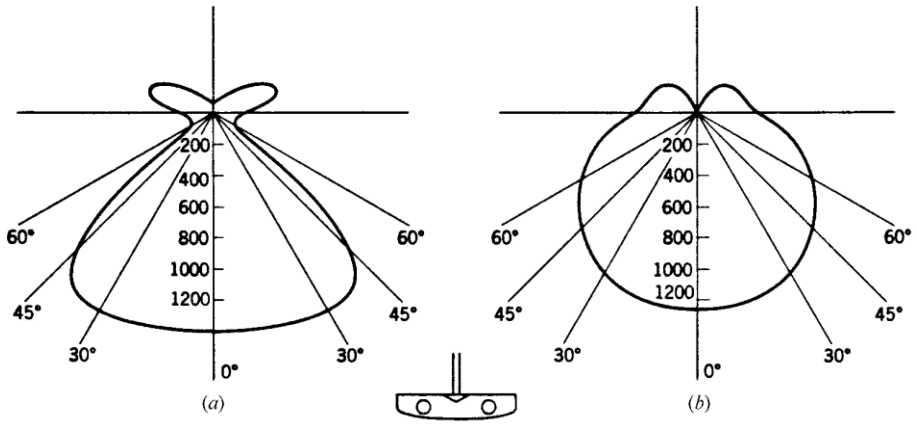
Electrical lighting design

Chapter 15 in your text book

LIGHTING FIXTURE (Luminaire) DISTRIBUTION



- ***Uniformity of illumination*** *(*intensity at angles above the nadir (0º from the vertical) be greater than the intensity at 0º 15.1a.

Therefore, such fixtures can be spaced more widely than the units of Fig. 15.1b

- ***High efficiency*** *(* directing the luminaries output to the work plane (i.e., from 0º to 45º from the vertical). Light above 45º is directed to the walls
- **Diffuseness exists** when light reaches the work plane from multiple directions. This requires that light be reflected from walls and ceilings to the work plane, which in turn requires luminaire light output above 45º from the vertical.
- ***Direct glare*** *(*above 45º from the vertical) glare from linear fluorescent fixtures can be minimized by placing the long axis parallel to the line of sight

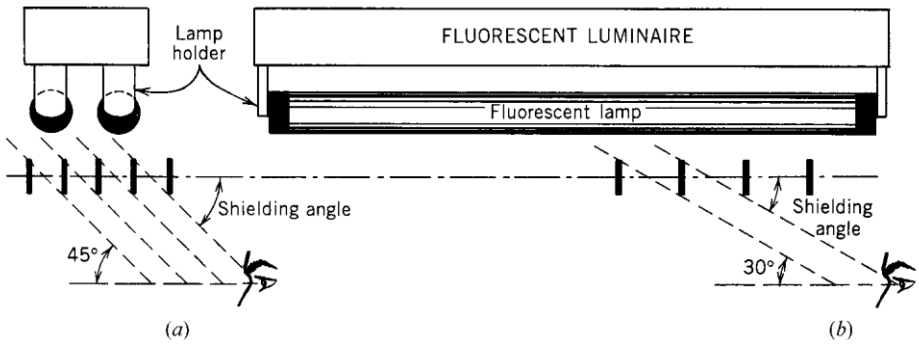
LUMINAIRE LIGHT CONTROL

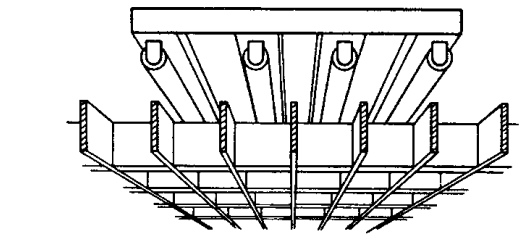
- **Lamp Shielding**
- **Reflectors**

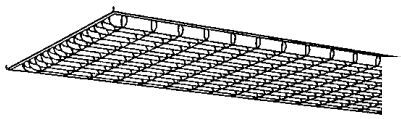
(Reflector Materials)

- **Diffusers**

- ***Shielding*** is a function of the shape of the fixture housing plus any additional lamp concealment means, such as louvers or baffles. The shielding angle is defined as the angle between a horizontal plane through the louvers or baffles and the inclined plane at which the lamp first becomes visible as one approaches the fixture

