Lighting Math

NOT SO SCARY LIGHTING MATH

Methods to Calculate Light

Point-by-Point

- Direct Illumination from a Fixture or Lamp
  - You need….
    - Photometry
    - Distances from Fixture or Lamp

Lumen Method

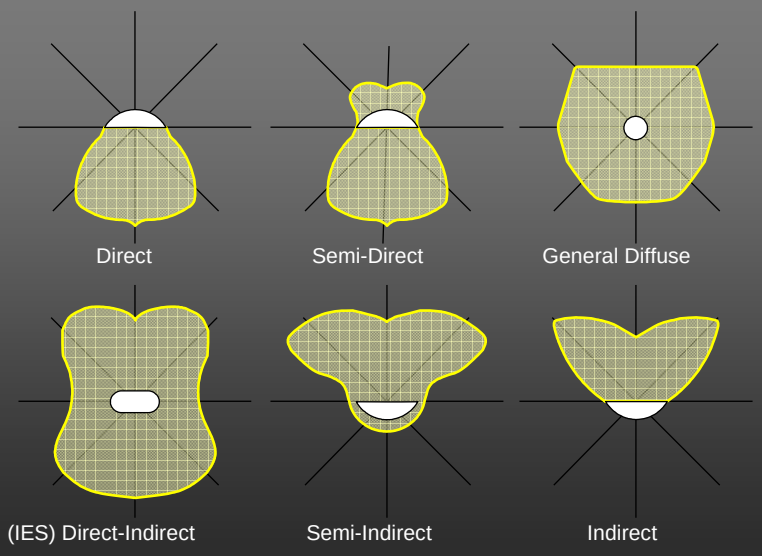
- Average Light Level in a Room from a Fixture
  - You need….
    - Photometry
    - Room Dimensions and Surface Reflectance's

Lighting Math

Direction of Light

- Goal of a luminaire is to put light where the user needs it
- Convenient way to classify luminaires is by the *direction* of light emitted from the luminaire
- Commission Internationale de l'Eclairage (CIE) sets up these classifications

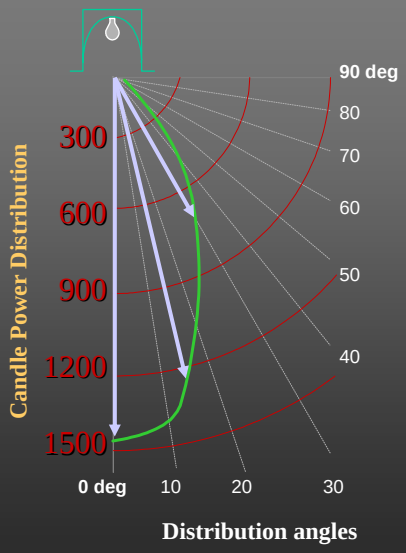
CIE Luminaire Types / Distributions



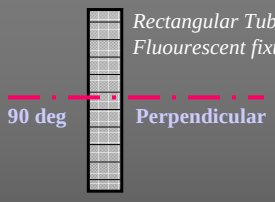
Lighting Math

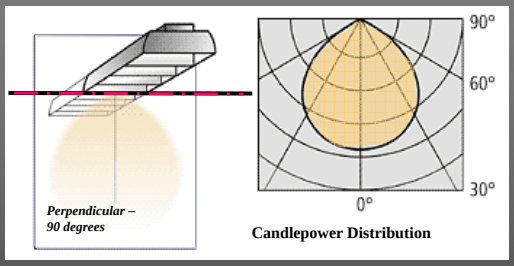
Candlepower Distribution Curve

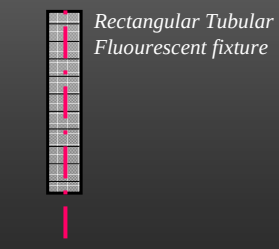
- **Candlepower distribution curves** provides intuitive information on how a **luminaire** will perform
- **Candela** values are used in calculations to predict light levels

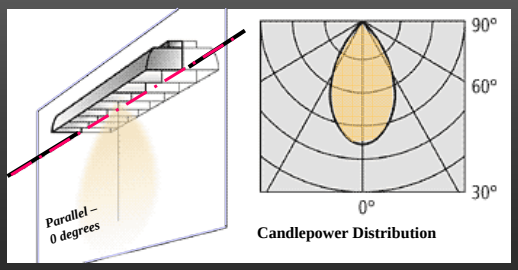


Asymmetrical Distribution Curve





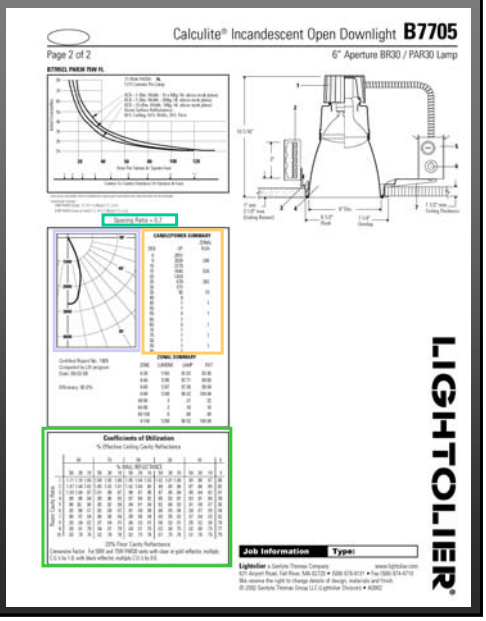




Lighting Math

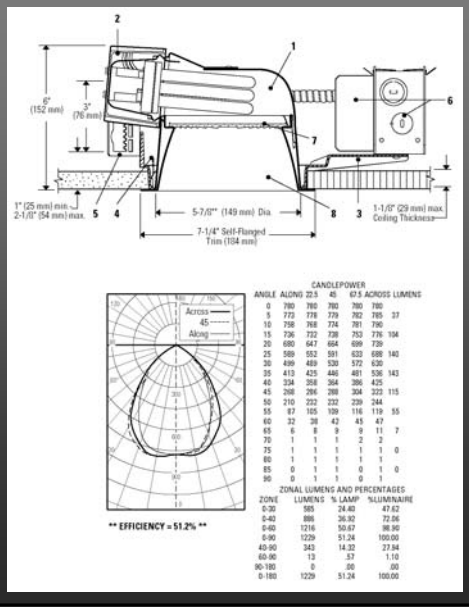
Photometry Reports

- Plot of candlepower values
- Summary of candlepower values in different planes
- Fixture Efficiency
- Lumen Summary
- Luminance summary
- Spacing criteria (SC) or Spacing/Mounting Height (S/MH) for uniformity
- Coefficient of Utilization Table
- Guides



