
Footcandles and Lux for Architectural Lighting

(An introduction to Illuminance)

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- [1.\) ILLUMINANCE - INTRODUCTION](#)
 - [2.\) HOW MUCH LIGHT IS ENOUGH?](#)
 - [3.\) ILLUMINANCE LEVELS](#)
 - [4.\) I.E.S. RECOMMENDATIONS](#)
 - [5.\) ALTERNATE TO IES METHOD](#)
 - [6.\) WHEN TO BREAK THE RULES](#)
 - [7.\) DEFINITIONS and CONVERSIONS](#)
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1.) ILLUMINANCE - INTRODUCTION

One of the factors used when designing architectural lighting systems is ILLUMINANCE.

ILLUMINANCE is a measure of the amount of light falling on a surface. It is defined as: 'the density of the luminous flux incident on a surface'. It is the quotient of the luminous flux by the area of the surface when the latter is uniformly illuminated. - ($E = d\phi / dA$)

One footcandle is the illuminance at a point on a surface which is one foot from, and perpendicular to, a uniform point source of one candela. One lux is the illuminance at the same point at a distance of 1 meter from the source. One lumen uniformly distributed over one square foot of surface provides an illumination of 1 footcandle.

If you work in feet, your results will be in footcandles - (1 footcandle = 1 lumen/square ft.)
If you work in meters, your results will be in lux - (1 lux = 1 lumen/square meter)

Formerly the term 'ILLUMINATION', was used for illuminance.

2.) HOW MUCH LIGHT IS ENOUGH?

In the interior modern workplace or home, illuminance levels commonly range between 10 and 100 FC or more. In exterior situations, levels may range from 100 to 10,000 FC or more.

Good lighting depends on more than just illuminance levels. The direction, distribution, color temperature and color rendering index of the source all contribute to effective lighting (and visibility). The task reflectance and contrast also contribute greatly. The determination of target illuminance levels are generally considered however to be a starting point of any effective lighting design.

Illumination levels are generally dictated by the needs of the visual task. Typically, the more light available, the easier it is to perform a specific task. But how much light is enough? Illuminance levels are influenced by:

a.) details of task

- a.) reflectance and contrast (task and background)
- b.) the eye - (age and condition)
- c.) importance of speed and accuracy

3.) ILLUMINANCE LEVELS

It is important today that the lighting designer provide appropriate lighting levels for the required task(s). It is also equally important to NOT underlight a task. There is generally little value in underlighting a task where human performance is concerned. The electrical energy saved is often offset by a far greater loss in human performance or productivity.

As the eye ages, it requires more light to see the same detail with the same speed and accuracy. For this reason lighting systems must be designed with specific human needs in mind. A classroom designed for children might require only 40 footcandles, while the same classroom designed for adult activities might require 80 footcandles or more. Today, lighting levels in the home, school or office may range from 20 to 100 footcandles or more.

Energy restrictions and building codes often tend to limit lighting to 'x' number of watts per square foot (or meter) in new constructions. It must be remembered that these are usually 'average' figures in that a storage room might require lower lighting levels and an office area might require higher lighting levels - than average. These average levels can and should be exceeded in respect to providing sufficient light for effective human performance.

Today there is great value in the task/ambient approach to lighting. This method first provides general room illumination and then specific, brighter illumination - only where needed. In this respect ambient lighting levels may be reduced to save energy and task area lighting may be increased for optimum human performance.

4.) IES - RECOMMENDATIONS

Since 1958 the Illuminating Engineering Society has published illuminance recommendations in table form. These tables cover both generic tasks (reading, writing etc), and 100's of very specific tasks and activities (such as drafting, parking, milking cows, blowing glass and baking bread).

All tasks fall into 1 of 9 illuminance categories, covering from 20 to 20,000 lux, (2 to 2000 footcandles). The categories are known as A - I, and each provide a range of 3 illuminance values (low, mid and high). See Table 1.

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TABLE 1

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IES ILLUMINANCE CATEGORIES and VALUES - for GENERIC INDOOR ACTIVITIES

ACTIVITY	CATEGORY	LUX	FOOTCANDLES
Public spaces with dark surroundings	A	20-30-50	2-3-5
Simple orientation for short temporary visits	B	50-75-100	5-7.5-10

Working spaces where visual tasks are only occasionally performed	C	100-150-200	10-15-20
Performance of visual tasks of high contrast or large size	D	200-300-500	20-30-50
Performance of visual tasks of medium contrast or small size	E	500-750-1000	50-75-100
Performance of visual tasks of low contrast or very sm size	F	1000-1500-2000	100-150-200
Performance of visual tasks of low contrast or very sm size over a prolonged period	G	2000-3000-5000	200-300-500
Performance of very prolonged and exacting visual tasks	H	5000-7500-10000	500-750-1000
Performance of very special visual tasks of extremely low contrast	I	10000-15000-20000	1000-1500-2000

A-C for illuminances over a large area (ie lobby space)
D-F for localized tasks
G-I for extremely difficult visual tasks

IES METHOD - RECOMMENDED PROCEDURE

STEP 1 - define visual task and visual plane.

STEP 2 - select illuminance CATEGORY (use IES tables or Table 1 above)

STEP 3 - determine illuminance RANGE. (from Table 1).

