text{LLF})}$$

$$\text{Lux [footcandles]} = \frac{(\text{number of luminaires}) \times (\text{lumens per luminaire}) \times (\text{CU}) \times (\text{LLF})}{\ldots}$$

Illumination & Acoustics

Example 1: Effective Ceiling Reflectance

TABLE 20.3 **Percent Effective Ceiling or Floor Cavity Reflectance (ρ_{CC}, ρ_{FC}) for Various Reflectance Combinations**

Percent Ceiling ρ_C or Floor Reflectance ρ_F:	*90*				*80*				*70*			*50*			*30*				*10*		
Percent Wall Reflectance ρ_W:	*90*	*70*	*50*	*30*	*80*	*70*	*50*	*30*	*70*	*50*	*30*	*70*	*50*	*30*	*65*	*50*	*30*	*10*	*50*	*30*	*10*
Ceiling or Floor Cavity Rates CCR or FCR 0	90	90	90	90	80	80	80	80	70	70	70	50	50	50	30	30	30	30	10	10	10
0.2	89	88	86	85	79	78	77	76	68	67	66	49	48	47	30	29	29	28	10	10	9
0.4	88	86	83	81	78	76	74	72	67	65	63	48	46	45	30	29	27	26	11	10	9
0.6	88	84	80	76	77	75	71	68	65	62	59	47	45	43	29	28	26	25	11	10	9
0.8	87	82	77	73	75	73	69	65	64	60	56	47	43	41	29	27	25	23	11	10	8
1.0	86	80	74	69	74	71	66	61	63	58	53	46	42	39	29	27	24	22	11	9	8
1.2	86	78	72	65	73	70	64	58	61	56	50	45	41	37	29	26	23	20	12	9	7
1.4	85	77	69	62	72	68	62	55	60	54	48	45	40	35	28	26	22	19	12	9	7
1.6	85	75	66	59	71	67	60	53	59	52	45	44	39	33	28	25	21	18	12	9	7
1.8	84	73	64	56	70	65	58	50	57	50	43	43	37	32	28	25	21	17	12	9	6
2.0	83	72	62	53	69	64	56	48	56	48	41	43	37	30	28	24	20	16	12	9	6
2.2	83	70	60	51	68	63	54	45	55	46	39	42	36	29	28	24	19	15	13	9	6
2.4	82	68	58	48	67	61	52	43	54	45	37	42	35	27	28	24	19	14	13	9	6
2.6	82	67	56	46	66	60	50	41	53	43	35	41	34	26	27	23	18	13	13	9	5
2.8	81	66	54	44	66	59	48	39	52	42	33	41	33	25	27	23	18	13	13	9	5
3.0	81	64	52	42	65	58	47	38	51	40	32	40	32	24	27	22	17	12	13	8	5
3.5	79	61	48	37	63	55	43	33	48	38	29	39	30	22	26	22	16	11	13	8	5
4.0	78	58	44	33	61	52	40	30	46	35	26	38	29	20	26	21	15	9	13	8	4
4.5	77	55	41	30	59	50	37	27	45	33	24	37	27	19	25	20	14	8	14	8	4
5.0	76	53	38	27	57	48	35	25	43	32	22	36	26	17	25	19	13	7	14	8	4

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Example 1

11. Calculate Effective Floor Reflectance

Stein: T.15.2 P. 666

(Give name of area and/or building and room number)

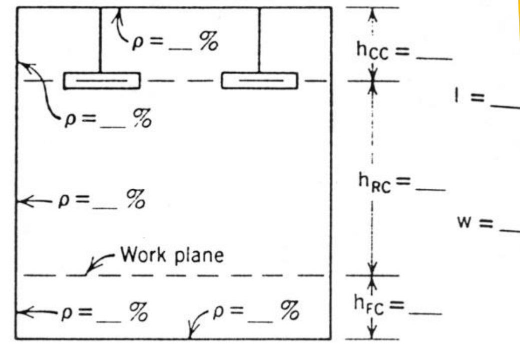
2. Average maintained illumination for design: ______ lux [footcandles]