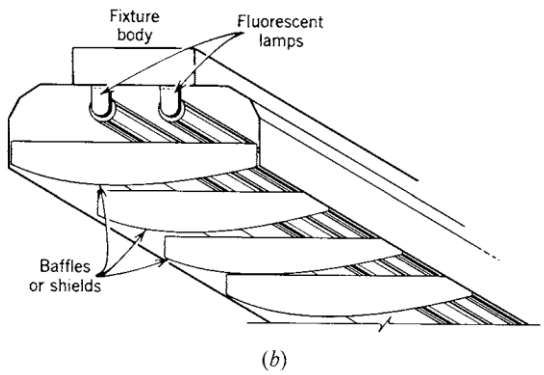




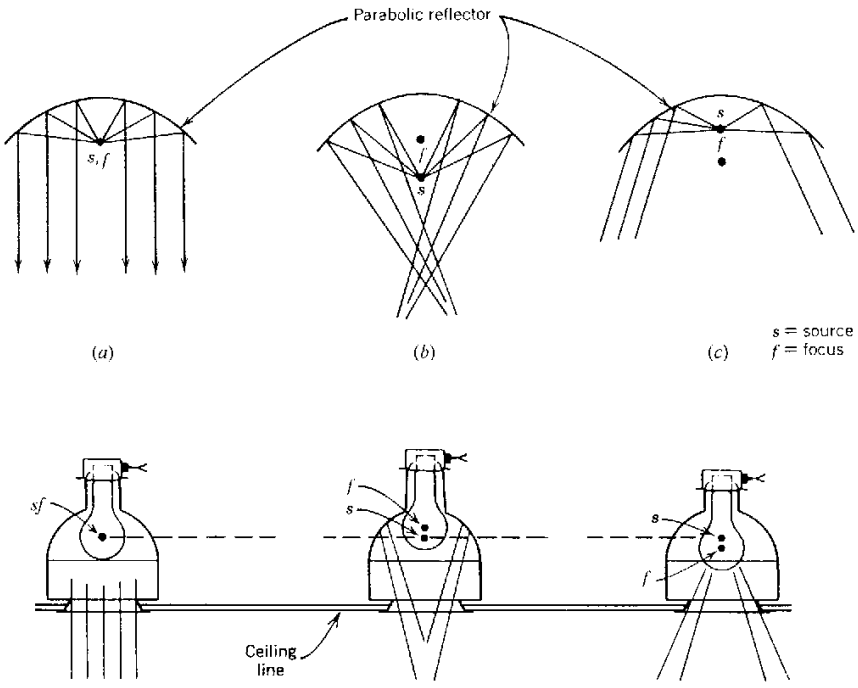


(c)

bare lamps are so bright that they usually constitute a source of direct or even disabling glare



(b)



- Approximately 40% of a lamp's output in an open luminaire is directed downward and is therefore completely independent of any reflector action.

- The difference in reflectance between a new, clean, painted surface and an old, dirty surface is, *at most, 50%. That means that the maximum* light loss of an open fixture due to poor maintenance is 50% of 60% (the maximum reflected light component), or 30% of the overall light output.

- The maximum reflectance of the best (and most expensive) silver reflectors is about 95%, comprising 93% specular and 2% diffuse.

- Simple cleaning of a very dirty fixture body restores 20% to 25% of the light loss. The remaining loss is due to aging of the paint.

Reflectors material

1. white gloss paint for portions of fixture body interiors that acted as reflectors,
2. and formed anodized aluminum sheet

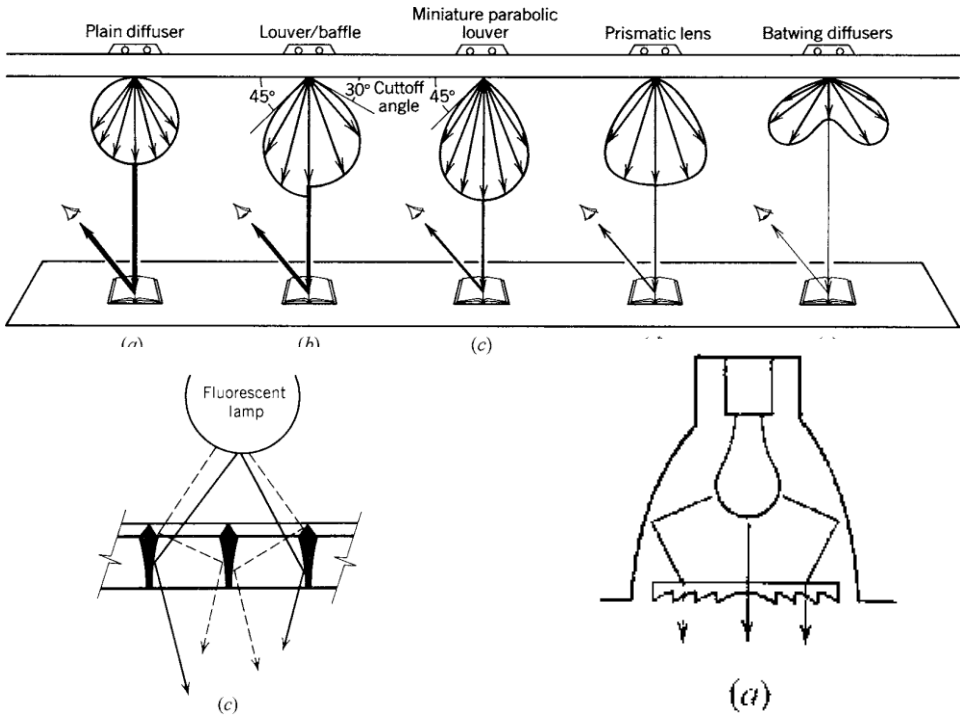
The reflectance (reflection factors) of both of these materials are approximately the same, varying between 0.84 and 0.88 *when new and clean*

