Chapter 7

ILLUMINATION

Engineering Practices

ENPRA101A

Topic 7-3

LUMINAIRES AND LIGHTING CONTROL

ENPRA101A – Engineering Practices

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LUMINAIRES

- Luminaires are designed to support and provide means of electrical connection to lamps, and to distribute the light produced by the lamps in the most effective manner to the task area.
- The light distribution from a luminaire will depend upon the task to be performed taking into account:
  - lamp luminous flux
  - position of task area
  - recommended task illuminance
  - visual comfort

DOMESTIC

- Until recently the majority of interior lighting of domestic premises was by incandescent lamps for one or more of the following reasons:
  - ➢ they are instantly on
  - ➢ they produce a warm comfortable light
  - ➢ they are most easily dimmed
- Now largely superseded by the Compact Fluorescent Lamp (CFL) which exhibit similar characteristics

DOMESTIC

- Luminaires using CFLs are:
  - generally relatively small
  - easily formed into attractive styles for various applications.
- Flood lighting for security often uses incandescent quartz-halogen lamps
- Luminaires using fluorescent lamps are generally only used for workshops and outdoor lighting (verandah, porch, etc.).

LUMINAIRES

COMMERCIAL/INDUSTRIAL

- Fluorescent luminaires are most frequently used in commercial lighting installations and industrial where the mounting height is less than about 6m.
- Fluorescent lamp luminaires for industrial use are usually fitted with a matt white reflector.
- For mounting heights above 6m, high bay luminaires using HID lamps are generally required.
- Some situations such as **hazardous areas**, **Damp situations and dust laden atmospheres** require specially constructed luminaires.

GENERAL CLASSIFICATION

- Luminaires for general indoor lighting are classified by the way the light produced by the lamps is controlled and directed
- Based upon the ratio of light above or below the horizontal plane of the lamp centre as follows: (see **Fig. PF-7-3-1** for clarity)
  - **Direct**:

    0 - 10% of received light is reflected from surfaces

    90 - 100% of the light received is direct from the source

GENERAL CLASSIFICATION

- Classification of Luminaires (Cont'd)
  - **Semi-direct:**

    10 - 40% of received light is reflected from surfaces

    60 - 90% of the light received is direct from the source
  - **General-diffuse:**

    40 - 60% of received light is reflected from surfaces

    40 - 60% of the light received is direct from the source
  - **Direct-indirect:**

    40 - 60% of received light is reflected from surfaces

    40 - 60% of the light received is direct from the source

GENERAL CLASSIFICATION

- Classification of Luminaires (Cont'd)
  - **Semi-indirect:**

    60 - 90% of received light is reflected from surfaces

    10 - 40% of the light received is direct from the source
  - **Indirect:**

    90 - 100% of received light is reflected from surfaces

    0 - 10% of the light received is direct from the source

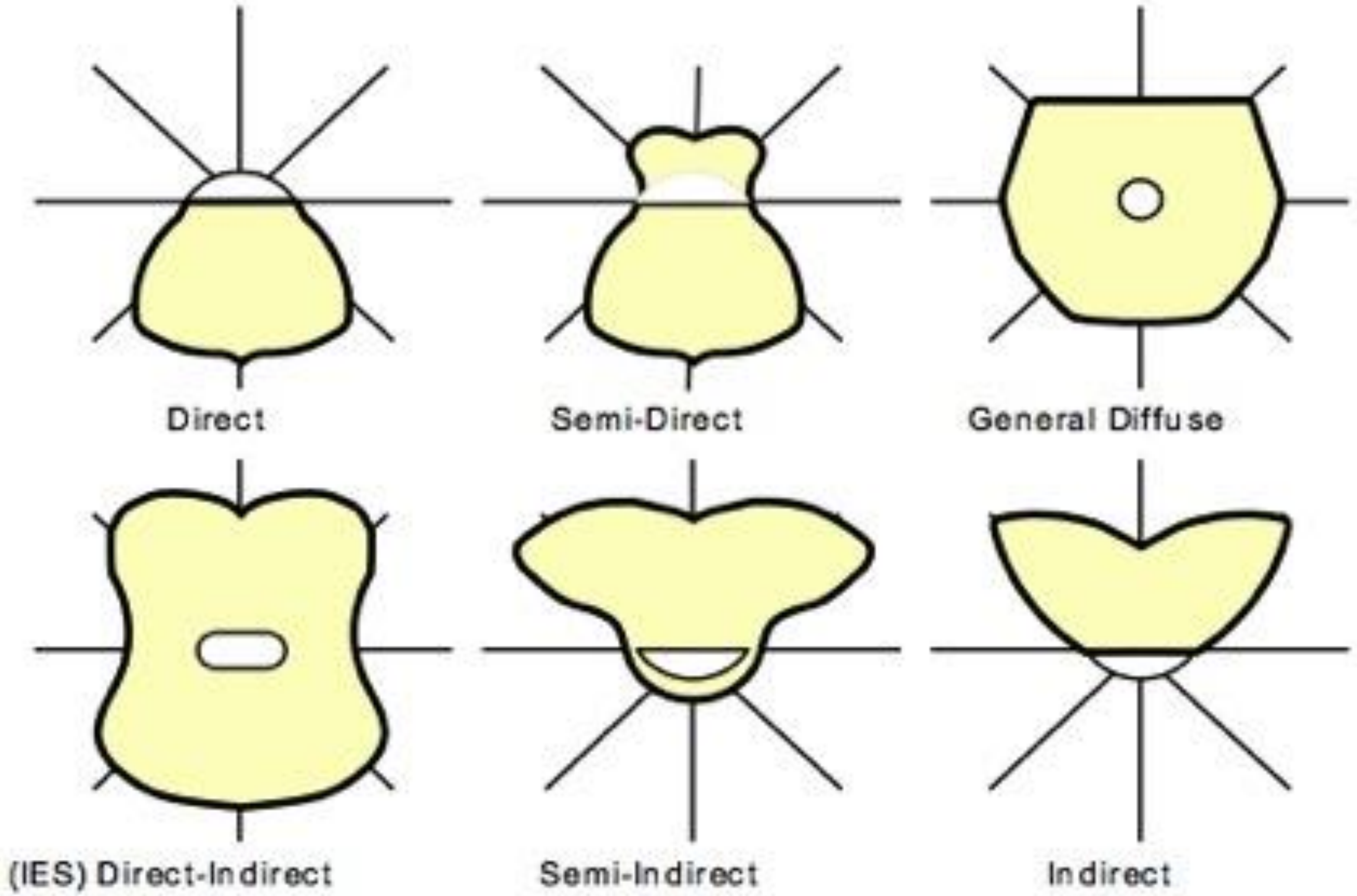


Fig. PF-7-3-1 Classification of Luminaires by light distribution ratio

FLUORESCENT LUMINAIRES

- Most fluorescent luminaires use reflectors, louvres, prismatic panels or opalescent diffuser panels.