Photometry Reports

- Lensed Downlight



Lighting Math

Photometry Reports

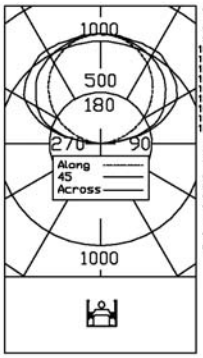
- Indirect Pendant

PHOTOMETRIC REPORT

FAR-FIELD PHOTOMETRY

REPORT NUMBER: 5395 DATE: 10-9-2001

CATALOG NUMBER: LL1-010000-T5HO
LUMINAIRE: 2 3/4"W X 2 1/2"H RECTANGULAR ALUMINUM INDIRECT LIGHT WITH WHITE PAINTED AND HAMMERTONE REFLECTOR
LAMP(S): FP54/835/HO RATED @ 5000 LUMENS
BALLAST: QT 1X54/120PHO
MOUNTING:
LUMEN TO CANDELA RATIO USED = 9.15
TOTAL INPUT WATTS = 60.9 AT 12.0 VOLTS
THE 0 DEGREE PLANE IS PARALLEL WITH THE LAMPS.



CANDELA DISTRIBUTION

	0.0	22.5	45.0	67.5	90.0	FLUX
90	0	0	0	0	0	
95	21	104	98	88	85	103
105	188	335	436	478	489	416
115	379	506	646	733	751	505
125	558	650	787	871	907	577
135	717	773	880	951	976	597
145	852	881	954	1022	1043	598
155	955	986	1004	1045	1058	484
165	1028	1028	1040	1052	1060	295
175	1067	1068	1067	1072	1072	102
180	1077	1077	1077	1077	1077	

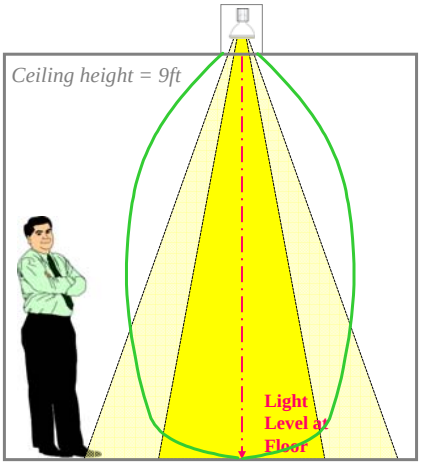
ZONAL LUMEN SUMMARY

ZONE	LUMENS	%LAMP	%FIXT
0- 90	0	0.0	0.0
90-120	1124	22.5	28.7
90-130	1801	36.0	45.9
90-150	3063	61.3	78.1
90-180	3924	78.5	100.0
0-180	3924	78.5	100.0

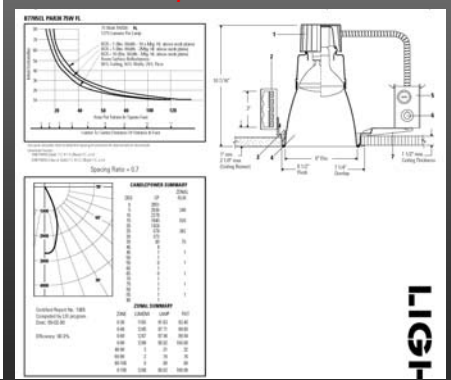
TOTAL LUMINAIRE EFFICIENCY = 78.5 %
CIE TYPE = INDIRECT

Point-by-Point

$$\text{Foot-candle} = \frac{\text{Candle Power}}{\text{Distance}^2}$$



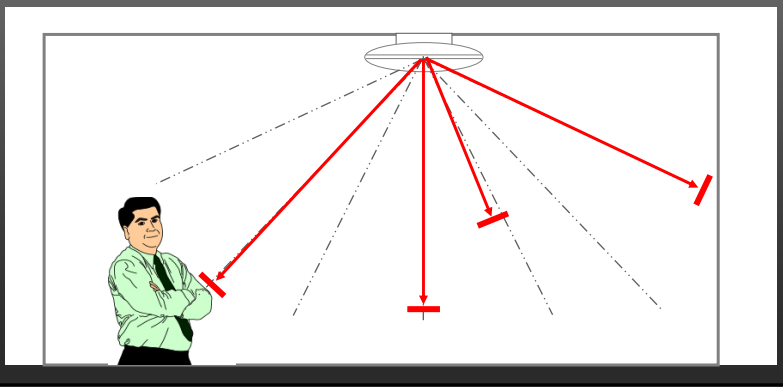
FC = 2651*candelas* / 9*ft*²
FC = 2651 / 81
FC = 32.7 *foot-candles*



Lighting Math

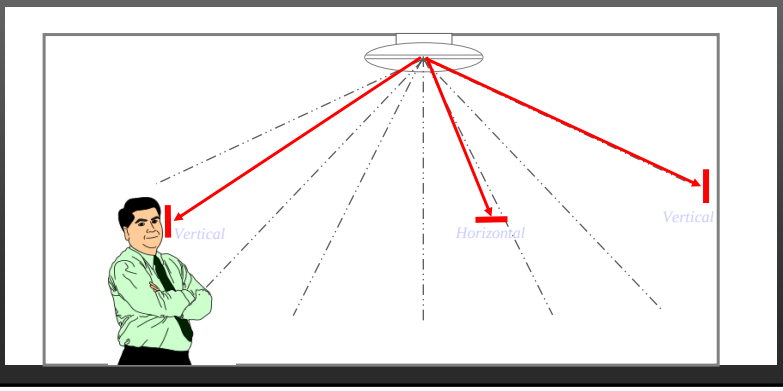
Point-by-Point Factors

- Calculated Levels are Facing the Light Fixture
  - *With the exception of directly below*



