

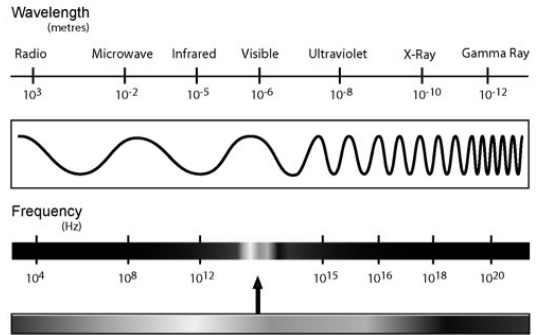
Assessment of lighting levels in workplaces

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Visible light and perceived colour

THE ELECTRO MAGNETIC SPECTRUM



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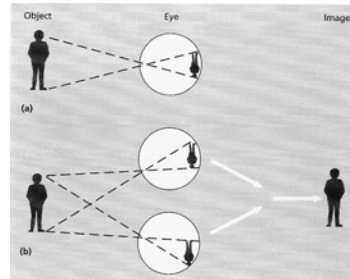
Characteristics of Vision

- Accommodation
- Adaption
- Acuity

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Accommodation

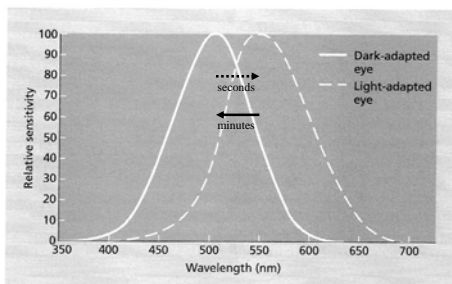
- Adjustment of the lens
- Convergence of the signal from each eye to the brain



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Adaption

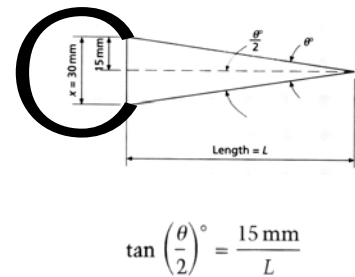
- Peak sensitivity at 555nm (green) (light-adapted) and 505nm (green-blue) (night-adapted)



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Acuity

- Defined as $1/q$,
 q is angle subtended at the eye that smallest detail can be detected, unit 'minutes of arc'
- Normal eye viewing a well illuminated subject with good contrast is about 1.0 minute^{-1}
(1 degree = 60 minutes)
- Example, distinguish a detail of 30mm from distance $L = 103.18\text{m}$



$$\tan\left(\frac{\theta}{2}\right)^\circ = \frac{15 \text{ mm}}{L}$$

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Basic laws of lighting

a) The inverse square law:

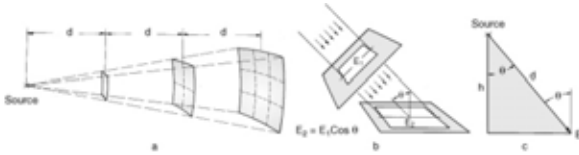
$$E = \frac{I}{d^2}$$

b) The cosine law (Lambert's law)

$$E = \frac{I}{d^2} \cos\theta$$

c) The cosine-cubed law

$$E = \frac{I \cos^3\theta}{h^2}$$



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Assessment of lighting levels

1. Identify defects in the lighting systems by walkthrough inspections
2. Estimation of average illuminance without using a lux meter
3. Use a luxmeter to determine the average illuminance

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Walkthrough inspections

- Need not take measurement
- Identify the observable lighting problems only:
 - Worn out luminaries
 - Flickering
 - Glare
 - Shadow
 - Reflection
- Sufficient illuminance?



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Illuminance Estimation

- Usually used at the design stage:
 - Lumen method
- Lumen method is to achieve a uniform general level of illuminance on a working plane within an interior of rectangular shape.
- Only determine the number of lamps required, the spacing between lamps is not considered.