3. silver reflectors is about 95%

LUMINAIRE DIFFUSERS (page 635-638)

Diffusers are the devices placed between the lamp(s) and the illuminated space, that function to diffuse the light, control fixture brightness, redirect the light, and obscure (hide) and shield the lamps.

- **Translucent Diffusers**
- **Louvers and Baffles**
- **Prismatic Lens**
- **Batwing Diffusers**

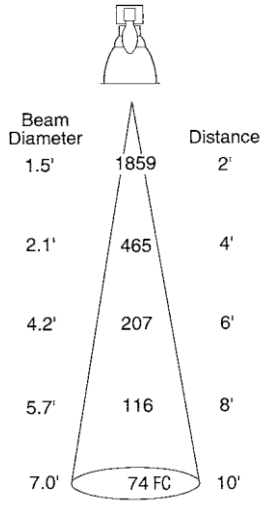


UNIFORMITY OF ILLUMINATION

- it is necessary to establish a fixture spacing that gives acceptable uniformity of illumination.
- A ratio of maximum to minimum illuminance on the working plane of 1:1.3 is readily acceptable because lesser ratios are not easily noticed.
- For general background or circulation lighting, a ratio of up to 1.5 is acceptable

LUMINAIRE MOUNTING HEIGHT (S/MH)

Spacing / mounting height (from luminaries to the working plane)



Illuminance calculations – lumen method

Once a luminaire has been selected on the basis of the foregoing criteria, it remains only to calculate the number of such fixtures required in each space, for uniform *general illuminance, and to arrange* them properly

the lumen (lighting flux) method of *average illuminance calculation is replete* with assumptions and estimates. Among these are:

1. It is assumed that the space is empty. This is not normally the case.
2. It is assumed that all surfaces are perfect diffusers. This is not the case.
3. All surfaces reflectance are estimates,
4. Maintenance conditions are estimates, at best
5. And Users effects

Electric lighting Design Methods

Step 1: Illuminance criterion

Orientation and simple visual tasks. Visual performance is largely unimportant. These tasks are found in public spaces where reading and visual inspection are only occasionally performed. Higher levels are recommended for tasks where visual performance is occasionally important.		
A	Public spaces	30 lx (3 fc)
B	Simple orientation for short visits	50 lx (5 fc)
C	Working spaces where simple visual tasks are performed	100 lx (10 fc)
Common visual tasks. Visual performance is important. These tasks are found in commercial, industrial, and residential applications. Recommended illuminance levels differ because of characteristics of the visual task being illuminated. Higher levels are recommended for visual tasks with critical elements of low contrast or small size.		
D	Performance of visual tasks of high contrast and large size	300 lx (30 fc)
E	Performance of visual tasks of high contrast and small size, or visual tasks of low contrast and large size	500 lx (50 fc)
F	Performance of visual tasks of low contrast and small size	1000 lx (100 fc)
Special visual tasks. Visual performance is of critical importance. These tasks are very specialized, including those with very small or very low contrast critical elements. Recommended illuminance levels should be achieved with supplementary task lighting. Higher recommended levels are often achieved with supplementary task lighting. Higher recommended levels are often achieved by moving the light source closer to the task.		
G	Performance of visual tasks near threshold	3000 to 10,000 lx (300 to 1000 fc)

*Expected accuracy in illuminance calculations should be checked with formulas in the *IESNA Lighting Handbook*. To account for both uncertainty in photometric measurements and uncertainty in space reflections, measured illuminances should be within 10% of the recommended value. It should be noted, however, that the final illuminance may deviate from the recommended values due to the other lighting design criteria.