Point-by-Point Factors

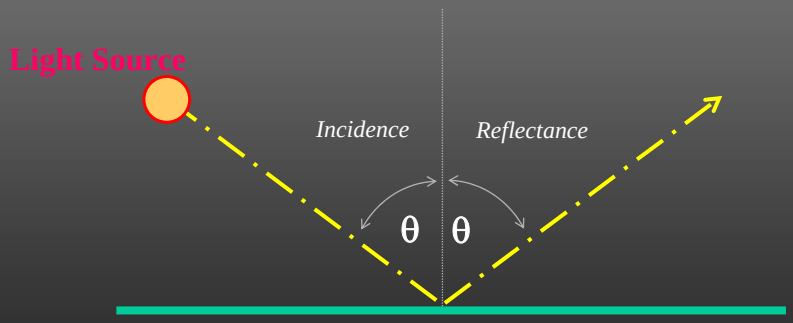
- You need to factor an adjustment if you want levels at other angles (IE Horizontal, Vertical Angles)
  - **COSINE Adjusted!!**



Lighting Math

COSINE Adjustments

$$\text{Foot-candle} = \frac{\text{Candle Power}}{\text{Distance}^2} \times \text{COS(Angle of Incidence)}$$



Point-by-Point Factors

- Calculated Levels are Initial.
- You need to factor an adjustment for Light Loss
  - Light Loss Factors to Consider
    - Dirt
    - Lamp Depreciation
    - Environment

$$\textbf{Foot-candle} = \frac{\textbf{Candle Power}}{\textbf{Distance}^2} \times \textbf{COS(Angle)} \times \textbf{MF}$$

Lighting Math

Methods to Calculate Light

Point-by-Point

- Direct Illumination from a Fixture or Lamp
  - You need….
    - Photometry
    - Distances from Fixture or Lamp

Lumen Method

- Average Light Level in a Room from a Fixture
  - You need….
    - Photometry
    - Room Dimensions and Surface Reflectance's

Calculations using Lumens

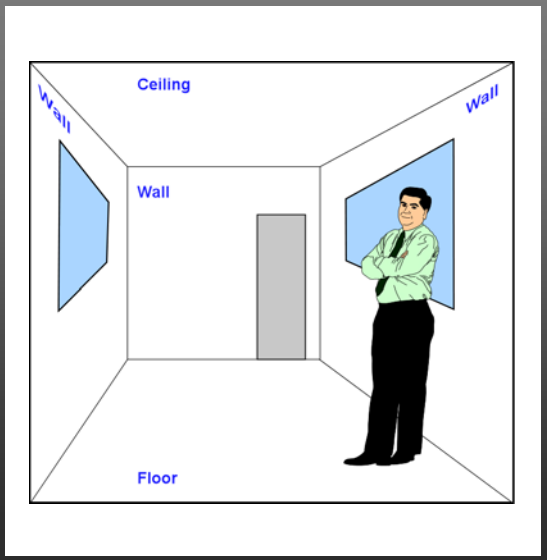
- **Lumen** is an amount of ENERGY
- **Candela** is an amount of INTESITY
- Lumen Method Calculation
  - ***Calculates the Average Illumination for a room.***
  - ***Takes into account the room surface reflectance's – but assumes the surfaces are diffuse (not shiny!).***
  - ***Assumes an empty room (without furniture).***
  - ***Can also be used to determine the required Quantity of Fixtures needed for a target light level.***
  - ***Does not determine light fixture layout or location – you must following mnfrs spacing criteria.***

Lighting Math

Lumen Method Steps

1. You need Room Dimensions and the Fixture Mounting Height.
2. You need to select a Light fixture
3. Determine the rooms Room Cavity Ratio (RCR).
4. Look-up the fixtures Coefficient of Utilization for the RCR.
5. Calculate!

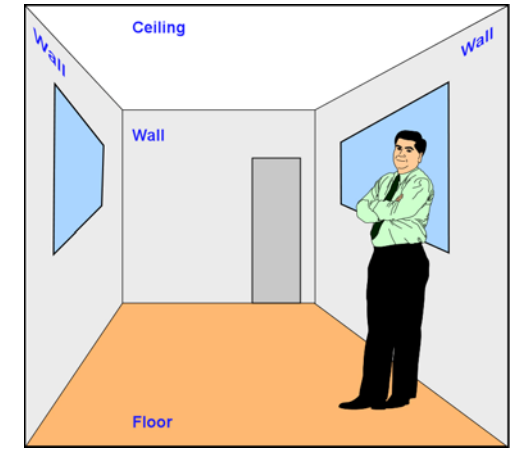
Room Reflectance



- Room comprised of Walls, Ceiling, and Floor.
- Walls typically have Doors and Windows
- All surfaces have a reflectance value to bounce light.
- Light from Light Fixture bounces off of all surfaces.

Lighting Math

Room Reflectance



- Surfaces with less reflectance will bounce less light
- Typical Reflectance Values:
  - **75%-90%** White, Off White, Grey, Light tints of Blue or Brown
  - **30%-60%** Medium Green, Yellow, Brown, or Grey
  - **10%-20%** Dark Grey, Medium Blue
  - **5%-10%** Dark Blue, Brown. Dark Green, and many wood finishes

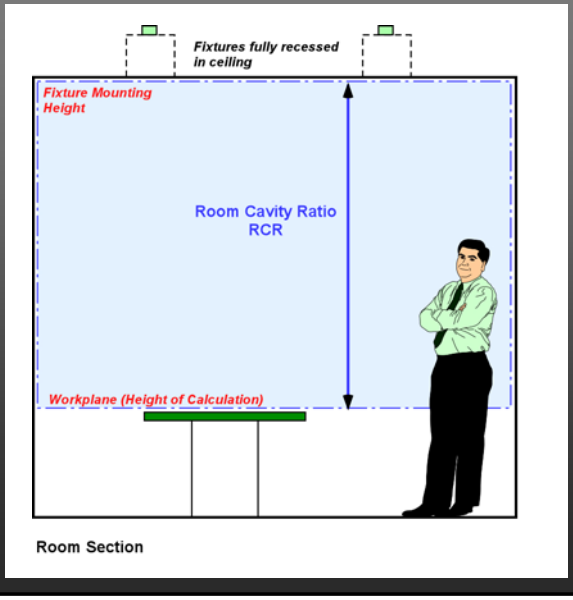
Room Reflectance

- Typical Commercial Values:
  - **80%** Ceiling
  - **50%** Wall
  - **20%** Floor
- Typical Industrial Values:
  - **50%** Ceiling
  - **30%** Wall
  - **20%** Floor