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Lumen method

- E (illuminance) = $n \times LDL \times LLF \times UF / \text{Area}$
 - n : no. of lamps
 - LDL: lighting design lumens per lamp
 - LLF: light loss factor
 - UF: utilisation factor

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Lamps Selection

- The efficacy of a lamp is measured in terms of light output/electrical input (lumens/watt)
- Types, e.g.
 - Incandescent
 - Fluorescent
 - LED
 - Arc Lamp
 - Gas Discharge

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Incandescent

- Electric heated filament
- General Lighting Service (GLS) Lamps, i.e. most domestic lamps, tungsten lamps, halogen lamps



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Fluorescent Lamps

- Low pressure mercury discharge lamps producing UV radiation which is converted by phosphor tube coating into visible light.
- Linear type:
 - T12 (38mm, ~70 lumen/W)
 - T8 (26mm, ~80 lumen/W)
 - T5 (16mm, ~100 lumen/W)
- CFL Compact Fluorescent Lamps, widely used for general lighting and energy saving



CFL

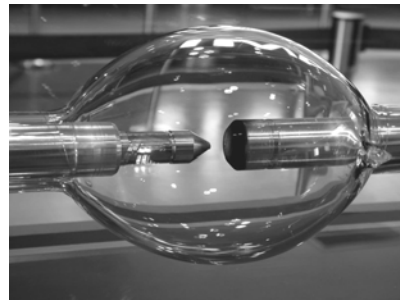
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Light Emitting Diodes



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Arc Lamps



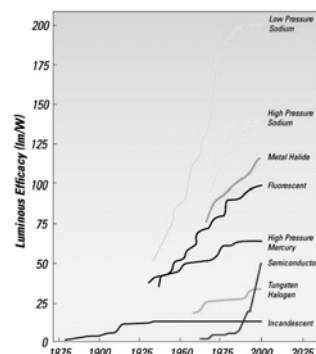
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Gas Discharge Lamps



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Efficacies of common lights



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Light loss factor

- also called maintenance factor (MF)
- $LLF = LLMF \times LSF \times LMF \times RSMF$
 - LLMF: lamp lumen maintenance factor: reduction in lumen output after specific burning hours
 - LSF: lamp survival factor: % of lamp failures after specific burning hours
 - LMF: luminaire maintenance factor: the reduction in light output due to dirt deposited on or in the luminaire
 - RSMF: room surface maintenance factor: the reduction in reflectance due to dirt deposition in the room surfaces
- LLF: ~0.8 for normal condition, ~0.9 (clean and air-conditioned room), ~0.5 (dusty, industrial area without proper cleaning)

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Utilisation factor

- Ratio of the utilised flux on the working plane to the luminous flux emitted by the lamp
- Depends on the following factors
 - fitting types, i.e. light output ratio (LOR)
 - room proportions, i.e. room index
 - room reflectances
- Details from lighting design handbooks

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Light output ratio

- Ratio of the output of the luminaries to the output of lamps
- LOR \uparrow : utilisation factor \uparrow

Classification	Direct	Semi-direct	General Diffusing	Indirect (up lighters)	semi-indirect
Luminaire					
Upper-hemisphere flux	0-10	10-40	40-60	90-100	60-90
Lower-hemisphere flux	100-90	90-60	60-40	10-0	40-10

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Room index

Length x Width

- Room index: -----

Hm x (Length + Width)

Hm: the height of luminaries above the working plan

- Narrow rooms : room index \downarrow
- Room index \downarrow : utilisation factor \downarrow

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Room reflectances

- Reflectance of room surfaces (i.e. ceiling, wall, floor) \uparrow : utilisation factor \uparrow

c: 0.9, w: 0.7, f: 0.5

c: 0.5, w: 0.3, f: 0.1



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Example: ET236 2 x T8 36W Specular Louvre