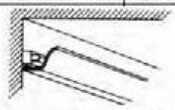
ILLUMINANCE ON TASK (LUX)					
			Illuminance Categories		
Average of Workers' Ages	**Demand for Speed and/or Accuracy[1, c]**	**Task Background[2] Reflectance (%)**	**D**	**E**	**F**
Under 40	NI	Over 70	300	500	1000
		30–70	300	500	1000
		Under 30	400	750	1500
	I	Over 70	300	500	1000
		30–70	400	750	1500
		Under 30	400	750	1500
	C	Over 70	400	750	1500
		30–70	400	750	1500
		Under 30	400	750	1500
40–55	NI	Over 70	300	500	1000
		30–70	400	750	1500
		Under 30	400	750	1500
	I	Over 70	400	750	1500
		30–70	400	750	1500
		Under 30	400	750	1500
	C	Over 70	400	750	1500
		30–70	400	750	1500
		Under 30	600	1000	2000
Over 55	NI	Over 70	400	750	1500
		30–70	400	750	1500
		Under 30	400	750	1500
	I	Over 70	400	750	1500
		30–70	400	750	1500
		Under 30	600	1000	2000
	C	Over 70	400	750	1500
		30–70	600	1000	2000
		Under 30	600	1000	2000

Step 2: Luminaire Selection

Example: class room

1. Low direct glare because schoolchildren spend a large proportion of their time in a heads-up position.
2. Low veiling reflections because much of the seeing task involves high-reflectance materials, occasionally specular.
3. High efficiency and low energy use to meet ANSI/ASHRAE/IESNA Standard 90.1 and most governmental requirements.
4. Minimum required maintenance in view of the poor cleaning and maintenance situation that exists in many schools.

Table: 15.1 page 640

Typical Luminaire	Typical Distribution and Percent Lamp Lumens	Maintenance Category	Maximum S/MH	RCR	ρcc: → 80			70			50			0	
					ρw: → 50	30	10	50	30	10	50	30	10	0	
					Coefficients of Utilization for 20% Effective Floor Cavity Reflectance (ρfc = 20)										
50  Single-row fluorescent lamp cove without reflector (multiply by 0.93 for two rows and by 0.85 for three rows)				1	.42	.40	.39	.36	.35	.33	.25	.24	.23	Coves are not recommended for lighting areas having low reflectances	
				2	.37	.34	.32	.32	.29	.27	.22	.20	.19		
				3	.32	.29	.26	.28	.25	.23	.19	.17	.16		
				4	.29	.25	.22	.25	.22	.19	.17	.15	.13		
				5	.25	.21	.18	.22	.19	.16	.15	.13	.11		
				6	.23	.19	.16	.20	.16	.14	.14	.12	.10		
				7	.20	.17	.14	.17	.14	.12	.12	.10	.09		
				8	.18	.15	.12	.16	.13	.10	.11	.09	.08		
				9	.17	.13	.10	.15	.11	.09	.10	.08	.07		
															ρcc = 10%
															ρw = 50 30 10
53 ρcc from below ~45%  Louvered ceiling. Ceiling efficiency ~50; 45° shielding opaque louvers of 80% reflectance. Cavity with minimum obstructions and painted with 80% reflectance paint—use ρcc = 50.				1							.51	.49	.48	.47	.46 .45
				2							.46	.44	.42	.43	.42 .40
				3							.42	.39	.37	.39	.38 .36
				4							.38	.35	.33	.36	.34 .32
				5							.35	.32	.29	.33	.31 .29
				6							.32	.29	.26	.30	.28 .26
				7							.29	.26	.23	.28	.25 .23
				8							.27	.23	.21	.26	.23 .21
				9							.24	.21	.19	.24	.21 .19
				10							.22	.19	.17	.22	.19 .17

Source: Data extracted from *IES Lighting Handbook Reference Volume*, (1981): with permission.

Notes:
1. Refer to the manufacturer's catalog data for more precise values when a specific luminaire type is proposed for use.
2. Multiply coefficients by 1.05 for three lamps and by 1.1 for two lamps.

Step 3: Calculation

E = Lumens/area

(N) Luminaries lumen = (n) lamps * lamb lumens

If you have two fixtures each one has three lamps each lamp has 2000 lumen

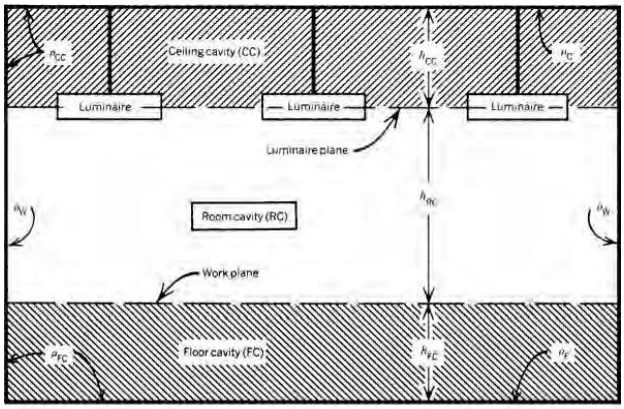
Then the overall lumen in the room is ?