Reflectors

- May be mirrored or enameled and used with or without louver shielding.
- Give the light a directional characteristic by forming it into a desired solid angle.
- Provide some amount of shielding (glare control), but more effective shielding is achieved by addition of louvres.

FLUORESCENT LUMINAIRES

Louvres

- Solid barriers placed in front of a luminaire to shield the lamp from direct view.
- They serve to reduce the luminance of a lamp in the direction where it may cause glare.
- Louvres may be thin strips of white opalescent plastic or metal and in some cases are V shaped with mirror finish.

FLUORESCENT LUMINAIRES

Louvres Cont'd)

- Louvres are of three basic forms:
  - **square mesh** - used with reflectorless box type luminaires to provide longitudinal and lateral screening.
  - **diamond mesh** - same as square mesh.
  - **lamellae** - strips positioned at right angle to the axis of the lamp, (See **Fig PF-7-3-2(a)**)
  - **prismatic diffuser (refractor)**: clear plastic material designed to refract the light in certain directions, whilst reducing luminance of the lamps in directions which would produce glare discomfort. (See **Fig PF-7-3-2(b)**)

FLUORESCENT LUMINAIRES

Louvres Cont'd)

- **opalescent diffusers**: Light output from a luminaire through these panels will be virtually uniform in all directions, (See **Fig PF-7-3-2(c)**)

Fig. PF-7-3-2(a)
lamellae diffuser

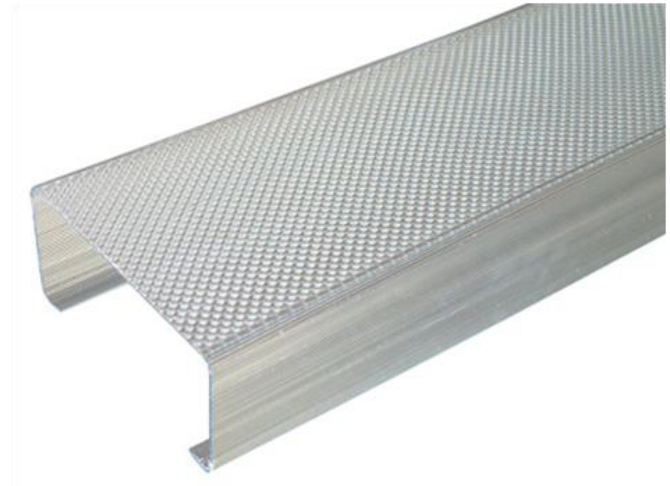


Fig. PF-7-3-2(b)
Prismatic Diffuser

Fig. PF-7-3-2(c) Opal Diffuser

HID HIGH BAY LUMINAIRES

- Used with high pressure mercury vapour or sodium vapour lamps.
- The luminaire controls the light output by mirrored parabolic reflectors (See Fig F-7-3-3)
- These luminaires are available with a range of reflectors for various lamps, shielding angles and luminaire spacing.
- Direct type industrial luminaires are further classified as to the beam angle and spacing height ratio as listed in Table following

Fig. PF-7-3-3 High Bay Luminaires

HID HIGH BAY LUMINAIRES

HID Luminaire Class	Approx. Beam angle	Space-Height Ratio
Highly Concentrating	up to 30°	Up to 0.5
Concentrating	30° to 40°	0.5 to 0.7
Medium Spread	40° to 60°	0.7 to 1.0
Spread	60° to 100°	1.0 to 1.5
Wide Spread	Greater than 100°	Greater than 1.5

SHIELDING ANGLE

Shielding angle

- The angle between the horizontal and the line of sight at which any point of high luminance of the lamps and luminaire become visible

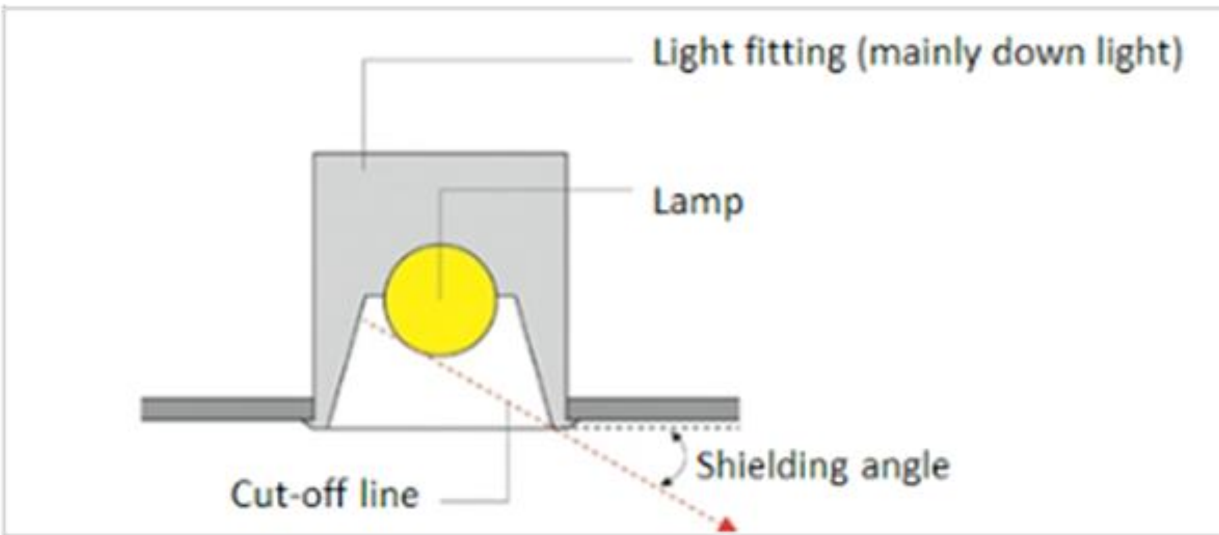


Fig. PF-7-3-4 Definition of Shielding Angle

CUT-OFF ANGLE

Cut-off angle

- The angle between the vertical axis of a luminaire light beam and the line of sight at which all points of high luminance of lamps and luminaire become invisible.
- Table 8.1 of AS/NZS 1680.1:2006 shows recommended cut-off angles for partially enclosed luminaires

