Lighting design for optimal light levels factors in location: the required illumination levels, working plane, lamp type, lumen output, mounting height and the required levels of uniformity.

General factors to consider in lighting design

The designs of buildings such as old industrial plant traditionally considered the optimisation of natural lighting to improve energy savings. This approach has, however, changed considerably in modern designs. Natural light and reflectance factors are almost never considered in light level calculations. Instead, more emphasis is placed on focused and localised lighting for task-specific areas. Nevertheless, natural light and reflectance can play an important role in improving lux levels.

Whether the lighting solution is an indoor or outdoor application determines the amount of protection the luminaires will have against atmospheric and environmental conditions such as dust or moisture ingress. Indoor luminaires may also be used in the absence of side walls, where only ceilings are provided, e.g. in pump sheds.

In outdoor applications, it must be established whether the light fitting is enclosed and what materials it would contain to withstand outdoor conditions such as corrosion.

Working plane, mounting heights

The working plane in reading areas or assembly shops is generally at desk level (750 – 900 mm from floor level). On verandahs or in indoor stadiums, the working place is taken as the floor level itself. The light falling on the working plane will depend on the mounting height of the lamps.

Indoor lighting is affected by the cavities above the mounting height (ceiling cavity) and below the working plane (floor cavity), as well as by the walls surrounding the area.

Reflectance factors

Reflectances are given the variables L, M and D to signify light, medium and dark reflectance respectively. Table 1 provides the average values of these factors for ceiling, walls and floor.

For indoor lighting calculations, manufacturers generally base the coefficient of use (CoU) on these reflectance factors for different room indices.

Coefficient of use

This is the ratio of luminous flux which reaches the work plane and the total flux emitted by mounted lamps, taking into account the floor and ceiling cavities, as well as reflectances.

For a closed room, CoU is based on the room’s internal dimensions (including luminaire mounting height) and is governed by the formula:

\[
\text{Room index} = \frac{\text{Length} \times \text{width}}{H_m \times (\text{length} + \text{width})}
\]

(1)

Luminaire manufacturers provide CoU factors for each type of luminaire, with different room indices and reflectance factors, used in the calculations to determine the number of luminaires required.

Luminaire depreciation factor

Luminaire depreciation factor refers to the depreciation in the output of the luminaire due to dirt ingress, materials degradation etc., as the lamp ages. Similarly, lamp depreciation factor indicates lamp output reduction due to filament evaporation and other factors as the lamp ages.

In lighting calculations, separate factors are sometimes considered for lamp and luminaire depreciation to factor in possible reduction in light output, provided that the designer can justify the values considered.

A single factor, the maintenance factor (MF), is also often assumed during design stages to cater for reduced light outputs by luminaires or lamps.

MF is commonly assumed as between 0,7 and 0,8 in the design calculations, in the absence of detailed information on the maintenance plan or on the properties of the selected luminaire or lamp.

Luminaire spacing

The design criteria should also take into account the ratio of spacing between successive luminaires to their mounting height to ensure aesthetics and uniformity in the luminaire layout. In the case of vertically downward light,
this can be on the two horizontal axes of the room, along 0 – 1800 axis, and along the 90 – 2700 axis.

Maximum recommended spacing = \( S \times (H_m – H_w) \)

where

- \( S \) = Recommended spacing.
- \( H_m \) = Height of the luminaires above the working plane.
- \( H_w \) = Height of the work plane above the floor.

A recommended rule of thumb to achieve uniform lighting is for the spacing between adjacent luminaries not to exceed 1.5 times their mounting height, i.e. luminaire spacing \(<1.5 \times H_w\).

**Simple calculation**

The IES zonal cavity method (also known as the lumen method) is used to decide the number of luminaires to achieve the required lux level on a work plane in an interior space, taking into account the room index, CoU, maintenance factor, etc.

Typical steps are:

- Decide on the type of luminaires you plan to use for the application, as well as on the number of lamps they should hold.
- Determine the dimensions and the CoU based on the manufacturer's luminaire catalogue and on the reflection factors of the ceiling, floor and walls. It is common to assume some nominal factor based on experience and knowledge. Consider a suitable MF based on your previous experiences or assume it to be between 0.7 and 0.8.
- Use the simple formula to determine the quantity (integer):

\[
\text{Number of luminaires} = \frac{\text{desired average lux} \times \text{work plane area}}{(\text{lamps per luminaire} \times \text{ lumens per lamp}) \times \text{CoU} \times \text{MF}}
\]  \hspace{1cm} (1)

- Make a practical and feasible layout for the calculated quantity.
- Recalculate and check the actual illuminance which the planned layout can achieve.
- Make a rough estimate on the approximate number of luminaire types required based on the average lux required for the task, using the formula in Eqn. 2.
- Determine the layout bearing in mind uniformity of spacing, aesthetics etc. and recalculate the achieved lux for the proposed layout to ensure that it gives the desired lux level. Use the formula illustrated (see Eqn. 3).

Contact Sara Ross, ACDC Dynamics, Tel 010 202-3300, sara@acdc.co.za

<table>
<thead>
<tr>
<th>Material</th>
<th>% Reflectance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glossy silver</td>
<td>95</td>
</tr>
<tr>
<td>Gold</td>
<td>75</td>
</tr>
<tr>
<td>Matt silver</td>
<td>85</td>
</tr>
<tr>
<td>Iron</td>
<td>50</td>
</tr>
<tr>
<td>Mirrors</td>
<td>80</td>
</tr>
<tr>
<td>Polished aluminum</td>
<td>70</td>
</tr>
<tr>
<td>Light green</td>
<td>75</td>
</tr>
<tr>
<td>Light blue</td>
<td>50</td>
</tr>
<tr>
<td>Light red</td>
<td>40</td>
</tr>
<tr>
<td>Dark brown, green and blue</td>
<td>15</td>
</tr>
<tr>
<td>Black</td>
<td>3 – 4</td>
</tr>
</tbody>
</table>

Table 2: Reflectance percentage.