Luminaire data:
3. Manufacturer: ______
4. Catalog number: ______

Lamp data:
5. Type and color: ______
6. Number per luminaire: ______
7. Total lumens per luminaire: ______

SELECTION OF COEFFICIENT OF UTILIZATION

8. Step 1: Fill in sketch at right.



9. Step 2: Determine Cavity Ratios by formulas.
   - 9a. Room cavity ratio, RCR = ______
   - 9b. Ceiling cavity ratio, CCR = ______
   - 9c. Floor cavity ratio, FCR = ______

10. Step 3: Obtain effective ceiling cavity reflectance (ρ_{CC}) from Table 20.3. ρ_{CC} = ______

11. Step 4: Obtain effective floor cavity reflectance (ρ_{FC}) from Table 20.3. ρ_{FC} = ______

12. Step 5: Obtain coefficient of utilization (CU) from manufacturer's data. CU = ______

SELECTION OF LIGHT LOSS FACTORS

Unrecoverable
13. Luminaire ambient temperature ______
14. Voltage to luminaire ______
15. Luminaire surface depreciation ______
16. Other factors ______

Recoverable
17. Room surface dirt depreciation ______
18. Lamp lumen depreciation ______
19. Lamp burnouts factor ______
20. Luminaire dirt depreciation LDD ______

21. Total light loss factor, LLF (product of individual factors above): ______

CALCULATIONS

(Average maintained illumination level)

$$\text{Number of luminaires} = \frac{(\text{Illuminance}) \times (\text{Area})}{(\text{Lumens per luminaire}) \times (\text{CU}) \times (\text{LLF})}$$

$$\text{Lux [footcandles]} = \frac{(\text{number of luminaires}) \times (\text{lumens per luminaire}) \times (\text{CU}) \times (\text{LLF})}{\ldots}$$

Example 1: Coefficient of Utilization (CU)

Percent Effective Ceiling or Floor Cavity Reflectance (ρ_{CC}, ρ_{FC}) for Various Reflectance Combinations

Percent Ceiling ρ_C or Floor Reflectance ρ_F:	90				80				70			50			30				10		
Percent Wall Reflectance ρ_W:	90	70	50	30	80	70	50	30	70	50	30	70	50	30	65	50	30	10	50	30	10
Ceiling or Floor Cavity Rates CCR or FCR																					
0	90	90	90	90	80	80	80	80	70	70	70	50	50	50	30	30	30	30	10	10	10
0.2	89	88	86	85	79	78	77	76	68	67	66	49	48	47	30	29	29	28	10	10	9
0.4	88	86	83	81	78	76	74	72	67	65	63	48	46	45	30	29	27	26	11	10	9
0.6	88	84	80	76	77	75	71	68	65	62	59	47	45	43	29	28	26	25	11	10	9
0.8	87	82	77	73	75	73	69	65	64	60	56	47	43	41	29	27	25	23	11	10	8
1.0	86	80	74	69	74	71	66	61	63	58	53	46	42	39	29	27	24	22	11	9	8
1.2	86	78	72	65	73	70	64	58	61	56	50	45	41	37	29	26	23	20	12	9	7
1.4	85	77	69	62	72	68	62	55	60	54	48	45	40	35	28	26	22	19	12	9	7
1.6	85	75	66	59	71	67	60	53	59	52	45	44	39	33	28	25	21	18	12	9	7
1.8	84	73	64	56	70	65	58	50	57	50	43	43	37	32	28	25	21	17	12	9	6
2.0	83	72	62	53	69	64	56	48	56	48	41	43	37	30	28	24	20	16	12	9	6
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2.8	81	66	54	44	66	59	48	39	52	42	33	41	33	25	27	23	18	13	13	9	5
3.0	81	64	52	42	65	58	47	38	51	40	32	40	32	24	27	22	17	12	13	8	5
3.5	79	61	48	37	63	55	43	33	48	38	29	39	30	22	26	22	16	11	13	8	5
4.0	78	58	44	33	61	52	40	30	46	35	26	38	29	20	26	21	15	9	13	8	4
4.5	77	55	41	30	59	50	37	27	45	33	24	37	27	19	25	20	14	8	14	8	4
5.0	76	53	38	27	57	48	35	25	43	32	22	36	26	17	25	19	13	7	14	8	4

