Task 3: Design of room illumination

Method 1

Simple method used for preliminary design of illumination system. Calculation requires uniform placement of light fittings over illuminated area. The result depends on illumination type, reflection coefficients of room surfaces, room height etc.

Required electricity input of lighting system :

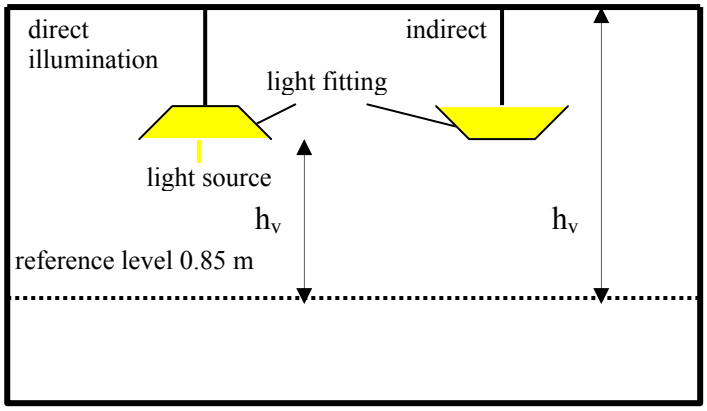
$$P = p.A.\frac{10}{\eta_z}\frac{E_{req}}{100} \quad [W]$$

p…..relative input due to specific illumination output of light source
A….illuminated surface (room surface) [m^2]
η_z… specific illumination output of light source [lm/W] (Fig.3)
E_{req}…required illuminance [lx] (the luminous flux density at a surface, lumens per m^2)

Room factor

$$\mu = \frac{w}{h_v} \quad [-]$$

w….room width (shorter room dimension) [m]
h_v…height of light sources above the reference level



Method 2

This method is based on luminous flux of a light source calculated form required illuminance of the room.

$$\phi_{req} = \frac{E_{req}.A}{z.\eta_e} \quad [lm]$$

ϕ_{req} required light source luminous flux [lm]
E_{req} required illuminance [lx] (average for the surface)
A illuminated surface (room surface) [m^2]
z maintenance factor
η_e utilization factor

Utilization factor η_e

The factor depends on a light source luminous flux distribution, reflectance of walls and ceiling and a shape of room. Usually given by producers of lighting systems for each light source separately according to room index *m* and reflection coefficients of floor, walls and ceiling.

Room index

$$m = \frac{a.b}{h_v.(a+b)}$$

h_v… height of light sources above the reference level
a,b ..room dimensions

You may use for factor definition also Fig. 6

Maintenance factor z

The factor describes a changes of luminous flux from light source caused by ageing, fouling as well as changes of reflexivity of room surfaces. Values are usually between 0.5 – 0.7. Minimum value is 0.5.

$z = z_z \,.\, z_s \,.\, z_{po} \,.\, z_{fz}$

z_z light source ageing
z_s light fitting ageing and fouling
z_{po} room surface fouling
z_{fz} light source reliability

Design of light fittings and light sources number

A) Light fitting
The first step is a choice of light fitting with certain light sources inside. Then we have the luminous flux of one light fitting (producer catalogue requred). The ratio of required light source luminous flux ϕ_z and luminous flux of one light fitting ϕ_{sv} gives the number of light fittings.

number of light fittings: $n = \frac{\phi_{req}}{\phi_f}$ $\phi_f = \eta_f \,.\, \phi_{fs}$ [lm]

B) Light source
Direct calculation of light source number without definition of fitting number. The problem is, that sum of light sources luminous fluxes is not equal to luminous flux of light fitting – the efficiency and wave interference decreases the sum.

number of light sources: $n = \frac{\phi_{req}}{\phi_{fs} \cdot \eta_{fs}}$

ϕ_{req} required light source luminous flux [lm]
ϕ_f luminous flux of one light fitting [lm]
ϕ_{fs} luminous flux of light sources in the fitting [lm]
η_f light fitting efficiency (0.6 - 0.8) [-]
η_{fs} light sources efficiency [-]

Homework 3
Design lighting system for 3 different room types in your residential building.