E = Lumens/area

E = lumens * Coefficient of utilization (CU) / Area

E = lumens * (CU) Coefficient of utilization **/ Area**

Room Cavity ratio



Legend:
ρ_C = ceiling reflectance
ρ_{CC} = ceiling cavity reflectance
ρ_W = wall reflectance
ρ_F = floor reflectance
ρ_{FC} = floor cavity reflectance
h = height in feet or meters
h_{RC} = height of room cavity

Room cavity ratio

$$RCR = 5h_{RC}\frac{l+w}{l\times w} \qquad (15.8)$$

Ceiling cavity ratio

$$CCR = 5h_{CC}\frac{l+w}{l\times w} \qquad (15.9)$$

Floor cavity ratio

$$FCR = 5h_{FC}\frac{l+w}{l\times w} \qquad (15.10)$$

L : room length w : Room width

TABLE 15.2 Percent Effective Ceiling or Floor Cavity Reflectance (ρ_{cc}, ρ_{fc}) for Various Reflectance Combinations

Percent Ceiling ρ_c or Floor Reflectance ρ_f:		90				80				70			50			30				10		
Percent Wall Reflectance ρ_w:		90	70	50	30	80	70	50	30	70	50	30	70	50	30	65	50	30	10	50	30	10
Ceiling or Floor Cavity Ratios—CCR or FCR	0	90	90	90	90	80	80	80	80	70	70	70	50	50	50	30	30	30	30	10	10	10
	0.2	89	88	86	85	79	78	77	76	68	67	66	49	48	47	30	29	29	28	10	10	9
	0.4	88	86	83	81	78	76	74	72	67	65	63	48	46	45	30	29	27	26	11	10	9
	0.6	88	84	80	76	77	75	71	68	65	62	59	47	45	43	29	28	26	25	11	10	9
	0.8	87	82	77	73	75	73	69	65	64	60	56	47	43	41	29	27	25	23	11	10	8
	1.0	86	80	74	69	74	71	66	61	63	58	53	46	42	39	29	27	24	22	11	9	8
	1.2	86	78	72	65	73	70	64	58	61	56	50	45	41	37	29	26	23	20	12	9	7
	1.4	85	77	69	62	72	68	62	55	60	54	48	45	40	35	28	26	22	19	12	9	7
	1.6	85	75	66	59	71	67	60	53	59	52	45	44	39	33	28	25	21	18	12	9	7
	1.8	84	73	64	56	70	65	58	50	57	50	43	43	37	32	28	25	21	17	12	9	6
	2.0	83	72	62	53	69	64	56	48	56	48	41	43	37	30	28	24	20	16	12	9	6
	2.2	83	70	60	51	68	63	54	45	55	46	39	42	36	29	28	24	19	15	13	9	6
	2.4	82	68	58	48	67	61	52	43	54	45	37	42	35	27	28	24	19	14	13	9	6
	2.6	82	67	56	46	66	60	50	41	53	43	35	41	34	26	27	23	18	13	13	9	5
	2.8	81	66	54	44	66	59	48	39	52	42	33	41	33	25	27	23	18	13	13	9	5
	3.0	81	64	52	42	65	58	47	38	51	40	32	40	32	24	27	22	17	12	13	8	5
	3.5	79	61	48	37	63	55	43	33	48	38	29	39	30	22	26	22	16	11	13	8	5
	4.0	78	58	44	33	61	52	40	30	46	35	26	38	29	20	26	21	15	9	13	8	4
	4.5	77	55	41	30	59	50	37	27	45	33	24	37	27	19	25	20	14	8	14	8	4
	5.0	76	53	38	27	57	48	35	25	43	32	22	36	26	17	25	19	13	7	14	8	4

Source: Extracted from the *IESNA Lighting Handbook* (1993); reprinted with permission. For more complete data, see the current *IESNA Lighting Handbook*.

TABLE 15.3 CU Factors for Effective Floor Cavity Reflectances Other Than 20% (Any Wall Reflectance)[a]

For 30% effective floor cavity reflectance, *multiply* standard CU value by the appropriate factor from the following table. For 10% effective floor cavity reflectance, *divide* standard CU value by the appropriate factor from the following table.

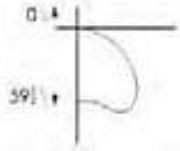
Room Cavity Ratio	Percent Effective Ceiling Cavity Reflectance, ρ_{cc}			
	80	70	50	10
1	1.08	1.06	1.04	1.01
2	1.06	1.05	1.03	1.01
3	1.04	1.04	1.03	1.01
4	1.03	1.03	1.02	1.01
5	1.03	1.02	1.02	1.01
6	1.02	1.02	1.02	1.01
7	1.02	1.02	1.01	1.01
8	1.02	1.02	1.01	1.01
9	1.01	1.01	1.01	1.01
10	1.01	1.01	1.01	1.01

Source: Extracted from the *IESNA Lighting Handbook* (1993); reprinted with permission.

