Course Titled: Energy Systems
Lecture: Illumination (4)
Prepared By: Prof. Mahmoud El-Gamal
Illumination System: Interior Lighting Design

Lecturer Schedule: 13th Week

12th Week is left for 2nd Mid Term exam
1. Lighting Design Criteria
   - Lighting Objectives
   - Choice of artificial lighting system
   - Choice of light sources or lamps
   - Choice of luminaires

2. Glare

3. Interior illumination calculations
Lighting Design Criteria

**Step 1: Lighting Objectives**

This is the first stage in planning a lighting scheme.

Ignoring this step results in a *design by default*.
**Step 1: Lighting Objectives**

- **Making objects visible**
  - City Beautification
  - Identity
- **Safety & Quality**
Lighting Design Criteria

**Step 2:** Choice of artificial lighting system

- **Uniform lighting system**

**Advantage:**

It permits complete flexibility of task location.

**Disadvantage:**

Energy is wasted illuminating the whole area to the level needed only for the most critical tasks.
Step 2: Choice of artificial lighting system

Localized lighting system

Advantage:

- It employs an arrangement of luminaires related to the position of tasks and workstations.

- It provides the required service illumination on work-areas together with a lower level of general illumination for the space.
Localized Lighting
Lighting Design Criteria

**Step 3:** Choice of light sources or lamps

The criteria of selecting an adequate lamp type include:

- Lumen output and Lamp efficacy.
- Color rendering properties.
- Run-up time.
- Lamp life and lumen maintenance.
Lighting Design Criteria

**Step 4: Choice of luminaires**

1. *Fluorescent luminaires*

   - **Reflector : Opal** for healthcare and hospital applications
   - **Reflector : Prismatic** for educational facilities & corridors
   - **Reflector : Parabolic** (high polished) for both office and school applications
Step 4: Choice of luminaires

2. Downlight luminaires

Extra-Low Voltage
downlights for dichroic halogen lamp

Recessed Downlight
with polished reflector
Step 4: Choice of luminaires

3. High bay luminaires

Use of HPL (250 & 400 W) lamps in aluminum reflector for haybay illumination in industrial plants (height > 6m)
Step 4: Choice of luminaires

4. Outdoor luminaires

Road Lighting Luminaires
Motorways for heavy and high speed traffic

Aluminum Bollard Luminaires
for ground-mounted applications

Pole Mount
For use in gardens and ways
Step 4: Choice of luminaires

5. Floodlight luminaires

Floodlight luminaires
(HL or SON 250 & 400 lamps)
for parks or sport playgrounds or architecture

Upright Floodlights
create smooth shadow to reinforce volume of column

High Mast Luminaire Assembly
For parking & outdoor large areas
Glare

Glare is the sensation produced by luminance (brightness) within the visual field that is sufficiently greater than the luminance to which the eyes are adapted to cause:

- Discomfort (discomfort glare)
- Reduced visibility (disability glare)
- or both
Glare

*Glare can be:*

- **Direct**: a bright luminaire appearing in the field of view of an observer
- **Reflected**: will occur if the observer sees the reflection of the such a bright luminaire in a glossy surface (VDU terminal for example)
Glare

- 45° Reflected glare zone
- 45° Direct glare zone
- 90° Field of view
- Direct glare
- Reflected glare
**Design Step 5: Interior illumination calculations**

\[ E_{av\text{ (manitained)}} = \frac{\text{Lamp Lumens } \times \text{CU } \times \text{LLD } \times \text{LDD}}{\text{Working Area } (\text{in m}^2)} \]

Lamp Lumens =

Number of luminaires \( \times \) lamps per luminaire \( \times \) lumens per lamp

<table>
<thead>
<tr>
<th>CU</th>
<th>Coefficient of Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>LLD</td>
<td>Lamp Lumen Depreciation Factor</td>
</tr>
<tr>
<td>LLD</td>
<td>Luminaire Dirt Depreciation Factor</td>
</tr>
</tbody>
</table>
Utilization Factor

Utilization factor $UF$ is dependent on:

- The light distribution of the luminaire
- Luminaire efficiency or light output ratio
- Room index
- Wall, floor and ceiling reflectances
- Arrangement of the luminaires in the room
Maintenance factor

*Maintenance factor takes into account:*

- Lumen depreciation of the lamps that is also related to the type of gear used
- Accumulation of dirt (cleanliness of the environment)
Interior Illumination Calculations

Step 1: Basic ceiling, wall and floor reflectances

- Ceiling cavity: CR = 0.8
- Floor cavity: $h_{fc} = 0.8\, \text{m}$
- Room cavity: $h_{rc} = 2\, \text{m}$
- Luminaire: FWR = 0.5, CWR = 0.5, $\rho_W = 0.5$, FR = 0.1