Fig.1 Residential building lighting

Room	required artificial illuminance [lx]
Overall room lighting with local lighting	50 - 100
Overall room lighting without local lighting	200 - 500
Dining room	200
Kitchen	100 - 150
Bedroom	100
Corridor	75
Bathroom, toilet	100

Fig.2 Local lighting (some activities)

Dining table	200 - 300lx
Reading, writing, drawing etc.	300 lx
Writing desk	500 lx
Filigree, sewing, modelling, etc.	300 - 750 lx
Reading on the bed	150 - 200 lx

Fig. 3 Specific illumination output of light source [lm/W]

Light source	**η_z [lm/W]**	**R_a [-]**
Common light bulb	10-18	100
Halogen bulb	20-30	100
Mercury-vapour lamp	40-60	10-60
Compact fluorescent tube	40-87	80-90
Linear fluorescent tube	50-110	40-80
Metal-halide lamp	60-130	70
High pressure sodium-vapour lamp	70-150	25-60-85
Low pressure sodium-vapour lamp	100-200	0

Fig. 4 Relative electric input *p* required to reach the average illuminance E = 100 lx related to specific illumination output of light source 10 lm/W

Illumination	Room factor μ [-]	Room walls and ceiling: Light surface Reflectance > 50%	Mediate Reflectance 30-50%	Dark surface Reflectance <30%
direct	<2	25	28	30
	2-4	19	20	22
	>4	15	16	18
mixed	<2	42	60	80
	2-4	28	36	48
	>4	20	26	32
indirect	<2	56	86	160
	2-4	36	56	106
	>4	26	40	74

Fig. 5 Reflectance factors for different surfaces and colors

White	0,75 - 0,80
Beige	0,60 - 0,70
Yellow – light	0,60 - 0,70
Yellow - dark	0,50 - 0,60
Red – light	0,40 - 0,50
Red – dark	0,15 - 0,30
Green – light	0,45 - 0,65
Green – dark	0,05 - 0,20
Blue – light	0,40 - 0,60
Blue – dark	0,05 - 0,20
Brown	0,12 - 0,25
Brown – light	0,40 - 0,60
Brown – dark	0,15 - 0,20
Black	0,01 - 0,03
Firebrick	0,25
Sand – light	0,50
Gypsum white	0,80 - 0,92
Marble	0,55 - 0,80
Granite	0,40 - 0,50
Wood – light	0,30 - 0,50
Wood – dark	0,10 - 0,25
Asphalt	0,10
Concrete paving	0,30
Earth	0,08 - 0,20
Steel	0,28
Aluminium – anodized, polished	0,75 - 0,85
Glass mirror	0,80 - 0,90
Window with bright glassing (outer side)	0,10
Window with bright glassing and white curtain	0,30 - 0,40
Snow	0,75 - 0,80