[a]For more precise data, for varying ρ_w, see the current *IESNA Lighting Handbook*.

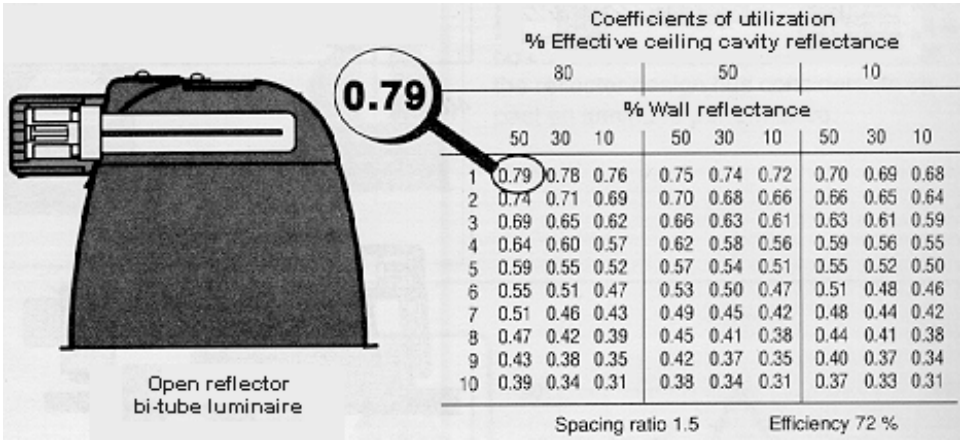
Percent Ceiling ρ_c or Floor Reflectance ρ_F:		90				80				70			50			30			10		
Percent Wall Reflectance ρ_w:		90	70	50	30	80	70	50	30	70	50	30	70	50	30	65	50	30	10	50	30	10
Ceiling or Floor Cavity Ratios—CCR or FCR	0	90	90	90	90	80	80	80	80	70	70	70	50	50	50	30	30	30	30	10	10	10
	0.2	89	88	86	85	79	78	77	76	68	67	66	49	48	47	30	29	29	28	10	10	9
	0.4	88	86	83	81	78	76	74	72	67	65	63	48	46	45	30	29	27	26	11	10	9
	0.6	88	84	80	76	77	75	71	68	65	62	59	47	45	43	29	28	26	25	11	10	9
	0.8	87	82	77	73	75	73	69	65	64	60	56	47	43	41	29	27	25	23	11	10	8
	1.0	86	80	74	69	74	71	66	61	63	58	53	46	42	39	29	27	24	22	11	9	8
	1.2	86	78	72	65	73	70	64	58	61	56	50	45	41	37	29	26	23	20	12	9	7
	1.4	85	77	69	62	72	68	62	55	60	54	48	45	40	35	28	26	22	19	12	9	7
	1.6	85	75	66	59	71	67	60	53	59	52	45	44	39	33	28	25	21	18	12	9	7
	1.8	84	73	64	56	70	65	58	50	57	50	43	43	37	32	28	25	21	17	12	9	6
	2.0	83	72	62	53	69	64	56	48	56	48	41	43	37	30	28	24	20	16	12	9	6
	2.2	83	70	60	51	68	63	54	45	55	46	39	42	36	29	28	24	19	15	13	9	6
	2.4	82	68	58	48	67	61	52	43	54	45	37	42	35	27	28	24	19	14	13	9	6
	2.6	82	67	56	46	66	60	50	41	53	43	35	41	34	26	27	23	18	13	13	9	5
	2.8	81	66	54	44	66	59	48	39	52	42	33	41	33	25	27	23	18	13	13	9	5
	3.0	81	64	52	42	65	58	47	38	51	40	32	40	32	24	27	22	17	12	13	8	5
	3.5	79	61	48	37	63	55	43	33	48	38	29	39	30	22	26	22	16	11	13	8	5
	4.0	78	58	44	33	61	52	40	30	46	35	26	38	29	20	26	21	15	9	13	8	4
	4.5	77	55	41	30	59	50	37	27	45	33	24	37	27	19	25	20	14	8	14	8	4
	5.0	76	53	38	27	57	48	35	25	43	32	22	36	26	17	25	19	13	7	14	8	4