BEAM

Beam

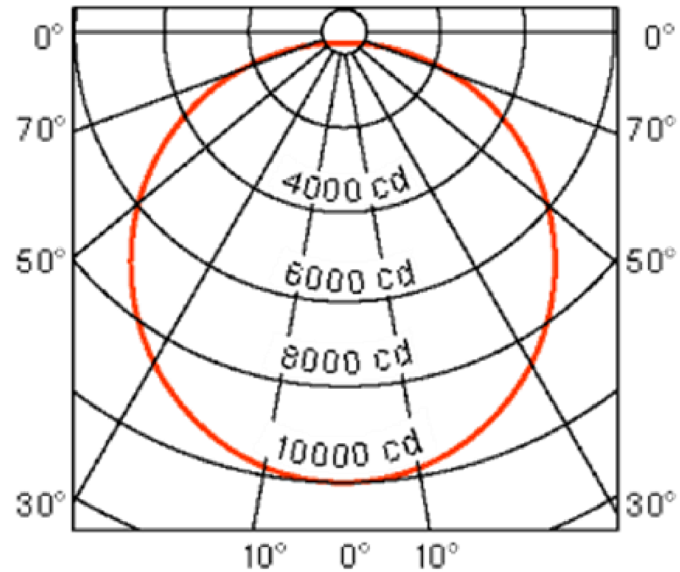
- Term refers to the shape of the controlled light from a luminaire and is generally used only when referring to flood, spot, down-lights and high bay lights.
- Beam data is often given as polar intensity diagrams or lux diagrams (See **Fig F-7-3-5**)

Beam axis

- The direction in the centre of the solid angle which is bounded by directions having luminous intensities of 90% of lamp maximum

BEAM

Fig. F-7-3-5 – Example of Polar Diagram



Beam spread

- The angle in the plane through the beam axis, over which the luminous intensity drops to a stated value of its peak value, usually 50% or 10%.

BEAM

Beam spread (Cont'd)

- For symmetrical beams only one figure is given
- For a rectangular or elliptical beam two figures may be given, one for the narrowest, and one for the widest beam angle).
- Efficiency is given as the ratio of the flux in the solid angle of the beam spread to the total flux produced by the bare lamp.

LUMINAIRE LIGHT OUTPUT RATIO (L.O.R.)

Luminaire Light Output Ratio (L.O.R.)

- This is sometimes termed the luminaire efficiency and is the ratio of the total flux output of a luminaire to the total luminaire lamp flux.
- The L.O.R. of a luminaire will always be less than unity
- Luminaires with reflectors and no screening have the highest L.O.R.
- For screened luminaires lamellae louvres have the best L.O.R., and opal diffusers have the lowest L.O.R.

GLARE CONTROL

- AS 1680.1 provides alternatives for the control of discomfort glare from electric lighting:

LUMINAIRE MAINTENANCE

- Maintenance is required for a lighting system to maintain the illuminance within the required limits.
- Maintenance can be divided into three basic components:
  - **Lamp replacement**: - either spot replacement as required or planned group replacement (whether they are working or not).
  - **Lamp and luminaire cleaning**: planned cleaning done at the same time as group replacement
  - **Cleaning of interior surfaces**: Rarely done - some advantage in extremely dirty environments

ILLUMINANCE LEVELS

Maintenance Illuminance (E)

- This is the lowest recommended light level (illuminance) for the working plane or surface
- General values for maintenance illuminance are stated in Table 3.1 of AS 1680.1, with more specific and detailed values in AS 1680.2 - parts 0, 1,2, 3.
- If illuminance falls to or below this level, then some form of maintenance must be undertaken to improve the level.

ILLUMINANCE LEVELS

Initial Illuminance

- This is the illuminance on the working plane at initial installation of the lighting system i.e.

$$\text{initial illuminance} = \frac{\text{maintenance illuminance}}{\text{light loss factor (LLF)}} \quad \text{lux}$$

Light Loss Factor (LLF)

- Also called maintenance factor (MF).
- This is the allowable factor of decrease in illuminance from the initial illuminance.

ILLUMINANCE LEVELS

Light Loss Factor (LLF) (Cont'd)

- If initial illuminance is known, LLF can be calculated from the equation for Initial illuminance.
- Otherwise the LLF can be calculated from:

$$\text{LLF} = \text{lamp lumen loss factor} \times \text{luminaire loss factor} \times \text{room surface loss factor}$$

  – **lamp lumen loss factor**: factor of lamp lumen depreciation with age, available from manufacturers' data and/or AS 1680.4.
  – **luminaire loss factor**: loss in light from the luminaire because of dirty environment – from AS 1680.4

CONTROL EQUIPMENT AND METHODS

- Incandescent lamp presents a relatively high resistance to the supply voltage
- A gas discharge lamp is an open circuit until the gas is ionised and becomes conductive.
- Once the gas becomes conductive it behaves like a short-circuit and would either destroy itself or trip the circuit protection unless some form of current limiting was employed.

CONTROL EQUIPMENT AND METHODS

- Additional equipment is required for gas discharge lamps to perform the following functions:
  - Provide a source of voltage higher than supply voltage, to ionise the gas and initiate conduction through the lamp. This is done by the collapsing field of a ballast or the HV output of an autotransformer or by electronic means.
  - Limit the power to that of the lamp rating. This is done by the ballast (or choke) which presents a high inductance but low resistance to the current.
  - Counteract the low power factor of the ballast by a power factor correction capacitor.

GLS and TUNGSTEN HALOGEN LAMPS

- The GLS lamp and **Tungsten Halogen Lamp** only require an on/off switch for control.