Fig. 6 Utilization factor η_e

A) Light bulb

CEILING REFLECTANCE								ROOM INDEX m	ILLUMINATION	
>50 %			30 - 50 %			< 30 %				
WALL REFLECTANCE										
>50 %	30 - 50 %	< 30 %	>50 %	30 - 50 %	< 30 %	30 - 50 %	< 30 %			
0,28	0,24	0,19	0,28	0,24	0,18	0,23	0,18	1	DIRECT	90-180°:0 % η_s = 75% 0 -90°: 75%
0,40	0,36	0,32	0,40	0,35	0,31	0,35	0,31	1,5		
0,46	0,43	0,39	0,45	0,42	0,39	0,42	0,39	2		
0,53	0,50	0,46	0,52	0,49	0,46	0,48	0,45	3		
0,58	0,55	0,51	0,57	0,54	0,51	0,53	0,51	4		
0,64	0,61	0,58	0,63	0,60	0,58	0,60	0,58	6		
0,67	0,65	0,63	0,66	0,64	0,62	0,63	0,61	8		
0,25	0,20	0,16	0,24	0,19	0,15	0,19	0,15	1	SEMI-DIRECT	90-180°:20% η_s = 80% 0 -90°:60%
0,34	0,30	0,26	0,33	0,29	0,25	0,28	0,25	1,5		
0,39	0,35	0,32	0,38	0,34	0,32	0,33	0,31	2		
0,46	0,42	0,38	0,44	0,40	0,37	0,38	0,36	3		
0,51	0,47	0,44	0,48	0,45	0,42	0,43	0,41	4		
0,57	0,54	0,50	0,54	0,51	0,48	0,48	0,46	6		
0,60	0,57	0,54	0,57	0,54	0,52	0,51	0,50	8		
0,17	0,12	0,09	0,15	0,10	0,08	0,09	0,07	1	COMBINATION	90-180°:35% η_s = 80% 0 -90°:45%
0,23	0,18	0,15	0,21	0,16	0,13	0,14	0,12	1,5		
0,28	0,22	0,19	0,25	0,20	0,17	0,18	0,15	2		
0,35	0,30	0,25	0,30	0,26	0,22	0,23	0,20	3		
0,40	0,34	0,30	0,35	0,30	0,27	0,26	0,23	4		
0,46	0,41	0,36	0,40	0,36	0,32	0,31	0,29	6		
0,51	0,45	0,41	0,45	0,40	0,37	0,35	0,32	8		
0,17	0,14	0,11	0,14	0,11	0,09	0,08	0,07	0,8	SEMI-INDIRECT	90-180°:60% η_s = 80% 0 -90°:20%
0,21	0,18	0,14	0,17	0,14	0,12	0,10	0,09	1		
0,27	0,23	0,20	0,22	0,18	0,16	0,13	0,12	1,5		
0,31	0,27	0,23	0,25	0,21	0,19	0,16	0,14	2		
0,38	0,33	0,30	0,30	0,27	0,24	0,20	0,18	3		
0,42	0,37	0,34	0,33	0,30	0,27	0,22	0,20	4		
0,47	0,43	0,39	0,38	0,35	0,32	0,26	0,24	6		
0,15	0,12	0,10	0,11	0,09	0,07	0,05	0,04	0,8	INDIRECT	90-180°:80% η_s = 80% 0 -90°: 0%
0,17	0,15	0,12	0,13	0,11	0,09	0,07	0,06	1		
0,23	0,21	0,18	0,17	0,14	0,12	0,09	0,08	1,5		
0,27	0,24	0,21	0,20	0,17	0,15	0,10	0,09	2		
0,33	0,30	0,27	0,23	0,21	0,19	0,12	0,11	3		
0,36	0,33	0,30	0,26	0,24	0,22	0,14	0,13	4		
0,41	0,38	0,36	0,30	0,27	0,25	0,16	0,15	6		