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Example 1

12. Select CU from mfr's data or see

(Give name of area and/or building and room number)

2. Average maintained illumination for design: ______ lux [footcandles]

Luminaire data:

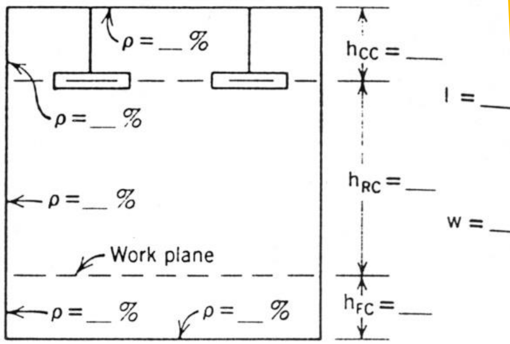
3. Manufacturer: ______
4. Catalog number: ______

Lamp data:

5. Type and color: ______
6. Number per luminaire: ______
7. Total lumens per luminaire: ______

SELECTION OF COEFFICIENT OF UTILIZATION

8. Step 1: Fill in sketch at right.



9. Step 2: Determine Cavity Ratios by formulas.
   - 9a. Room cavity ratio, RCR = ______
   - 9b. Ceiling cavity ratio, CCR = ______
   - 9c. Floor cavity ratio, FCR = ______
10. Step 3: Obtain effective ceiling cavity reflectance (ρ_{CC}) from Table 20.3. ρ_{CC} = ______
11. Step 4: Obtain effective floor cavity reflectance (ρ_{FC}) from Table 20.3. ρ_{FC} = ______
12. Step 5: Obtain coefficient of utilization (CU) from manufacturer's data. CU = ______

SELECTION OF LIGHT LOSS FACTORS

Unrecoverable

13. Luminaire ambient temperature ______
14. Voltage to luminaire ______
15. Luminaire surface depreciation ______
16. Other factors ______

Recoverable

17. Room surface dirt depreciation ______
18. Lamp lumen depreciation ______
19. Lamp burnouts factor ______
20. Luminaire dirt depreciation LDD ______

21. Total light loss factor, LLF (product of individual factors above): ______

CALCULATIONS

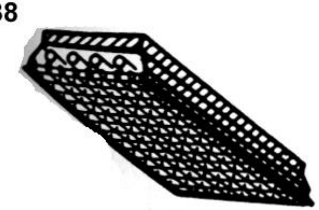
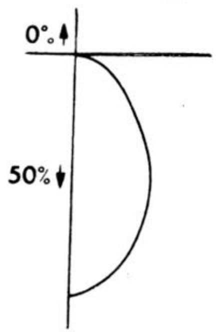
(Average maintained illumination level)

$$\text{Number of luminaires} = \frac{(\text{Illuminance}) \times (\text{Area})}{(\text{Lumens per luminaire}) \times (\text{CU}) \times (\text{LLF})}$$

$$\text{Lux [footcandles]} = \frac{(\text{number of luminaires}) \times (\text{lumens per luminaire}) \times (\text{CU}) \times (\text{LLF})}{\ldots}$$

Example 1: Coefficient of Utilization (CU)