FLUORESCENT LAMPS

Control Equipment

- The fluorescent lamp requires either a specialized transformer/ballast or a starter/ballast combination or an electronic controller to function.
- An older type fluorescent lamp circuit using electromagnetic ballast and glow-type starter is shown in **Fig PF-7-3-6**.
- Operation of the circuit is as follows:
  1. Circuit is switched on and 230V appears across the contact gap of the starter

FLUORESCENT LAMPS

Control Equipment (Cont'd)

2. The gas inside the starter is ionised (it glows) heating the bi-metallic contacts which close completing the circuit through the ballast and cathode filaments.
3. Current flows in the filaments heating them and producing a cloud of electrons surrounding the filaments.
4. As the glow discharge in the starter has disappeared because the contacts are closed the bimetallic strip cools and breaks the filament circuit.

FLUORESCENT LAMPS

Control Equipment (Cont'd)

5. The sudden interruption of the current in the ballast causes it to produce a high voltage spike which initiates the arc through the tube by ionising the argon gas within.
6. The tube is now operating in series with the ballast which also restricts the current to rated value.
7. The voltage across the tube is relatively low (100V for 36W tube) and is insufficient to re-ionise the gas in the starter

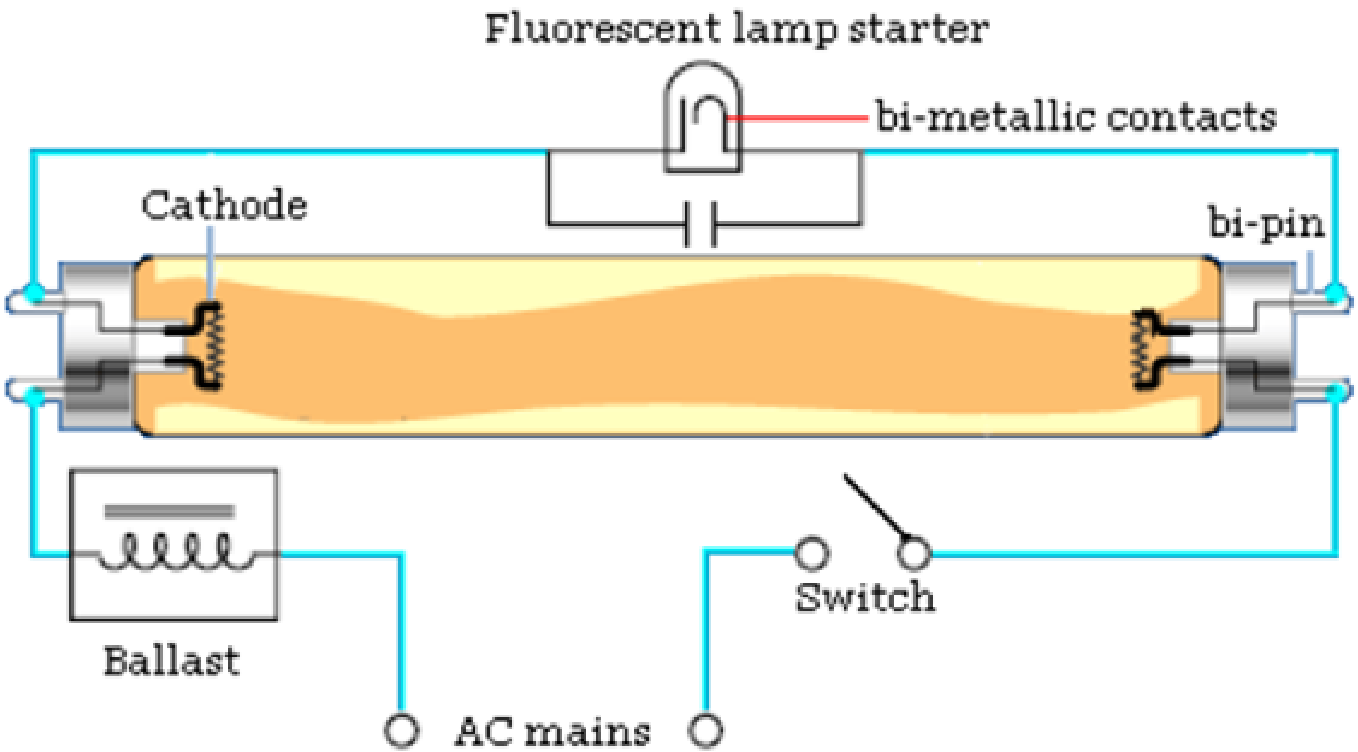


Fig. PF-7-3-6 – Older type Fluorescent Lamp Circuit using Electromagnetic Ballast and Glow-type Starter

FLUORESCENT LAMPS

Electromagnetic Ballasts

- The circuit shown in **Fig. PF-7-3-6** is an example of electromagnetic ballasts.
- Another electromagnetic ballast is shown in **Fig PF-7-3-7** - this is the 'quick-start' ballast and uses an auto-transformer but no starting switch.
- The circuit shown in **Fig. PF-7-3-8** is an arrangement used to eliminate the stroboscopic effect when fluorescent lights connected to the same phase are installed near rotating machinery.