Lighting Math

Room Cavity Ratio

$$RCR = \frac{5xMHx(L+W)}{\text{Room Area}}$$

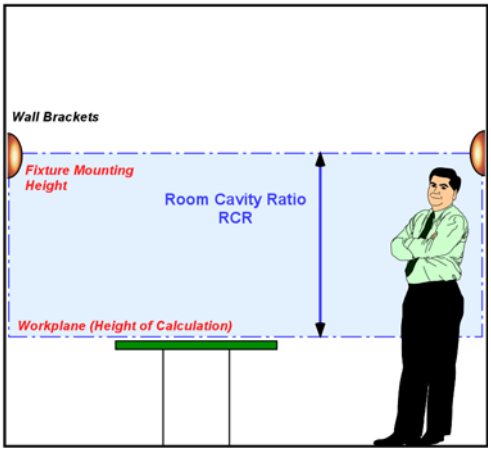


Room Section

- Room Cavity Ratio (aka **RCR**) is the volume between the **Fixture** and **Height of Calculation**
- Workplane height is typically 30-inches above the floor
- A rooms RCR will always be between 1 and 10

Room Cavity Ratio

$$RCR = \frac{5xMHx(L+W)}{\text{Room Area}}$$



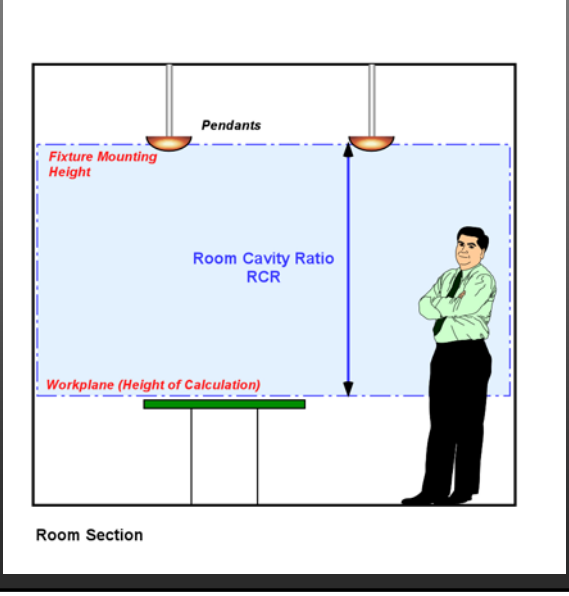
Room Section

- The **RCR** can vary depending on the height of the fixture….***as shown here with Wall Brackets or Sconces.***

Lighting Math

Room Cavity Ratio

$$RCR = \frac{5xMHx(L+W)}{\text{Room Area}}$$

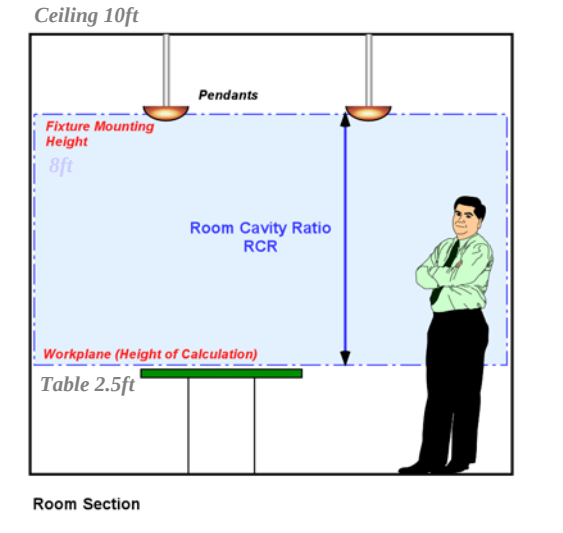


Room Section

- The RCR can vary depending on the height of the fixture….*as shown here with Pendants.*

Room Cavity Ratio

$$RCR = \frac{5xMHx(L+W)}{\text{Room Area}}$$



Room Section

Example:
Room Width: 12*ft*
Room Length: 15*ft*
Ceiling Height: 10*ft*

$$RCR = \frac{5(5.5)(12+15)}{(12x15)}$$

$$RCR = \frac{742.5}{180}$$

RCR = 4.1

Lighting Math

Lumen Method Formula

To Calculate Foot-candle level:

$$FC = \frac{\text{Qty of Fixtures x Number of Lamps per Fixture x Lumens per Lamp x CU}}{\text{Area of the Room}}$$

To Calculate number of Fixtures:

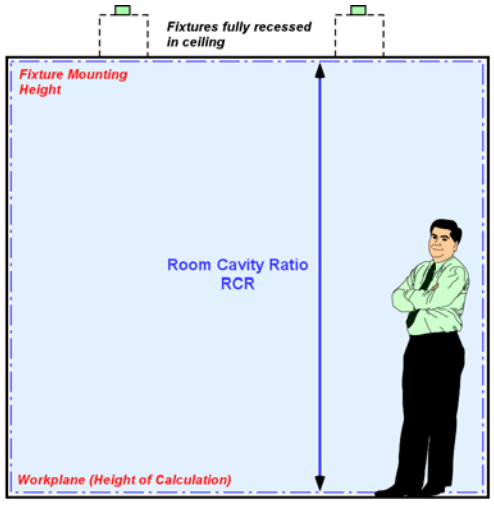
$$FC = \frac{\text{Total Lumens in the Room x CU}}{\text{Area of the Room}}$$

$$\text{Qty of Fixtures} = \frac{\text{FC x Area of the Room}}{\text{Number of Lamps per Fixture x Lumens per Lamp x CU}}$$

$$\text{Qty of Fixtures} = \frac{\text{FC x Area of the Room}}{\text{Total Lumens in the Room x CU}}$$

Room Cavity Ratio

$$RCR = \frac{5 \times MH \times (L+W)}{\text{Room Area}}$$

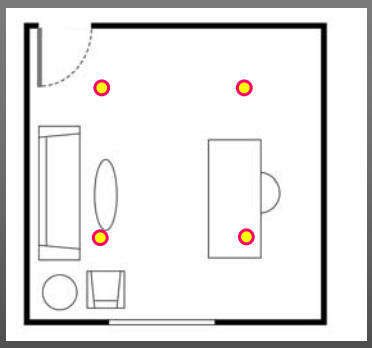


Room Section

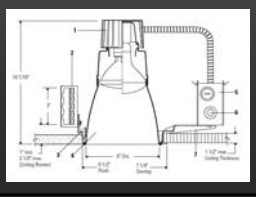
- The **RCR** can vary depending on the height you want to calculate…***as shown here with the calculation height at the floor.***

Lighting Math

Lumen Method Example 1



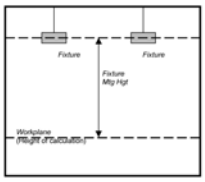
What is the resulting Foot-candle Level at table height from four downlights?