CU=0.32

Luminaire	Typical Distribution and Percent Lamp Lumens											
			ρ_{CC}: →	80			70			50		0
			ρ_W: →	50	30	10	50	30	10	50	30	10	0
	Maintenance Category	Maximum S/MH	RCR	Coefficients of Utilization for 20% Effective Floor Cavity Reflectance (ρ_{FC} = 20)									
38 	IV	1.0	0	.60	.60	.60	.58	.58	.58	.56	.56	.56	.50
Four-lamp, 610 mm (2ft)-wide troffer with 45 plastic louver			1	.54	.52	.50	.52	.51	.49	.50	.49	.48	.44
			2	.48	.45	.43	.47	.44	.42	.45	.43	.41	.39
			3	.43	.40	.37	.42	.39	.37	.41	.38	.36	.34
			4	.39	.35	.32	.38	.35	.32	.37	.34	.32	.30
			5	.35	.31	.28	.35	.31	.28	.34	.30	.28	.26
			6	.32	.28	.25	.32	.28	.25	.31	.27	.25	.23
			7	.29	.25	.22	.29	.25	.22	.28	.25	.22	.21
			8	.26	.22	.20	.26	.22	.20	.25	.22	.20	.18
			9	.24	.20	.17	.24	.20	.17	.23	.20	.17	.16

S: T.15.1 p. 641

RCR	CU
4.0	0.39
4.1	X
5.0	0.35

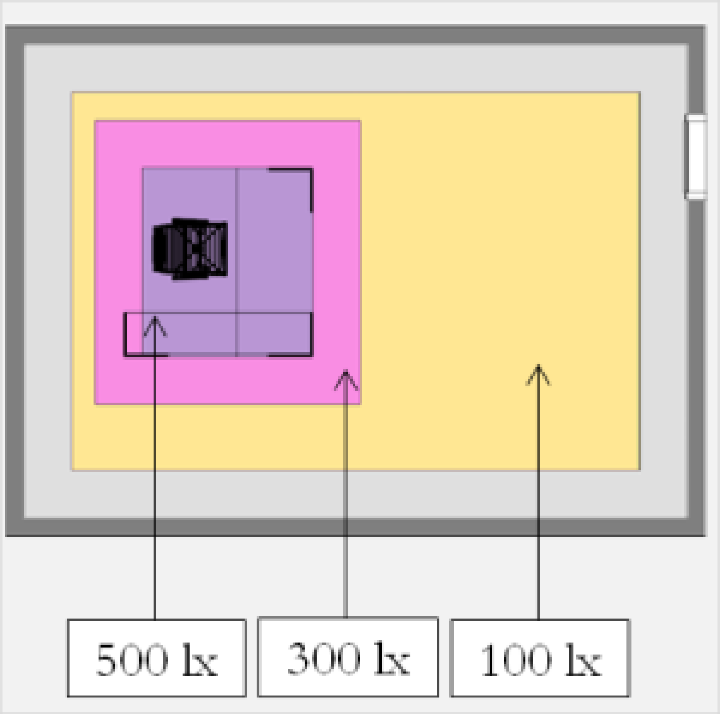
CU= 0.386

Illumination & acoustics

CALCULATION OF AVERAGE ILLUMINANCE

Example of office area where the requirement is 500 lx for data processing:

500 Lux for the **Task Area**
300 Lux for **Surrounding area**
100 Lux for the **Background area**



2-CALCULATING ILLUMINANCE AT A POINT

The basis of point source calculations is the **inverse square law**

1 **candlepower** equals 12.57 **lumens**.

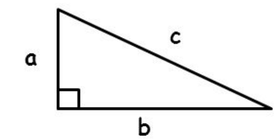
$$fc = \frac{cp}{D^2}$$

Where
fc: footcandle illuminance
Cp: candlepower
D: distance

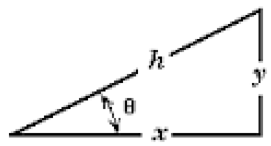
The horizontal illuminance at a point *P* as shown in Fig.