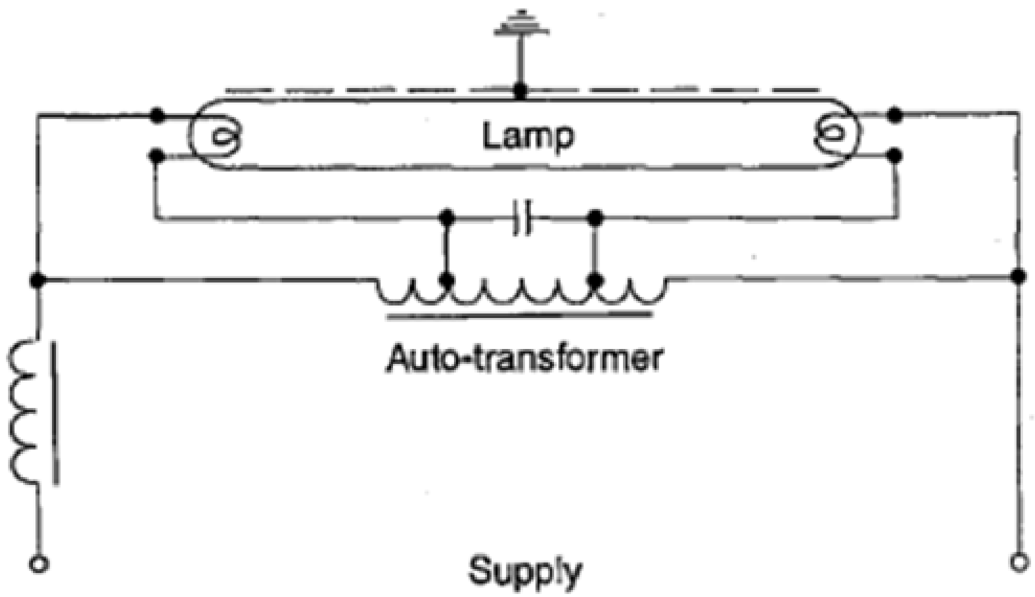


Fig. PF-7-3-7 – 'Quick start" Fluorescent Lamp Circuit using Autotransformer

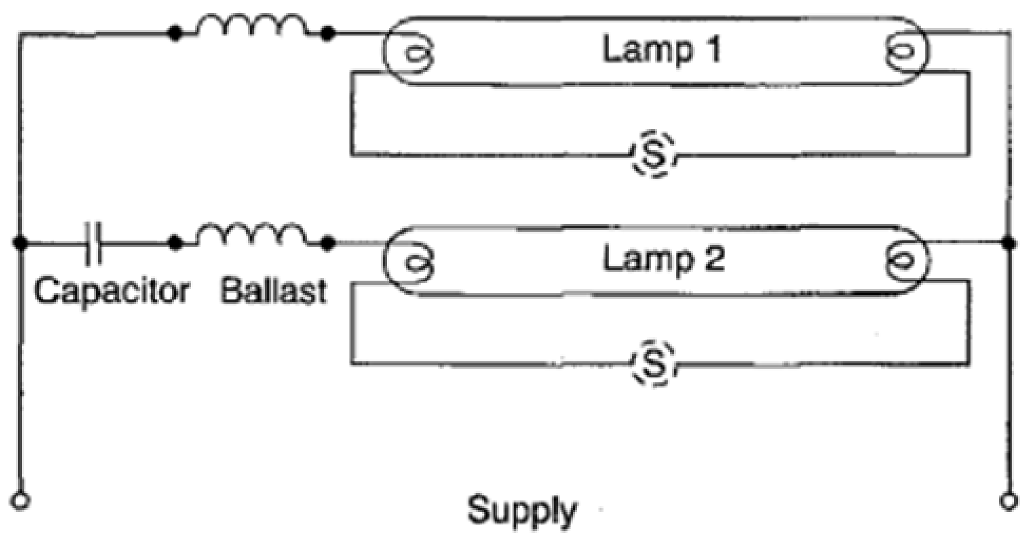


Fig. PF-7-3-8 – Lead-Lag Circuit

FLUORESCENT LAMPS

Electromagnetic Ballasts (Cont'd)

- Fig. PF-7-3-9 shows a standard 18W electromagnetic ballast

Fig. PF-7-3-9 – standard 18W electromagnetic ballast

FLUORESCENT LAMPS

Electronic Ballasts

- A lot of the problems associated with electromagnetic ballasts have been overcome with electronic ballasts (See Fig PF-7-3-10). These ballasts operate at high frequency and:
  - Overcome stroboscopic effects
  - Increase the efficacy of lamps
  - Start instantly
  - Eliminate need for a power factor correction capacitor

FLUORESCENT LAMPS

Electronic Ballasts

Fig. PF-7-3-10
Electronic Ballast

- ct replacement for GLS lamps have ancillary equipment built into their base. LED lighting has similar arrangements

MERCURY VAPOUR LAMPS

- Mercury Vapour Lamps normally use an electromagnetic ballast – this is normally due to the relatively harsh environment they usually operate in (See Fig F-7-3-11)

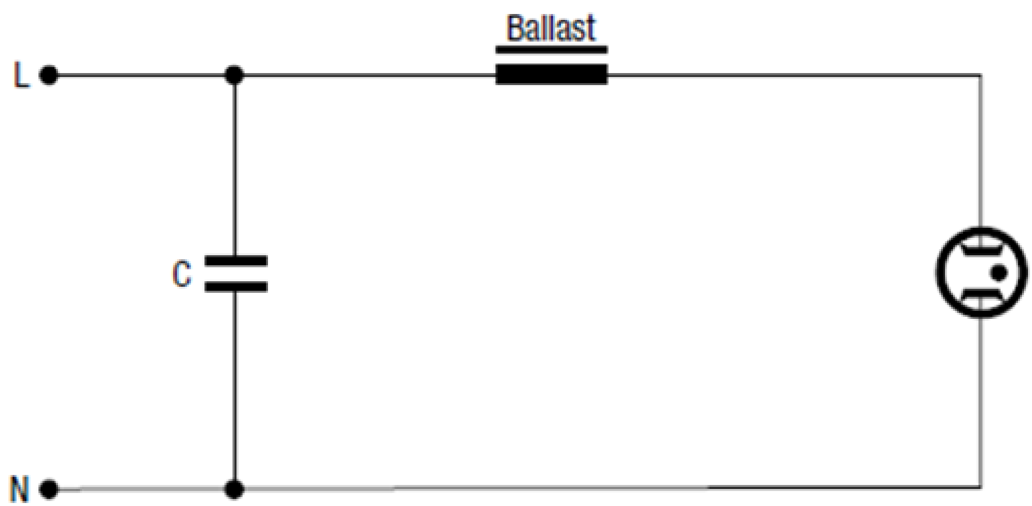


Fig. PF-7-3-11 – Mercury Vapour Lamp Control Circuit

METAL HALIDE LAMPS

- Metal halide lamps require higher voltages for starting than the usual supply voltages.
- Various circuits are used to achieve the required starting conditions including:
  - leakage reactance ballasts;
  - constant wattage auto-transformer
  - series lag type ballasts with igniter.
- Most metal halide lamps will require an igniter to start the discharge in the arc.