Lumen Method Calculation

Project: _____

Room/Area: _____



Room Cavity Ratio:

Room Width (W): _____

Room Length (L): _____

Fixture Mtg Height (MH): _____

RCR = 5 x (MH) x (L+W) / L x W

RCR = 5 x (____) x (____ + ____) / ____ x ____

RCR = _____

Irregular Room

RCR = 2.5(MH) x (Perimeter Length) / Area

Calculation:

Fixture Description: _____ CU: _____

Lamp: _____ Lamps per Fixture: _____ Lumens per Lamp: _____

FC = (Qty of Fixtures) x (Lumens per Lamp) x (# of Lamps per Fixture) x CU x MF / L x W

FC = (____) x (____) x (____) x (____) x (____) / (____) x (____)

FC = _____

Qty of Fixtures = FC x L x W / (Lumens per Lamp) x (# of Lamps per Fixture) x CU x MF

Qty of Fixtures = (____) x (____) x (____) / (____) x (____) x (____) x (____)

Qty of Fixtures = _____

MF = Maintenance Factors

Non-Recoverable

Recoverable

Lighting Math

Non-Recoverable Light Loss Factors

- Ballast Factor *(Fluourescent approx 90%)*
- Ambient Fixture Temperature
- Supply Voltage Variation *(Low Voltage approx 4%)*

Recoverable Light Loss Factors

- Lamp Burnouts *(approx 80%)*
- Lamp Lumen Depreciation *(Fluourescent approx 70%)*
- Fixture (Luminaire) Dirt Depreciation
  - *Indirect Lighting (approx 65%)*
  - *Industrial Environments (ranges from approx 50% to 80%)*
  - *Open Fixtures – Lamp exposed (approx 85%)*

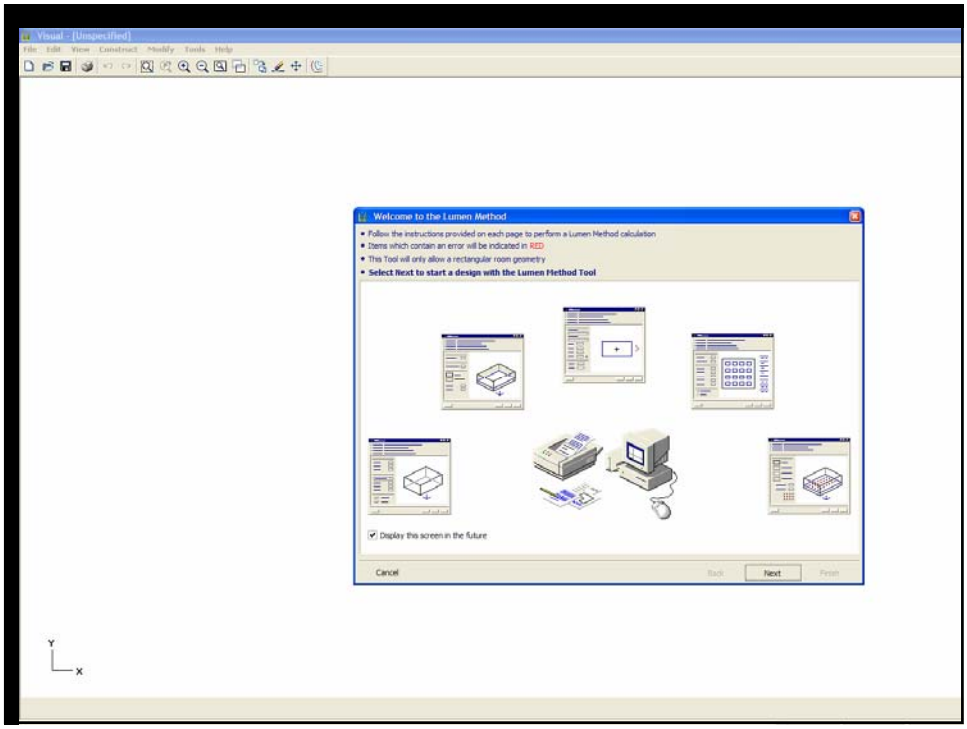
Lighting Math

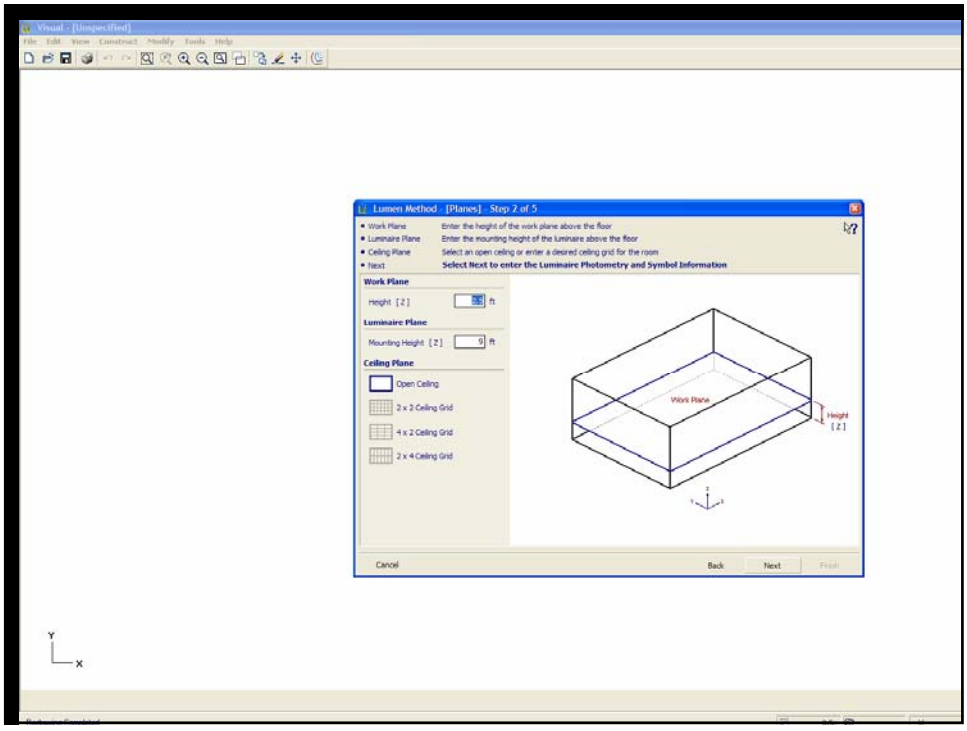
Multiply one factor against another and you get the…….