Typical Luminaire	Typical Distribution and Percent Lamp Lumens	Maintenance Category	Maximum S/MH	RCR	ρ_{cc}: → 80			70			50			0
					ρ_w: → 50	30	10	50	30	10	50	30	10	0
					Coefficients of Utilization for 20% Effective Floor Cavity Reflectance (ρ_{fc} = 20)									
1 Pendant diffusing sphere with incandescent lamp	5% 45%	V	1.5	0	.87	.87	.87	.81	.81	.81	.69	.69	.69	.44
				1	.71	.67	.63	.66	.62	.59	.56	.53	.50	.31
				2	.61	.54	.49	.56	.50	.46	.47	.43	.39	.23
				3	.52	.45	.39	.48	.42	.37	.41	.36	.31	.18
				4	.46	.38	.33	.42	.36	.30	.36	.30	.26	.15
				5	.40	.33	.27	.37	.30	.25	.32	.26	.22	.12
				6	.36	.28	.23	.33	.26	.21	.28	.23	.19	.10
				7	.32	.25	.20	.29	.23	.18	.25	.20	.16	.09
				8	.29	.22	.17	.27	.20	.16	.23	.17	.14	.07
				9	.26	.19	.15	.24	.18	.14	.20	.15	.12	.06
3 Porcelain-enameled ventilated standard dome with incandescent lamp	10% 85%	IV	1.3	0	.99	.99	.99	.97	.97	.97	.92	.93	.93	.83
				1	.88	.85	.82	.86	.83	.81	.83	.80	.78	.72
				2	.78	.73	.68	.76	.72	.67	.73	.69	.66	.61
				3	.69	.62	.57	.67	.61	.57	.65	.60	.56	.52
				4	.61	.54	.49	.60	.53	.48	.58	.52	.48	.45
				5	.54	.47	.41	.53	.46	.41	.51	.45	.41	.38
				6	.48	.41	.35	.47	.40	.35	.46	.39	.35	.32
				7	.43	.35	.30	.42	.35	.30	.41	.34	.30	.28
				8	.38	.31	.26	.38	.31	.26	.37	.30	.26	.24
				9	.35	.28	.23	.34	.27	.23	.33	.27	.23	.21
7 EAR-36 lamp above 51-mm (2 in.)-diameter aperture (increase efficiency to 54½% for 76-mm (3 in.)-diameter aperture)	0% 43½%	IV	0.7	0	.52	.52	.52	.51	.51	.51	.48	.48	.48	.44
				1	.49	.48	.48	.48	.48	.47	.47	.46	.46	.42
				2	.47	.46	.45	.46	.45	.44	.45	.44	.43	.41
				3	.45	.44	.43	.45	.43	.42	.44	.42	.42	.40
				4	.43	.42	.41	.43	.41	.40	.42	.41	.40	.38
				5	.42	.40	.39	.41	.40	.38	.41	.39	.38	.37
				6	.40	.39	.37	.40	.38	.37	.39	.38	.37	.36
				7	.39	.37	.36	.39	.37	.36	.38	.37	.35	.35
				8	.37	.36	.34	.37	.35	.34	.37	.35	.34	.33
				9	.36	.34	.33	.36	.34	.33	.35	.34	.33	.32
18 "High-bay" wide distribution ventilated reflector with clear HID lamp	77½%	III	1.5	0	.93	.93	.93	.91	.91	.91	.87	.87	.87	.78
				1	.85	.82	.80	.83	.81	.79	.79	.78	.76	.70
				2	.77	.73	.70	.76	.72	.69	.73	.70	.67	.63
				3	.70	.65	.61	.68	.64	.60	.66	.62	.59	.56
				4	.63	.58	.53	.62	.57	.53	.60	.56	.52	.49
				5	.57	.51	.47	.56	.51	.47	.55	.50	.46	.44
				6	.51	.45	.41	.51	.45	.41	.49	.44	.40	.38
				7	.46	.40	.35	.45	.39	.35	.44	.39	.35	.33
				8	.41	.35	.31	.41	.35	.31	.40	.34	.31	.29
				9	.37	.31	.27	.37	.31	.27	.36	.30	.27	.25

Typical Distribution and Percent Lamp Lumens			ρcc →	80			70		
			ρw →	50	30	10	50	30	10
Maintenance Category	Maximum S/MH		RCR	Coefficients of Utilization for 20% Ef (ρcc = 2					
47  Radial batwing distribution—four-lamp, 610-mm (2-ft)-wide fluorescent unit with flat prismatic lens—see note 2	V	1.7	0	.71	.71	.71	.69	.69	.69
			1	.62	.60	.58	.61	.59	.57
			2	.55	.51	.47	.53	.50	.47
			3	.48	.43	.39	.47	.43	.39
			4	.42	.37	.33	.41	.37	.33
			5	.37	.32	.27	.36	.31	.27
			6	.33	.27	.23	.32	.27	.23
			7	.29	.24	.20	.29	.24	.20
			8	.28	.21	.17	.25	.20	.17
			9	.23	.18	.14	.23	.18	.14