STEP 4 - select WEIGHTING factors:
for category A-C use 'Table 1a' below.
for category D-I use 'Table 1b' below.

TABLE - 1a - (for Categories A-C)			
ROOM AND OCCUPANT CHARACTERISTICS	Weighting Factor		
	-1	0	+1
Occupant ages	under 40	40-55	over 55
Average room surface reflectances	more than 70%	30-70%	less than 30%

INSTRUCTIONS for Table 1a: Add both weighting factors algebraically.
If the total factor is -2 use the low illuminance value.
If the total factor is +2 use the high illuminance value.
If the total factor is 0 use the middle illuminance value.

TABLE - 1b - (for Categories D-I)			
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ROOM AND OCCUPANT CHARACTERISTICS	Weighting Factor		
	-1	0	+1
Occupant ages	under 40	40-55	over 55
Importance of speed and/or accuracy	not important	important	critical
Reflectance of task background	more than 70%	30-70%	less than 30%

INSTRUCTIONS for Table 1b: Add all 3 weighting factors algebraically.

If the total factor is -2 or -3 use the low illuminance value.

If the total factor is +2 or +3 the high illuminance value.

Otherwise use middle illuminance value.

EXAMPLE

STEP 1 - What illuminance is recommended for an adult aged 56, performing detailed accounting tasks of medium contrast or small size?

STEP 2 - From 'Table 1' we identify CATEGORY 'E' as the appropriate category.

STEP 3 - From 'Table 1' we also identify the illuminance RANGE as 50-75-100 fc.

STEP 4 - From 'Table 1b' we calculate the weighting factor:

AGE - 56	factor +1
IMPORTANCE OF SPEED AND ACCURACY - (important)	factor 0
BACKGROUND REFLECTANCE - (medium contrast, about 40%)	factor 0

	+1

In accordance with 'Table 1b' instructions, we use a weighting factor of +1 and then select the middle value of 75 footcandles for the task.

5.) ALTERNATE TO IES METHOD

Here is an alternative to the IES method of determining target illuminance values. This method by M.S. Rae was presented in the IES Journal V17#1, 1988. The 'Rae' method is somewhat simpler and results generally seem to agree with the IES method of calculation.

PROCEDURE:

STEP 1 - Select appropriate illuminance level from TABLE 2.

STEP 2 - Multiply by appropriate "weighting" factor from TABLE 2a.

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TABLE 2

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TASK CATEGORIES AND REFERENCE ILLUMINANCE LEVELS

ILLUMINANCE CATEGORY	DIFFICULTY OF VISUAL TASK	IMPORTANCE OF SPEED & ACCURACY	
		non critical	critical
A	MOVEMENT THROUGH PUBLIC SPACES	50 (5)	75 (7)
B	INFREQUENT READING OR WRITING; High contrast & large size	100 (9)	150 (14)
C	FREQUENT (& easy) READING OR WRITING; High contrast & large size (e.g. typewritten page)	200 (19)	300 (28)
D	MODERATELY DIFFICULT READING OR WRITING; low contrast or small size (e.g. penciled mechanical drawings)	300 (28)	450 (42)
E	DIFFICULT READING OR WRITING; low contrast & small size (e.g. poor copy of a blueprint)	500 (46)	750 (70)

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TABLE 2a

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ADJUSTMENTS TO REFERENCE ILLUMINANCES
(for different task background reflectances and worker ages)

TASK	R	AGE (A, in years)				
		> 30	30-40	40-50	50-60	60+
BACKGROUND	> 0.8	1.0	1.2	1.5	2.0	3.1
REFLECTANCE (R)	0.8 - 0.6	1.2	1.5	1.9	2.6	3.9
	0.6 - 0.4	1.7	2.0	2.5	3.4	5.2
	0.4 - 0.2	2.5	3.0	3.8	5.1	7.8
	0.2 or less	5.0	6.0	7.6	10.2	15.6

6.) WHEN TO BREAK THE RULES

There are times that the IES and RAE recommended illuminance levels do not apply. This is true for applications involving merchandising, advertising, decorative, artistic applications or in matters related to safety. In these instances, it may be necessary to provide higher than recommended lighting levels to achieve proper impact.

There are also instances when lower than recommended lighting levels should be provided. This is particularly true in respect to the conservation of rare artifacts and valuable art works.

7.) DEFINITIONS, CALCULATIONS and CONVERSIONS

ILLUMINANCE: (old term: ILLUMINATION)

Definition: (density of luminous flux on a surface)

Symbol: E

Unit: Footcandle (fc) = (1 lumen per sq. foot)

Unit: Lux (lx) = (1 lumen per sq. meter)

EQUATIONS

$$\text{FC} = \frac{\text{Candela}}{\text{Distance square (ft.)}}$$

$$\text{FC} = \frac{\text{Lamp Lumens}}{\text{Area (sq.ft)}}$$

$$\text{LUX} = \frac{\text{Candela}}{\text{Distance square (m.)}}$$

$$\text{LUX} = \frac{\text{Lamp Lumens}}{\text{Area (sq. m.)}}$$

CONVERSIONS

$$\text{FC} = \text{Lux} \times .0929$$

$$\text{LUX} = \text{FC} \times 10.76 \text{ - (ie: } 50 \text{ FC} = 538 \text{ LUX)}$$

[Home](#)