METAL HALIDE LAMPS

- Ignition voltage is generally 4 to 5 kV peak for a cold start with the lamps requiring a cooling period of between 10—15 minutes before they will re-ignite.
- Certain lamps are capable of hot re-ignition in which cases voltages of up to 35kV peak are required.
- Some of the higher wattage 2000W and 3500W lamps can require hot instant re-strike voltages of up to 60kV peak.
- See **Fig. PF-7-3-12** – Metal Halide Lamp Control Circuit

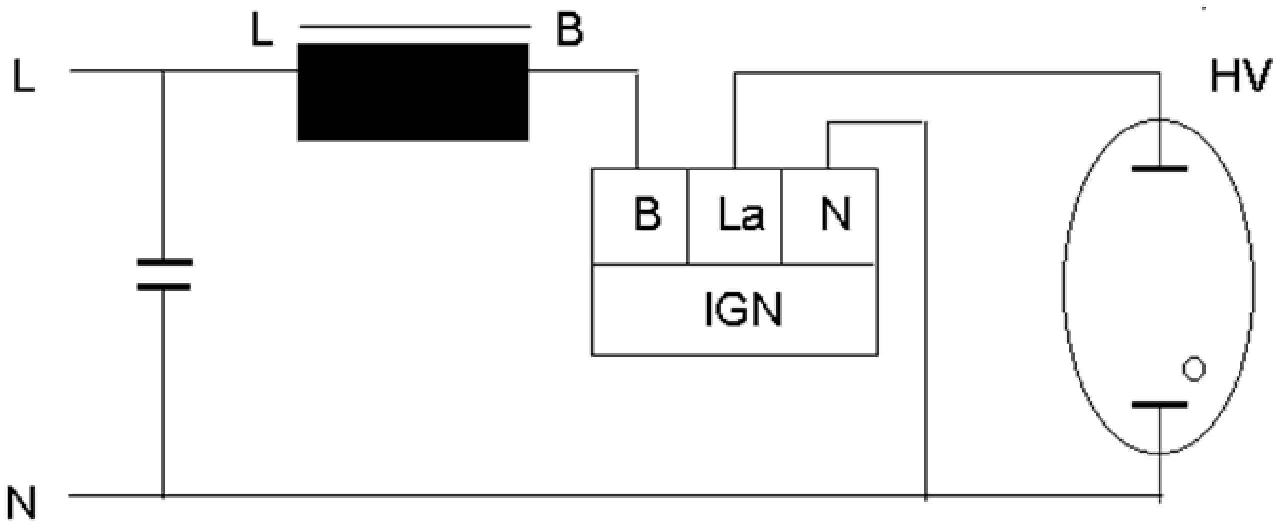


Fig. PF-7-3-12 – Metal Halide Control Circuit

HIGH PRESSURE SODIUM LAMPS

- HPS lamps can operate satisfactorily from -30°C to 100°C on series reactor ballast circuits
- Standard lamps with standard igniters re-ignite after 60 to 90 seconds requiring 2kV to 5kV to ignite from a cold start depending on the lamp specifications.
- HPS lamps can only be re-ignited hot if they are of linear double ended construction because hot re-strike requires 18kV to 25kV peak starting pulses.
- HPS lamps are most commonly used in a series reactor ballast and Igniter circuit (See Fig PF-7-3-13).

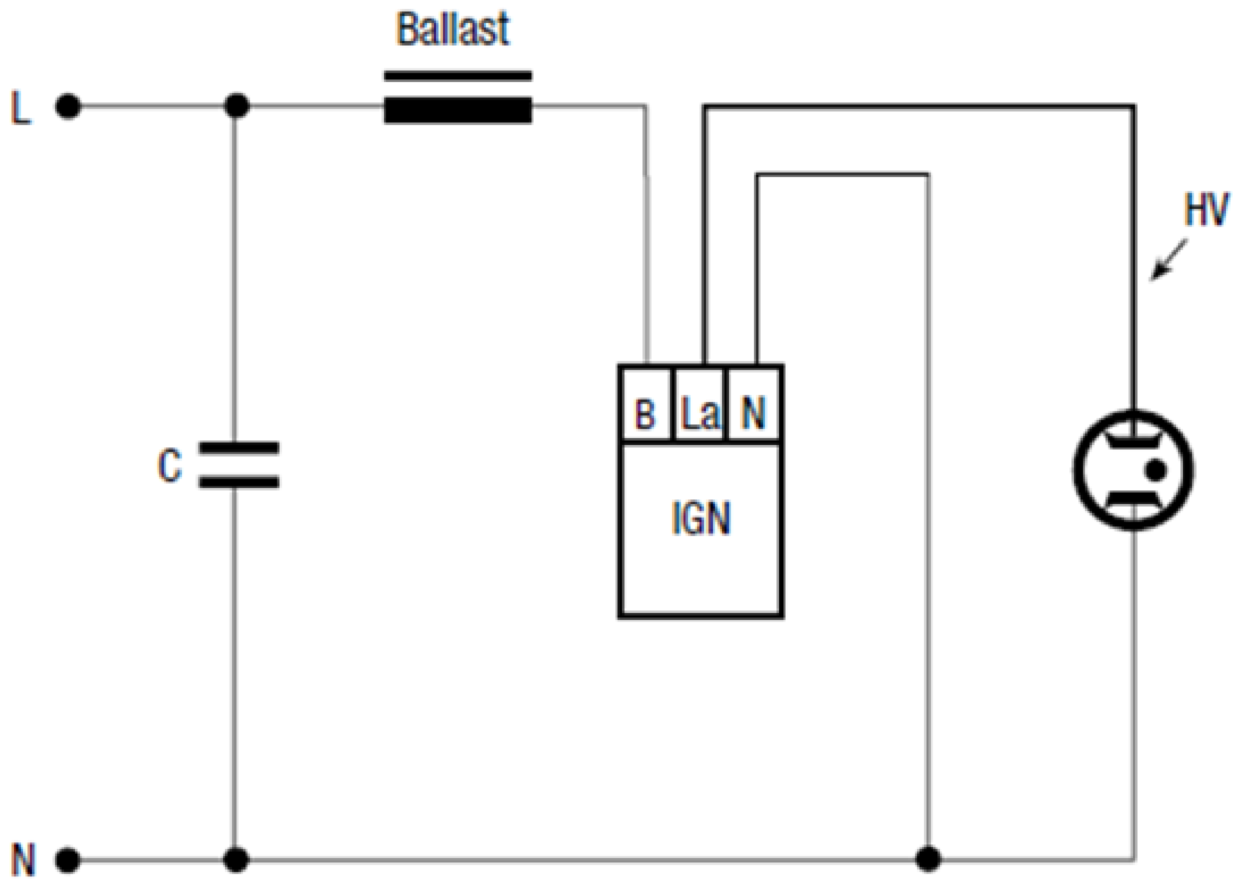


Fig. PF-7-3-13 – High Pressure Sodium Control Circuit

LOW PRESSURE SODIUM LAMPS

- LPS lamps require voltages from 390V to 670V (ballast open circuit voltage) for ignition and are therefore operated on leakage reactance ballasts or on series reactor ballasts with an igniter (See Fig. PF-7-3-14)
- The latter system is only suitable for lamp ratings up to 100W on 240V supply.