$$\text{horizontal } E = \frac{cp}{D^2}\cos\theta$$

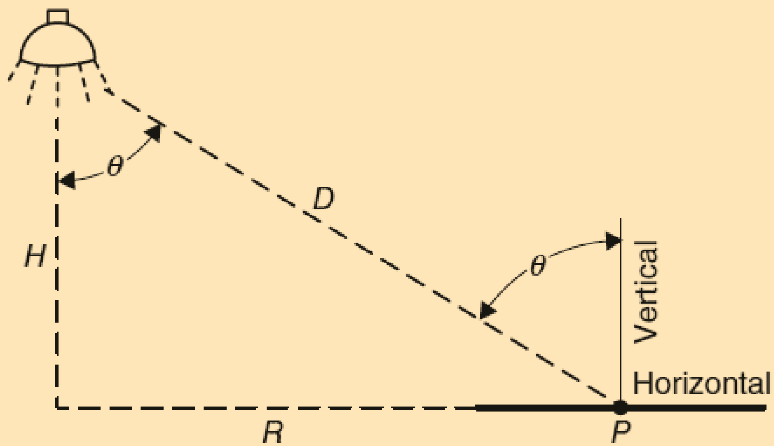
Remember



$$a^2 + b^2 = c^2$$



$$\sin(\theta) = \frac{y}{h}$$
$$\cos(\theta) = \frac{x}{h}$$
$$\tan(\theta) = \frac{y}{x}$$



Horizontal footcandles at point *P*

$$E_H = \frac{CP \times \cos\theta}{D^2} = \frac{CP}{H^2}\cos^3\theta$$

Vertical footcandles at point *P*

$$E_V = \frac{CP \times \sin\theta}{D^2} = \frac{CP}{R^2}\sin^3\theta$$

CALCULATING ILLUMINANCE AT A POINT

EXAMPLE 16.5 in textbook pp744-745.

Referring to Fig. shown, **find the horizontal and vertical illuminance at point *P***. Given that CP for the source is 6600. the point *P* is 10 ft (3 m) below and 12 ft (3.7 m) horizontally distant from the source.

SOLUTION

$$H = 10 \text{ ft} \quad R = 12 \text{ ft}$$

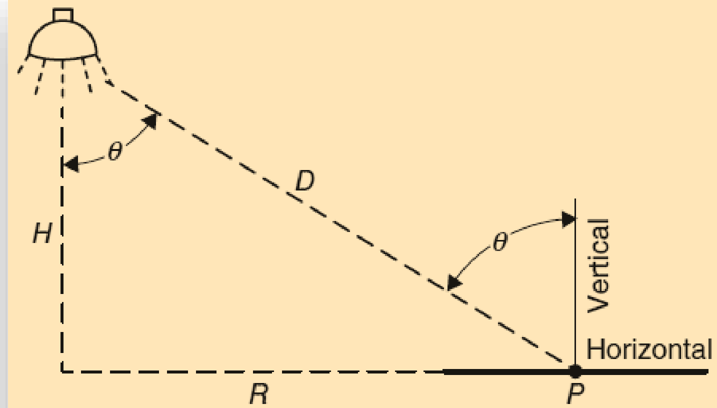
$$\theta = \tan^{-1}\frac{12}{10} = 50°$$

$$\sin\theta = 0.766 \qquad \cos\theta = 0.643$$

$$cp \text{ at } 50° = 6600 \text{ (from Fig. 16.47)}$$

$$\text{Horizontal illuminance: } \frac{6600}{10^2} \times (0.643)^3 = 17.5 \text{ fc}$$

$$\text{Vertical illuminance: } \frac{6600}{12^2} \times (0.766)^3 = 20.8 \text{ fc}$$