B) Light tube

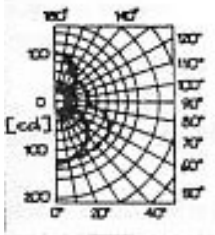
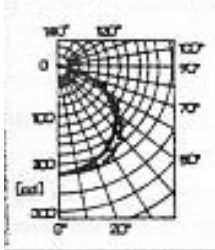
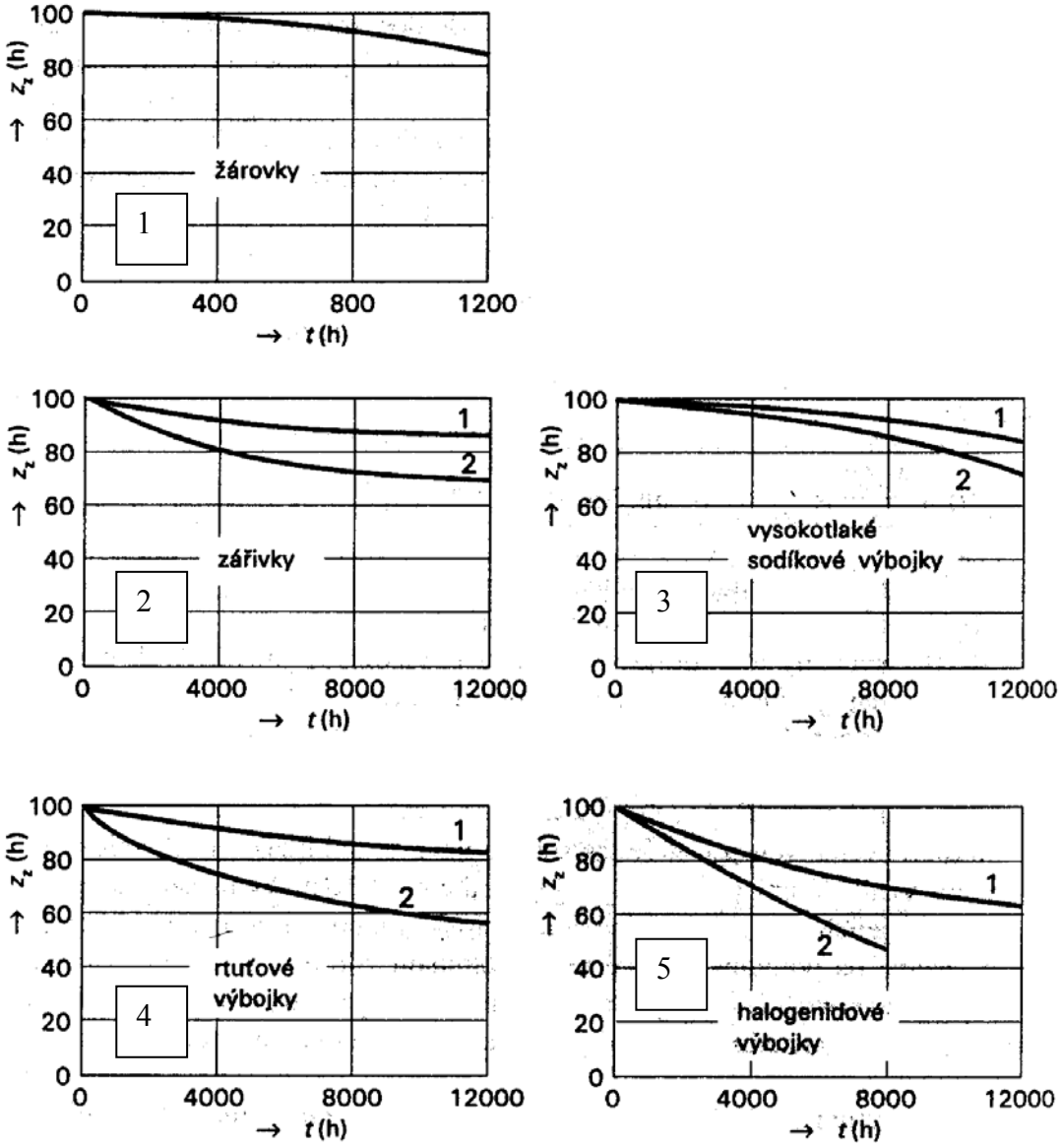
REFLECTANCE									
FLOOR		0,2				0,1			
CEILING		0,7		0,5		0,7		0,5	
WALL		0,5	0,2	0,5	0,2	0,5	0,2	0,5	0,2
ROOM INDEX									
	0,6	0,30	0,25	0,29	0,23	0,21	0,25	0,28	0,22
	0,8	0,41	0,33	0,34	0,30	0,29	0,32	0,34	0,29
	1,0	0,47	0,39	0,41	0,35	0,44	0,37	0,39	0,33
	1,25	0,54	0,46	0,46	0,40	0,50	0,43	0,44	0,38
	1,5	0,59	0,51	0,51	0,44	0,54	0,48	0,47	0,42
	2,0	0,66	0,59	0,57	0,51	0,60	0,54	0,53	0,48
	2,5	0,71	0,64	0,61	0,56	0,64	0,59	0,56	0,52
	3,0	0,75	0,69	0,64	0,59	0,67	0,62	0,59	0,55
	4,0	0,80	0,75	0,69	0,64	0,71	0,67	0,63	0,59
	5,0	0,84	0,79	0,71	0,66	0,73	0,70	0,65	0,62
	0,6	0,24	0,28	0,23	0,27	0,23	0,27	0,22	0,27
	0,8	0,43	0,36	0,41	0,34	0,41	0,35	0,40	0,34