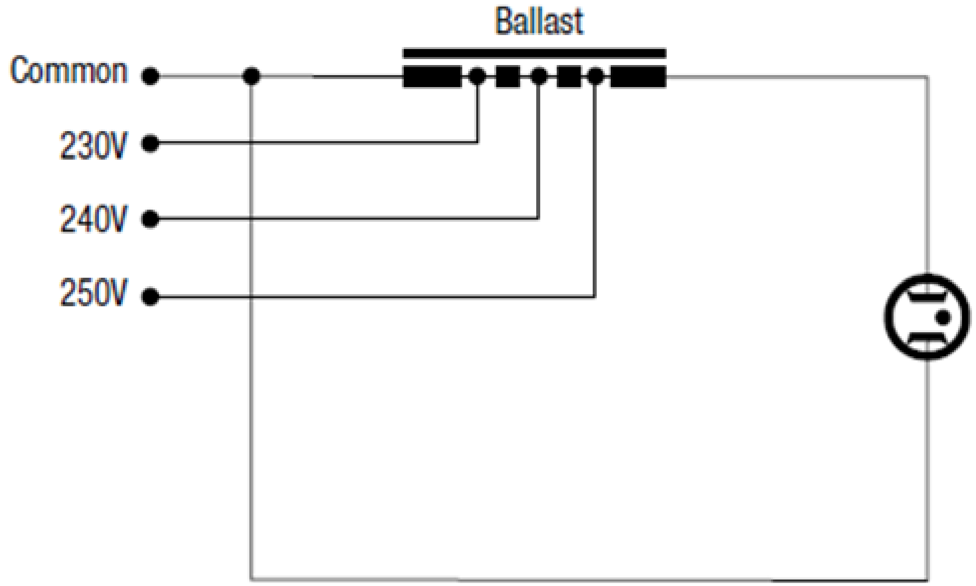


Fig. PF-7-3-14(a) – Leakage reactor ballast circuit for LPS lamps

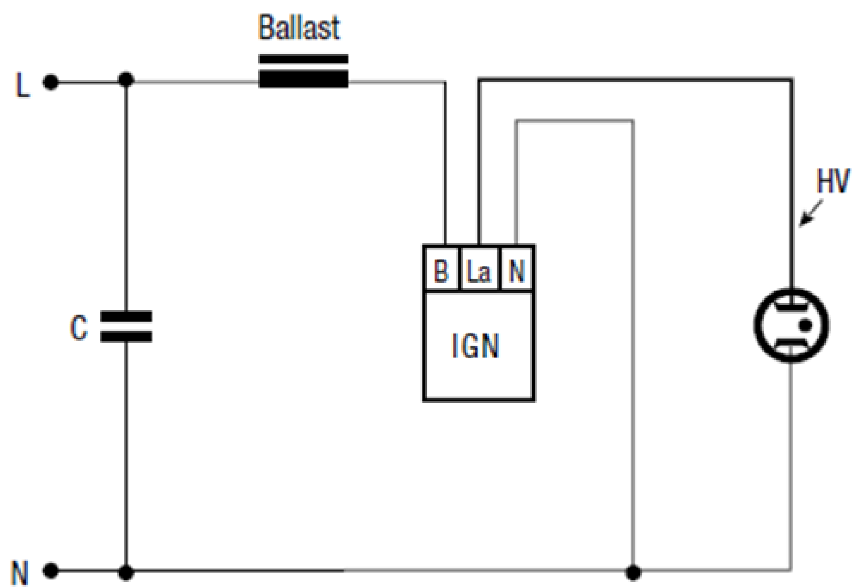


Fig. PF-7-3-14(b) – Igniter circuit for LPS lamps

Topic 7-4

BASIC LIGHTING DESIGN

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INTRODUCTION

- In designing a lighting system the designer has four main objectives:
  - **Comfort of occupants** – People should be able to perform their assigned tasks in a well lit glare free environment
  - **Safety** – The illuminance level must be sufficient to perform tasks safely.
  - **Minimise energy consumption** – Energy efficient lighting systems should be selected.
  - **Colour rendering** - the colour characteristics of a lighting scheme will affects tasks performed. Some tasks require a light with the spectral characteristics of daylight.

INTRODUCTION

A lighting design has several stages:

- Identify requirements – this will involve:
  - Determining illuminance levels
  - colour requirements
  - available space, etc.
- Selection of equipment, ie lamps and luminaires
- Design of the lighting system: In this section the Lumen Method will be outlined, although increasingly like many design tasks lighting design is being handled by computers

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THE LUMEN METHOD

- The basis of the lumen method is the following equation:

$$N = \frac{E \times A}{n \times F \times MF \times UF}$$

- Where:

  N - is the number of luminaires required;

  E - is the required illuminance (lux);

  A - is the area to be lit;

  n - is the number of lamps per luminaire;

THE LUMEN METHOD

- Lumen method equation (Cont'd)

F   is the lamp lumen output (lumens);

MF is known as the maintenance factor, which is a combination of three factors;

- Dust and dirt inside luminaire surfaces,
- Aging of light bulbs,
- Lamp survival factor

UF is the utilisation and is a function of the luminaire properties and room geometry.

THE LUMEN METHOD

Required Illuminance (E)

- This is the illumination required at the work surface.
- AS 1680.2 series give recommendations for illuminance levels for various types of areas.
- Separate publications in the series cover General Areas, Office, Industrial, Hospital and Schools.
- AS 1680 series also give recommended colour rendering and maximum glare index.

THE LUMEN METHOD

Required Illuminance (E) (Cont'd)

- For example recommended illumination for an general office area is given as 320 lux, while the general work area in a Bakery requires 160 lux.