MF = LIGHT LOSS FACTOR!

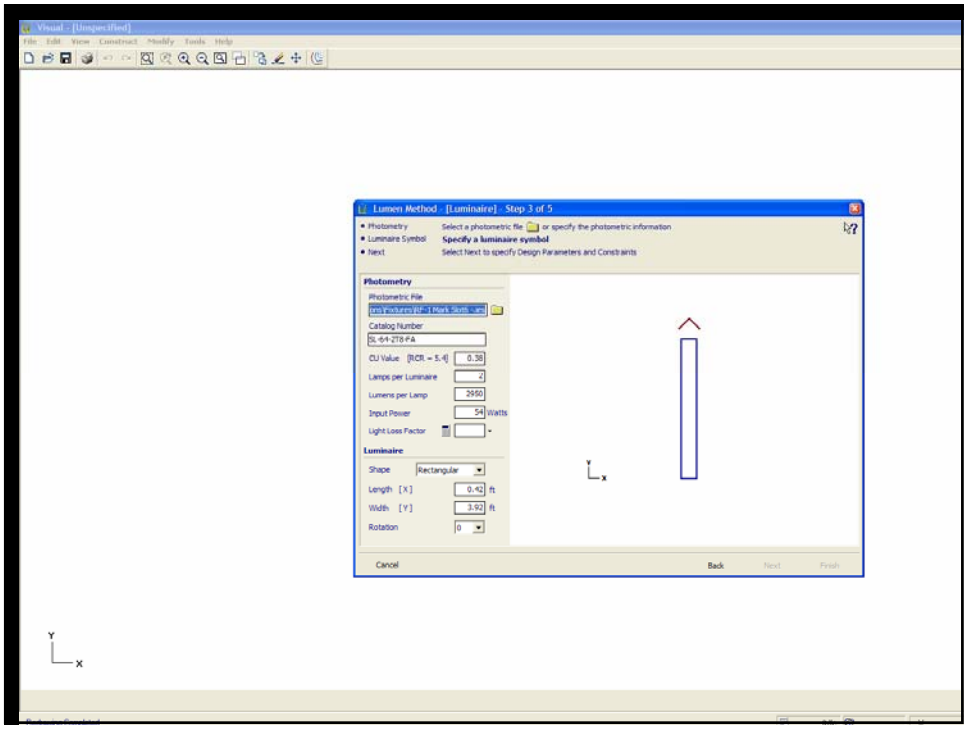
$$\text{Foot-candle} = \frac{\text{Candle Power}}{\text{Distance}^2} \times \text{COS(Angle)} \times \text{MF}$$