	1,0	0,49	0,42	0,47	0,41	0,46	0,41	0,45	0,40
	1,25	0,56	0,49	0,53	0,47	0,52	0,46	0,50	0,45
	1,5	0,60	0,54	0,57	0,52	0,56	0,51	0,54	0,49
	2,0	0,67	0,61	0,64	0,59	0,61	0,57	0,59	0,55
	2,5	0,72	0,67	0,68	0,63	0,68	0,61	0,63	0,59
	3,0	0,75	0,71	0,71	0,67	0,67	0,64	0,65	0,62
	4,0	0,80	0,76	0,75	0,71	0,70	0,68	0,68	0,66
	5,0	0,83	0,79	0,77	0,74	0,72	0,70	0,70	0,68
	0,6	0,24	0,20	0,23	0,19	0,23	0,19	0,22	0,18
	0,8	0,30	0,25	0,28	0,24	0,28	0,24	0,27	0,23
	1,0	0,34	0,29	0,32	0,28	0,32	0,28	0,30	0,27
	1,25	0,39	0,34	0,36	0,32	0,36	0,32	0,34	0,30
	1,5	0,42	0,37	0,40	0,36	0,39	0,35	0,38	0,33
	2,0	0,47	0,43	0,44	0,40	0,43	0,40	0,41	0,38
	2,5	0,50	0,46	0,46	0,43	0,45	0,42	0,43	0,41
	3,0	0,52	0,49	0,48	0,46	0,47	0,44	0,45	0,43
	4,0	0,56	0,53	0,51	0,49	0,49	0,47	0,47	0,45
	5,0	0,58	0,56	0,53	0,51	0,51	0,49	0,48	0,47