Utilisation factor table

Reflectances			Room index								
c	w	f	0.75	1.00	1.35	1.50	2.00	2.50	3.00	4.00	5.00
0.70	0.50	0.20	38	43	47	49	52	54	55	57	58
0.70	0.30	0.20	35	40	44	46	50	52	53	55	56
0.70	0.10	0.20	33	38	42	44	48	50	52	54	55
0.50	0.50	0.20	37	42	45	48	50	52	53	55	55
0.50	0.30	0.20	34	40	43	45	48	50	52	53	54
0.50	0.10	0.20	32	38	41	44	47	49	50	52	54
0.30	0.50	0.20	37	41	44	46	49	50	51	53	53
0.30	0.30	0.20	34	39	42	44	47	49	50	52	53
0.30	0.10	0.20	32	37	41	43	46	48	49	51	52
0.00	0.00	0.00	31	36	39	42	44	46	47	49	50

Ceiling mounted

(extracted from Pierlite Professional Lighting Solutions)

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Example of Lumen method

- Room: 15m x 10m x 2m (height above desk)
- 30 luminaries: 2 x 36W with louvre /luminary
- Assume: normal MF: 0.8, 80 lumen/W, reflectance: C:0.7, W: 0.3, F: 0.2
- Room index: $15 \times 10 / 2 / (15 + 10) = 3$, UF: 0.53
- Rough estimation of illuminance:

$$E = 30 \times (2 \times 36 \times 80) \times 0.8 \times 0.53 / (15 \times 10)$$

$$= 488 \text{ lux}$$

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Spacing to height ratio

- Ratio of the distance between luminaries to their height above working plane
- Distance between luminaries: centre to centre
- SHR ↓ : uniformity ↑

$$SHR = \frac{1}{H_m} \sqrt{\frac{A}{N}}$$

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Determine the average illuminance

- Luxmeter indicates the illuminance at the measurement point only
- Find the average illuminance by averaging the results of measurement points.....how many points?



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Determine the average illuminance

- Take four measurements at different places representative of the level of lighting at the task position or , in an area, representative of the level of lighting 1 m above the floor of the area.
- Divide the summation of the results by four.

(Canada Occupational Health and Safety Regulations Part 6 – Lighting, section 6.3)

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Determine the average illuminance

- CIBSE, 1994, *Interior Lighting Code*:
 - Divide the room into equal areas, the shape of each area should be similar to a square as far as possible.
 - Minimum no. of equal areas depends on the room index.

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Determine the average illuminance

- CIBSE, 1994, *Interior Lighting Code*:

Room Index	Number of Points
Below 1	9
1 and below 2	16
2 and below 3	25
3 and above	36

Room index	Minimum number of measurement points	
	For ± 5% accuracy	For ± 10% accuracy
RI < 1	8	4
1 < RI < 2	18	9
2 < RI < 3	32	16
RI > 3	50	25

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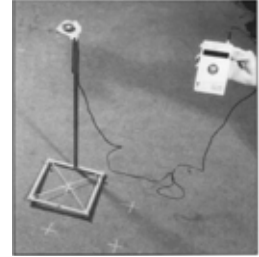
Determine the average illuminance

- Measurement be taken at least 0.5m away from walls for fixed obstructions, i.e. columns or partitions.
- Measure the illuminance at the centre of each square and take the average readings.

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Determine the average illuminance

- Take measurement when readings are stable
- Take readings at working plane height (~0.8-1.0m)
- Avoid shadowing or reflecting light on to the photocell, i.e. use a portable stand if possible



(extracted from CIBSE)

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Optimum average illumination

Item	Task position or area	Optimum average illumination in lux	Notes
1. OFFICES			
	General offices	500	
	Computer work stations	500	Local lighting may be required for reading a document
	Drawing work stations	750	Local lighting is appropriate
	Other areas, e.g. file storage and reception, telephone operators	300	

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Optimum average illumination

- Offices, banks, shops & supermarkets, libraries, schools, manufacturing and processing areas, distribution and storage and catering services, etc.:

(Minimum levels of lighting : measured average levels of lighting should not be less than 1/3 of optimum average illumination.)

- General building areas and construction sites, etc.:

(Minimum levels of lighting: measured average levels of lighting should not be less than 1/10 of optimum average illumination.)

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Guidelines on Lighting



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Thank You

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