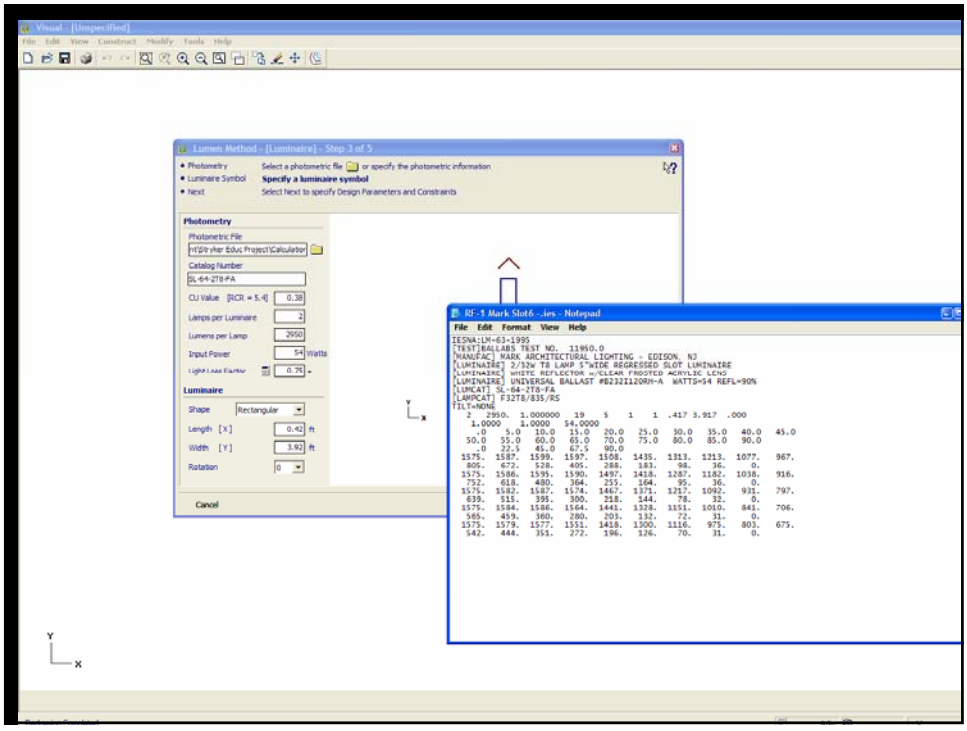
Lighting Math



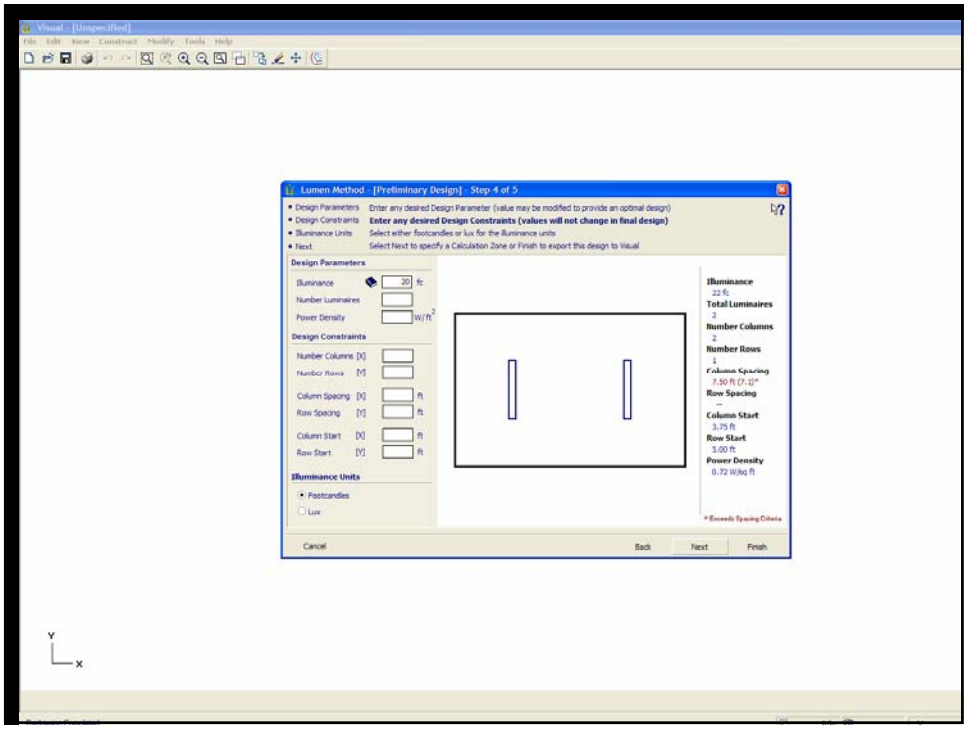


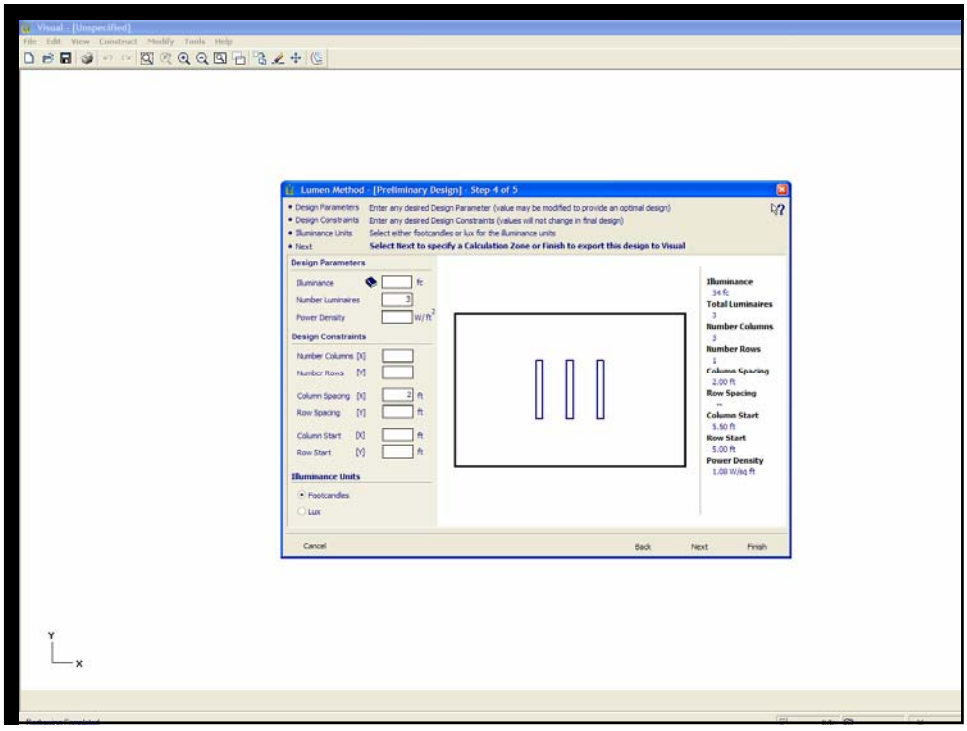
Lighting Math



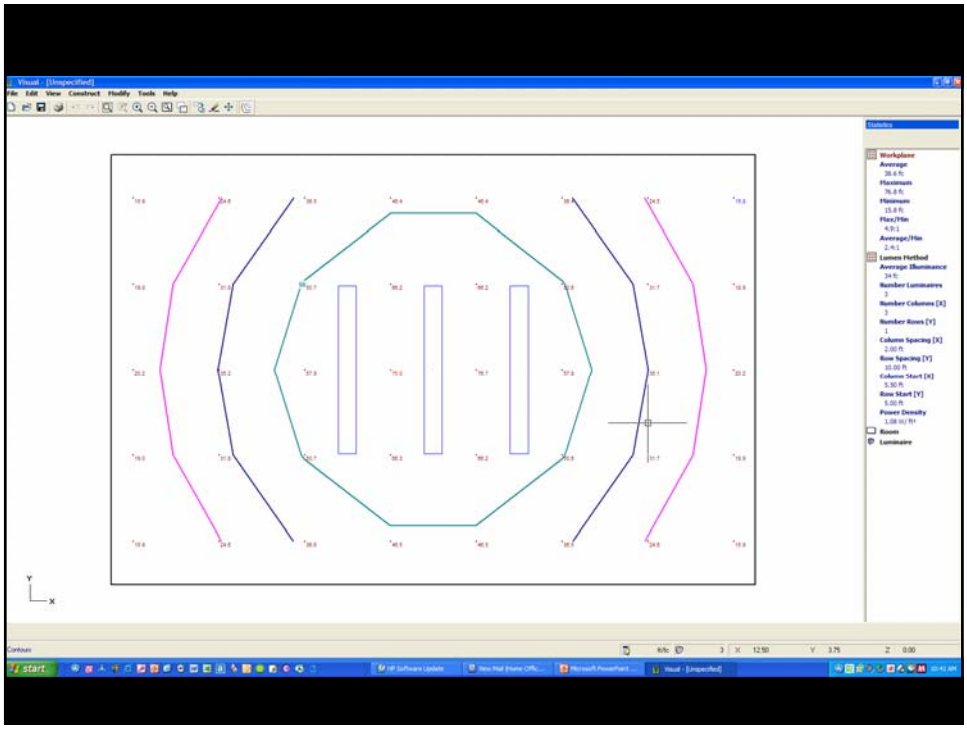