Fig. 7 Maintenance factor z

A) Light source ageing z_z

Factor z_z defines drop of light source luminous flux during lifetime. (bulb lifetime 800 – 1000 hours, tube lifetime 8000 hours)

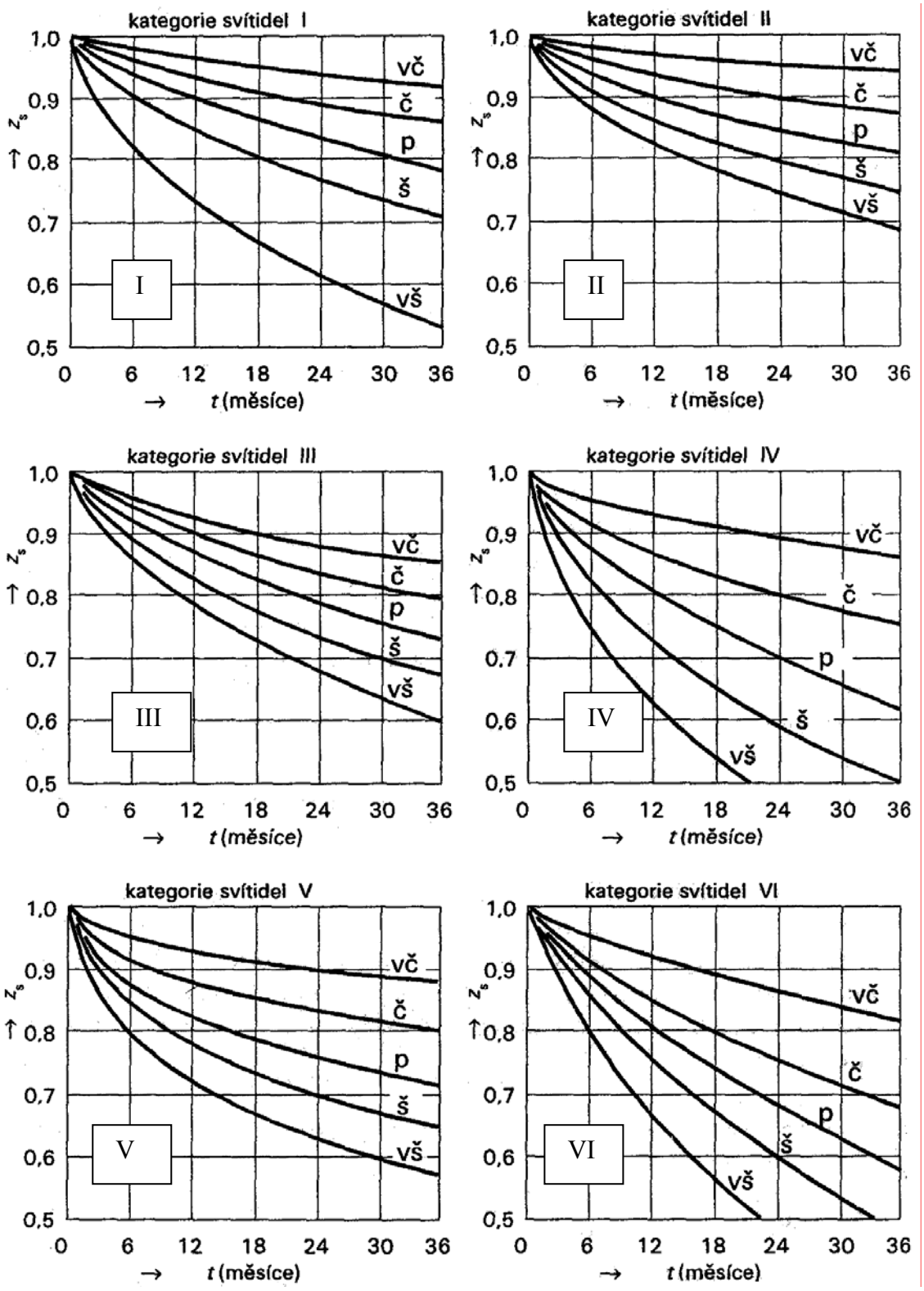


1 - Common light bulb 2 - Linear fluorescent tube 3 - High pressure sodium-vapour lamp
4 - Mercury-vapour lamp 5 - Halogen tube

B) Light fitting ageing and fouling z_s

Fouling and ageing of light source is the most significant influence to luminous flux decrease. Fouling may be eliminated with regular cleaning. The factor definition requires proper designation to one of six categories. If the light fitting corresponds to more than one category, than use lower category number.

Time dependent change of fouling coefficient z_s for categories I to VI and different levels of cleanness of the space.



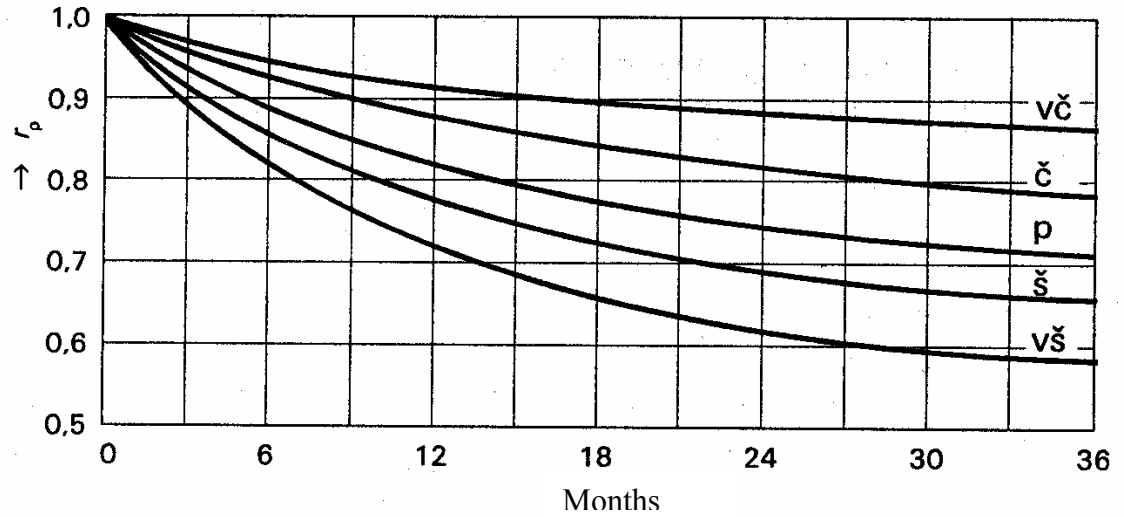
Light fitting classification (acc. to standard ČSN 36 0450)