---

September 7, 2011
Prepared by: prof Mah El-Gammal
**Step 2: Determine cavity ratios**

\[
\text{RCR} = 5h_{rc} \frac{L + W}{L \times W} = 5 \times 2 \times \frac{9 + 6}{9 \times 6} = 2.78
\]

\[
\text{CCR} = 5h_{cc} \frac{L + W}{L \times W} = 5 \times 0.8 \times \frac{9 + 6}{9 \times 6} = 1.1
\]

\[
\text{FCR} = 5h_{fc} \frac{L + W}{L \times W} = 5 \times 0.8 \times \frac{9 + 6}{9 \times 6} = 1.1
\]
**Step 3:** Determine the effective ceiling cavity reflectance $\rho_{cc}$

### Effective ceiling cavity reflectance $\rho_{cc}$

<table>
<thead>
<tr>
<th>Basic ceiling reflectance CR</th>
<th>80%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall reflectance $\rho_w$</td>
<td>80% 70% 50% 30%</td>
</tr>
<tr>
<td>CCR</td>
<td>1.1 74 71 65 60</td>
</tr>
</tbody>
</table>

**Step 4:** Determine the effective floor cavity reflectance $\rho_{FC}$

### Effective floor cavity reflectance $\rho_{FC}$

<table>
<thead>
<tr>
<th>Basic ceiling reflectance CR</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall reflectance $\rho_w$</td>
<td>50% 30% 10%</td>
</tr>
<tr>
<td>FCR</td>
<td>1.1 11 9 8</td>
</tr>
</tbody>
</table>
Step 5: Obtain the coefficient of utilization for fluorescent lamps used

<table>
<thead>
<tr>
<th>Floor</th>
<th>$\rho_{FC} = 20%$</th>
<th>$\rho_{CC} = 80%$</th>
<th>$\rho_{CC} = 50%$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walls</td>
<td>50%</td>
<td>30%</td>
<td>10%</td>
</tr>
<tr>
<td>RCR</td>
<td>3</td>
<td>57</td>
<td>52</td>
</tr>
</tbody>
</table>

$$\rho_{CC} = \frac{52 + 5 \times \frac{15}{30}}{57} = 54.5\%$$
Step 5 (cont.): Obtain the corrected coefficient of utilization for floor cavity reflectance $\rho_{FC}$ other than 20%

<table>
<thead>
<tr>
<th>Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho_{cc}$</td>
</tr>
<tr>
<td>$\rho_{W}$</td>
</tr>
<tr>
<td>RCR</td>
</tr>
</tbody>
</table>

Correction Factor $= 1.03 + 0.02 \times \frac{15}{20} = 1.045$

Corrected $\text{CU} = 0.545 \times \frac{1}{1.045} = 0.522$
**Step 6: Determine the maintenance factor**

Maintenance Factor (MF) = \( LDD_{\text{Rapid start Standard colors & 6 Hrs start}} \times LDD_{\text{Category V Medium 12 month}} \)

\[ = 0.87 \times 0.86 = 0.7482 \]
Step 7: Determine the number of luminaries

Area per luminaire =

\[
\frac{\text{Number of lamps per luminaire} \times \text{Lumens per lamp} \times \text{CU} \times \text{MF}}{E_{av}} = \frac{2 \times 3250 \times 0.522 \times 0.7482}{700} = 3.63 \text{ m}^2
\]

\[
\text{Number of luminaires} = \frac{\text{Room Area}}{\text{Area per luminaire}} = \frac{6 \times 9}{3.63} \approx 15
\]
Step 8: Luminaires configuration

Spacing requirements for illumination uniformity distribution according to IES recommendations:

<table>
<thead>
<tr>
<th>Distance (in cm)</th>
<th>Preferred</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>15 to 30</td>
<td>60</td>
</tr>
<tr>
<td>y</td>
<td>75 to 90</td>
<td>s/2</td>
</tr>
</tbody>
</table>
**Step 8: Luminaires configuration**

As the manufacturer recommends that luminaires spacing \( S \) to mounting height \( h_{rc} \) not to exceed 1.4

Then \( S \leq 1.4 \times 2 \leq 2.8 \) m

Assume spacing between luminaires row and wall \( y \) as 1.2 m, then for selected three rows \( S = \frac{6 - 2 \times 1.2}{2} = 1.8 < 2.8 \) m

*which is acceptable*

Finally, \( x = \frac{9 - 4 \times 1.8 - 1.2}{2} = 0.3 \) m \( \approx 1.0 \) ft which is acceptable according to IES recommendations.
Step 8 (cont.): Luminaires configuration

Recommended IES spacing for “uniformity”

<table>
<thead>
<tr>
<th>Distance</th>
<th>Preferred</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>6 to 12 inch</td>
<td>2 feet</td>
</tr>
<tr>
<td>y</td>
<td>2.5 to 3 feet</td>
<td>S/2</td>
</tr>
</tbody>
</table>