Area to be Illuminated (A)

- This is the task area – not necessarily the floor area.

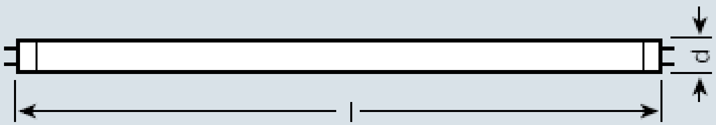
Number of Lamps per Luminaire (n)

- Many luminaires have more than just the one lamp especially the fluorescent luminaires.

THE LUMEN METHOD

Lamp Lumen Output (F)

- This information is supplied by the lamp manufacturer in catalogues or separate data sheets. The table following is a typical fluorescent lamp data table from "Osram Lighting"



Product reference	Product number	W	lm			Ra	TUBE d [mm]	l [mm]	
LUMILUX® DE LUXE T8, tubular, G13 base									
L 18 W/940	4050300**011257**	18	1200	LUMILUX DE LUXE Cool White		› 90	26	590	25
L 36 W/930	4050300**011318**	36	2700	LUMILUX DE LUXE Warm White		› 90	26	1200	25
L 36 W/940	4050300**011301**	36	2900	LUMILUX DE LUXE Cool White		› 90	26	1200	25
L 36 W/954	4050300**018263**	36	2850	LUMILUX DE LUXE Daylight		› 90	26	1200	25
L 58 W/940	4050300**011356**	58	4600	LUMILUX DE LUXE Cool White		› 90	26	1500	25

LUMILUX® DE LUXE lamps from OSRAM offer excellent color rendering of more than 90 and are extremely efficient. They are ideal for all applications in which color rendering plays an important role and high luminous flux is needed, such as in schools, offices, training rooms and retail outlets.

THE LUMEN METHOD

Maintenance Factor (MF)

- The maintenance factor (or Light Loss Factor LLF) is a value between 0 and 1
- Account for the reduction in light output from a lighting system due to:
  - degradation of lamp output over time
  - Failure of lamps over time, if failed lamps are replaced immediately this factor can be ignored
  - Dirt and dust accumulation on the luminaire.

THE LUMEN METHOD

Maintenance Factor (MF) (Cont'd)

- In the absence of any data or maintenance plans a value 0.8 can be used as 'safe' value of MF

Utilisation Factor (UF)

- A value between 0 and 1 (or sometimes a %).
- Represents the percentage of total lamp lumens in the room that fall on the work plane.
- Takes into account room reflectances, room shape, polar distribution and light output ratio of the fitting.

THE LUMEN METHOD

Space to Height Ratio (SHR)

- Nominal Spacing to Height ratio. E.g. 1.75 to 1 means that for every 1 metre of mounting height (above work plane) there should be a maximum 1.75 metres between fittings.
- The steps in determining UF are:

1. Determine the Room Index from the formula:

$$K = \frac{L \times W}{(L + W)h_m}$$

THE LUMEN METHOD

- where:

  K Room Index (calculation will usually result in a number between 0.75 and 5 (Note that any number outside this range will make this method invalid

  L Length of room

  W Width of room

  h_m Vertical distance between Luminaire and workplane

2. Determine Reflectances of the room floor, walls, and ceiling. As a guide those given in the following table are typical:

THE LUMEN METHOD

Colour	Reflectance
White, Off-white, light shades of gray, brown, blue	75-90%
Medium green, yellow, brown or grey	30-60%
Dark grey, medium blue	10-20%
Dark blue, green, wood panelling	5-10%

- Typical values are in the range:
  - Ceiling: 70 – 90%
  - Walls: 50 – 70%
  - Floor: 20 – 50%

THE LUMEN METHOD

3. Once the room index and the room reflectances are decided on the UF can be read of a table similar to the one following .
   Different tables apply to different luminaires and data should be sought on specific models

Utilisation Factors (UF)								SHR Nom = 2.00			
Reflectances			**Room Index**								
C	**W**	**F**	**0.75**	**1.00**	**1.25**	**1.50**	**2.00**	**2.50**	**3.00**	**4.00**	**5.00**
0.70	0.50	0.20	0.31	0.39	0.43	0.46	0.51	0.55	0.57	0.61	0.63
	0.30		0.25	0.33	0.37	0.41	0.46	0.50	0.53	0.57	0.60
	0.10		0.21	0.29	0.33	0.36	0.42	0.46	0.49	0.54	0.57
0.50	0.50	0.20	0.27	0.34	0.37	0.40	0.45	0.48	0.50	0.53	0.55
	0.30		0.23	0.29	0.33	0.36	0.41	0.44	0.46	0.50	0.52
	0.10		0.19	0.26	0.29	0.32	0.37	0.41	0.44	0.47	0.50
0.30	0.50	0.20	0.24	0.30	0.32	0.35	0.39	0.41	0.43	0.45	0.47
	0.30		0.20	0.26	0.29	0.31	0.36	0.38	0.40	0.43	0.47
	0.10		0.17	0.23	0.26	0.29	0.33	0.36	0.38	0.41	0.43
0.00	0.00	0.00	0.13	0.18	0.20	0.22	0.26	0.28	0.30	0.32	0.34

EXAMPLE

A general open plan office has dimensions 12 x 8.5 x 2.8 m. The illuminance required is 320 lux. The reflectance of the ceiling is known as 0.70 and the reflectance of the wall is 0.50 m.

The work areas (desks) are at a height of 0.80 m. The luminaires chosen are twin tube (each tube is 36W 'daylight' 2850 lumens) direct-indirect type with UF data as shown in table above. Determine Number of luminaires required.

Solution to EXAMPLE

- The mounting height is: H_m = 2.8 - 0.8 = 2.0 m.
- The Room Index is:

$$K = \frac{L \times W}{(L + W)h_m} = \frac{12 \times 8.5}{(12 + 8.5)2} = 2.5$$

- From the UF table shown above the UF is found to be 0.55
- Assuming MF = 0.8 (as no other data available)

Solution to EXAMPLE

- Then from

$$N = \frac{E \times A}{n \times F \times MF \times UF} = \frac{320 \times (12 \times 8.5)}{2 \times 2850 \times 0.8 \times 0.55} = 13.01$$

- In this case the number of luminaires actually installed might be 15 (3 rows of 5)


END