Category	Upper lamp-shade	Lover lamp-shade
I	1. None	1. None
II	1. None 2. Transparent, openings ≥ 15 % 3. Translucent, openings ≥ 15% 4. Opaque, openings ≥15%	1. None 2. Grid or lamina
III	1. None 2. Transparent, openings ≤15 % 3. Translucent, openings ≤ 15% 4. Opaque, openings ≤ 15%	1. None 2. Grid or lamina
IV	1. Transparent, no openings 2. Translucent, no openings 3. Opaque, no openings	1. None 2. Grid
V	1. Transparent, no openings 2. Translucent, no openings 3. Opaque, no openings	1. Transparent, no openings 2. Translucent, no openings
VI	1. None 2. Transparent 3. Translucent 4. Opaque	1. Transparent 2. Translucent 3. Opaque

Proportion of the space pollution

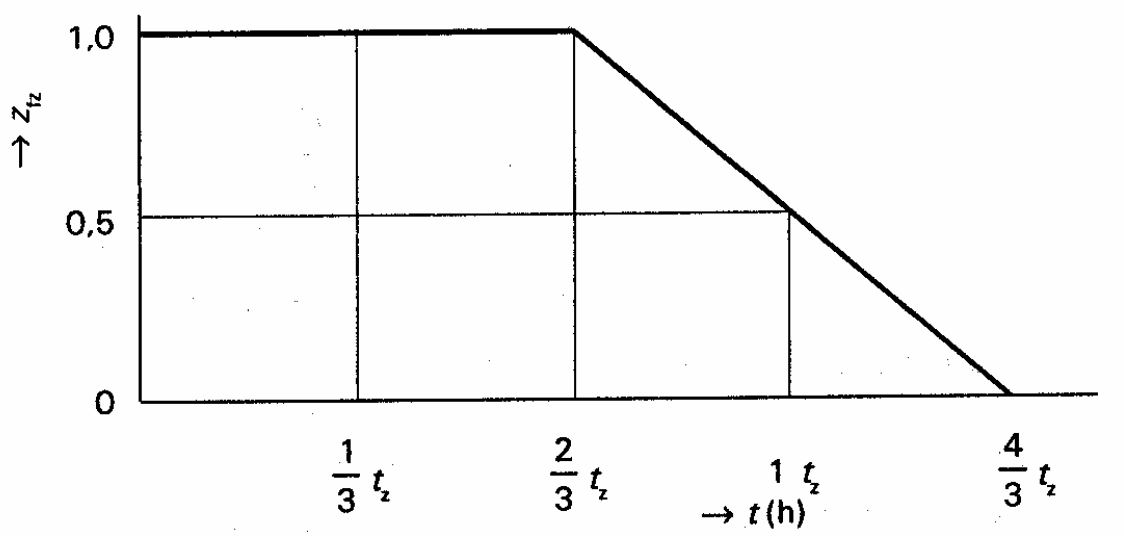
Dirtiness	Environment				
	very clean "vč"	clean "č"	average "p"	dirty "š"	very dirty "vš"
Rising in the environment	none	low production	apparent	high production	very high production
Transport form surrounding	none	scarcely any	low	high	very high
Level cleaning (filtration)	excellent	very good	average	low	none
Dirtiness adhesion	none	low	average (significant after long period)	high (significant in short period)	very high
Example	operating room, laboratory,	office, studio, classroom, residential rooms,	restaurant, gymnasium, light industry	heavy industry, paintshop, room with solid fuel boiler	the same as previous – lights are placed in the space of direct pollution

C) Room surface fouling z_{po}
This factor defines the illumination decrease due to the reflectance of room surfaces drop. Use minimum time period 2 years.



D) Light source reliability z_{fz}
basically two cases:

- defective light source immediately changed $z_{fz} = 1{,}0$
- defective light source changed only for entire light fitting $z_{fz} \leq 1{,}0$



t_z light source lifetime