$\rho_f = 0.2$

Coefficients of Utilization — Zonal Cavity Method																			
Effective floor cavity reflectance: 20%																			
RCC%		80				70				50			30			10			0
RW%		70	50	30	0	70	50	30	0	50	30	20	50	30	20	50	30	20	0
RCR	0	.95	.95	.95	.95	.93	.93	.93	.80	.89	.89	.89	.85	.85	.85	.82	.82	.82	.80
	1	.88	.84	.81	.78	.85	.82	.79	.69	.79	.76	.74	.76	.74	.72	.73	.71	.70	.68
	2	.80	.74	.69	.64	.78	.72	.68	.59	.70	.66	.62	.67	.64	.61	.65	.62	.59	.58
	3	.74	.66	.59	.54	.72	.64	.58	.51	.62	.57	.53	.60	.56	.52	.58	.54	.51	.49
	4	.68	.58	.52	.47	.66	.57	.51	.44	.55	.50	.46	.54	.49	.45	.52	.48	.44	.43
	5	.62	.52	.45	.40	.61	.52	.45	.39	.50	.44	.40	.48	.43	.39	.47	.42	.39	.37
	6	.58	.47	.40	.35	.56	.47	.40	.34	.45	.39	.35	.44	.39	.35	.43	.38	.34	.33
	7	.54	.43	.36	.31	.52	.42	.36	.31	.41	.35	.31	.40	.35	.31	.39	.34	.31	.29
	8	.50	.39	.33	.28	.49	.39	.32	.27	.38	.32	.28	.37	.31	.28	.36	.31	.28	.26
	9	.47	.36	.30	.25	.45	.36	.29	.25	.35	.29	.25	.34	.29	.25	.33	.28	.25	.23
	10	.44	.33	.27	.23	.43	.33	.27	.23	.32	.27	.23	.31	.26	.23	.31	.26	.23	.21



Coefficients of utilization
% Effective ceiling cavity reflectance

	80			50			10		
% Wall reflectance									
	50	30	10	50	30	10	50	30	10
1	0.79	0.78	0.76	0.75	0.74	0.72	0.70	0.69	0.68
2	0.74	0.71	0.69	0.70	0.68	0.66	0.66	0.65	0.64
3	0.69	0.65	0.62	0.66	0.63	0.61	0.63	0.61	0.59
4	0.64	0.60	0.57	0.62	0.58	0.56	0.59	0.56	0.55
5	0.59	0.55	0.52	0.57	0.54	0.51	0.55	0.52	0.50
6	0.55	0.51	0.47	0.53	0.50	0.47	0.51	0.48	0.46
7	0.51	0.46	0.43	0.49	0.45	0.42	0.48	0.44	0.42
8	0.47	0.42	0.39	0.45	0.41	0.38	0.44	0.41	0.38
9	0.43	0.38	0.35	0.42	0.37	0.35	0.40	0.37	0.34
10	0.39	0.34	0.31	0.38	0.34	0.31	0.37	0.33	0.31

Spacing ratio 1.5 Efficiency 72 %

E = lumens * CU * Light Loss Factor (LLF) / Area

A. **Luminaire Ambient Temperature (1)**
B. **Voltage (1)**
C. **Luminaire Surface Depreciation (LSD)** This factor is proportional to age and depends upon the type of surface involved
D. **Components** Losses due to components include ballast factor, ballast-lamp photometric factor, equipment operating factor, and lamp position (tilt) factor
E. **Room Surface Dirt (RSD)**

Direct lighting: $0.92 \pm 5\%$

Semi-direct lighting: $0.87 \pm 8\%$

Direct-indirect lighting: $0.82 \pm 10\%$

Semi-indirect lighting: $0.77 \pm 12\%$

Indirect lighting: $0.72 \pm 17\%$

F. Lamp Lumen Depreciation (LLD)

	Group Replacement	Replacement on Burnout
Incandescent	0.94	0.88
Tungsten-halogen	0.98	0.94
Fluorescent	0.90	0.85
Mercury-vapor	0.82	0.74
Metal-halide	0.87	0.80
High-pressure sodium	0.94	0.88

G. Burnouts

Group replacement procedures: 1.0

Individual replacement on burnout: 0.95

H. Luminaire Dirt Depreciation (LDD)

depends upon luminaire design, atmosphere conditions in the space, and maintenance schedule. The luminaire maintenance category is obtained from the manufacturer's data

- Very clean = 0.95
- Clean = 0.85
- Dirty = 0.75
- Very dirty = 0.5

LLF = A*B*C*D*E*F*G*H

LLF = LSD * RSD * LLD * LDD

Example Calculations.

- hCC = 1.0 m
- hRC = 1.95 m
- hFC = 0.75 m
- l = 8 m
- w = 6 m
- ρC = 80%
- ρw = 50%
- ρF = 20%