Horizontal footcandles at point *P*

$$E_H = \frac{CP \times \cos\theta}{D^2} = \frac{CP}{H^2}\cos^3\theta$$

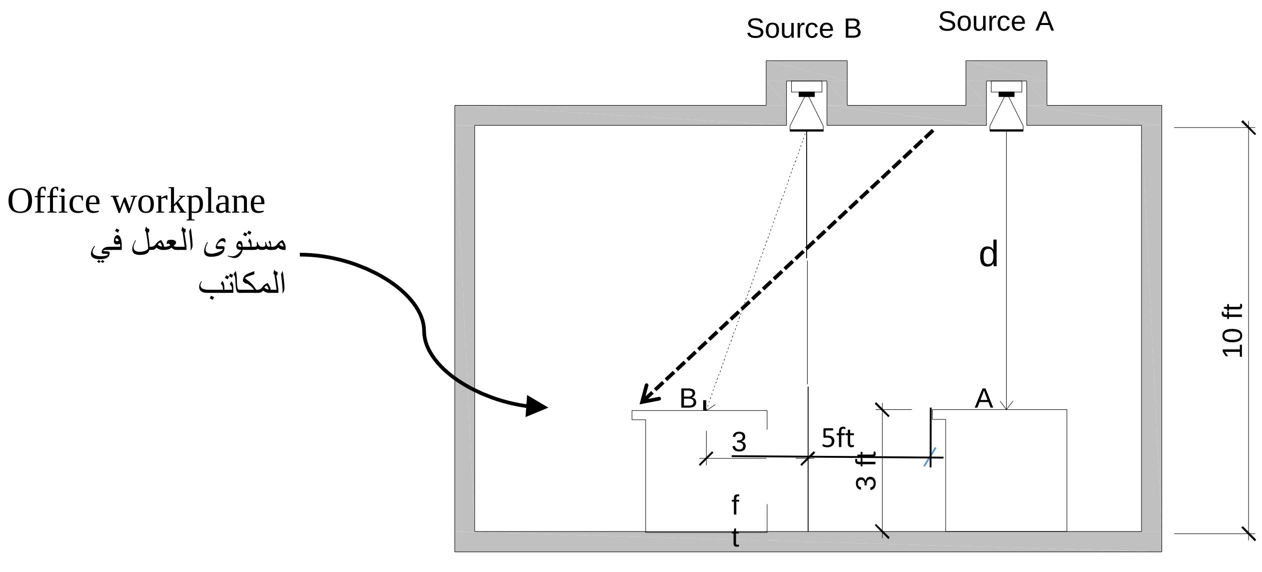
Vertical footcandles at point *P*

$$E_V = \frac{CP \times \sin\theta}{D^2} = \frac{CP}{R^2}\sin^3\theta$$

Assignment 1

CALCULATIONS

The office shown in section below is to be shared by two workers, Mr. A and Mr. B. Given that CP for source A = 2000 and CP for source B = 2,800, calculate the illumination levels at Point A and Point B.



Section

Electric Lighting Applications

Assignment 2: **each student will prepare a presentation on at least one electric lighting application.**

Chapter 17, pp751-773

Electric Lighting Applications

1. RESIDENTIAL OCCUPANCIES, pp751-756
2. EDUCATIONAL FACILITIES, pp757-765
3. COMMERCIAL INTERIORS, pp765- 770
4. INDUSTRIAL LIGHTING, pp770-773

Illumination & Acoustics

Lighting Simulation software

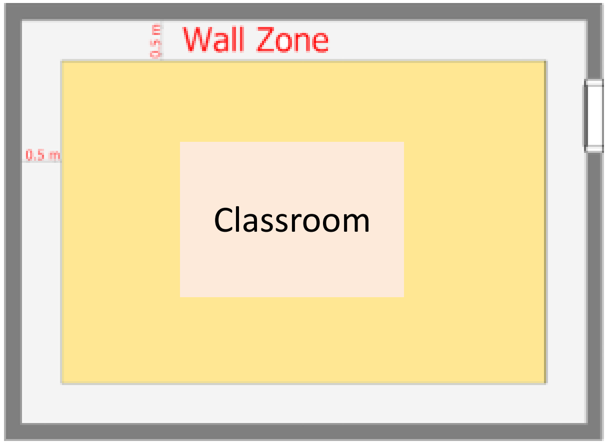
Assignment 3

1-Design a proper lighting for class room (w6*l10*h3.20)- use DIALUX program.

2-Design a proper lighting for one-story house. Use DIALUX program

Notes:

- ✓ The wall Zone of 0.5 could be ignored if the workstation is not placed near wall.
- ✓ The wall zone will not be taken into consideration for the average value of Lux or uniformity.



Thank you