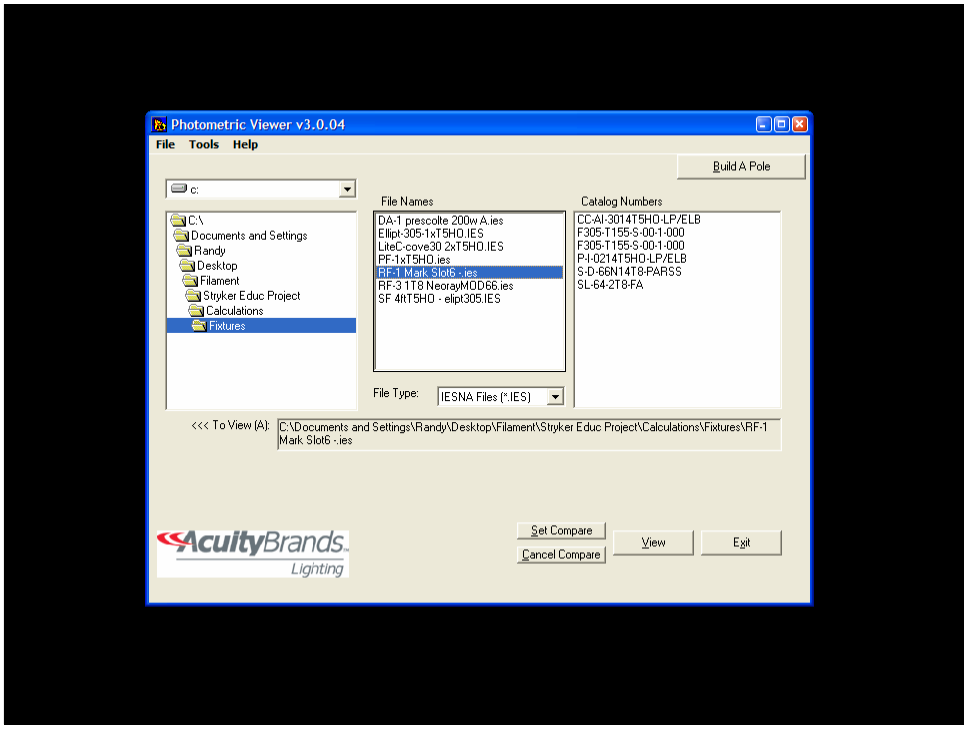
Lighting Math



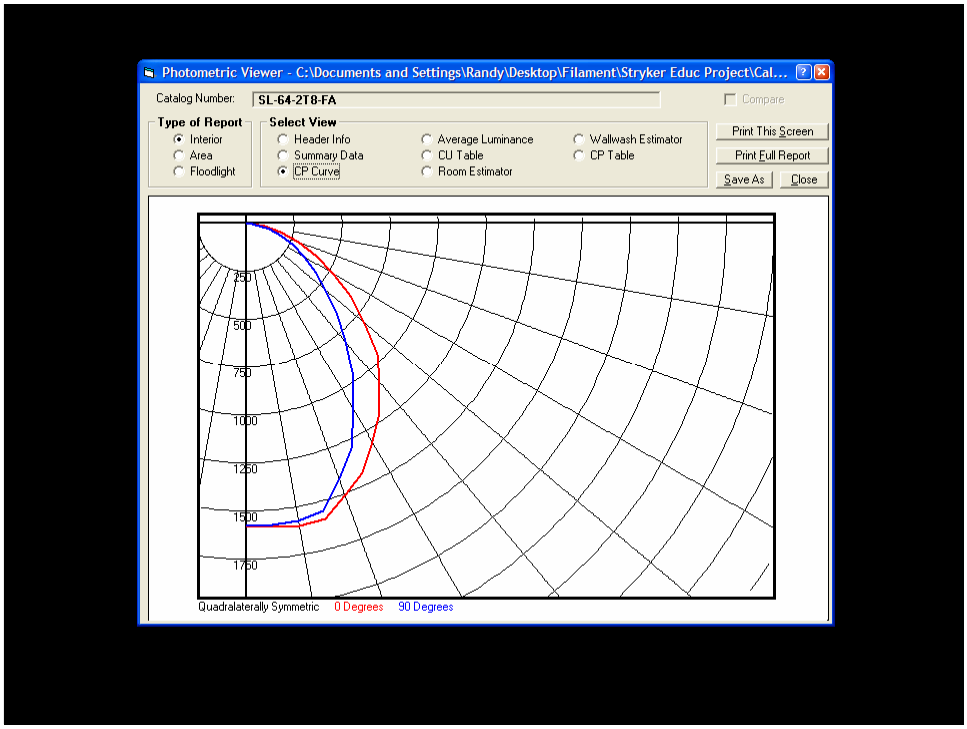


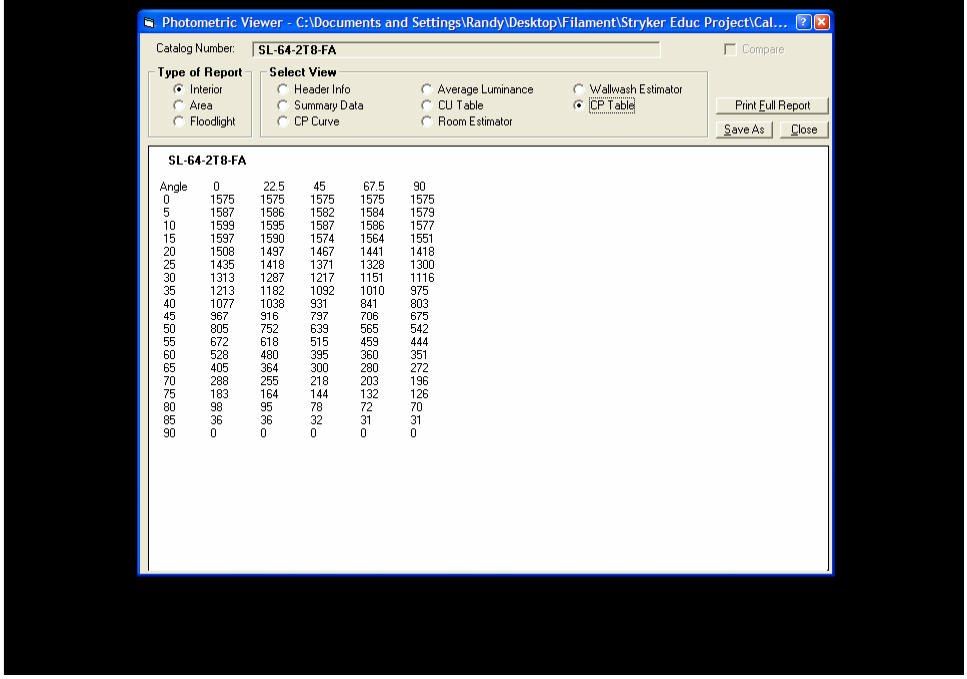
Lighting Math





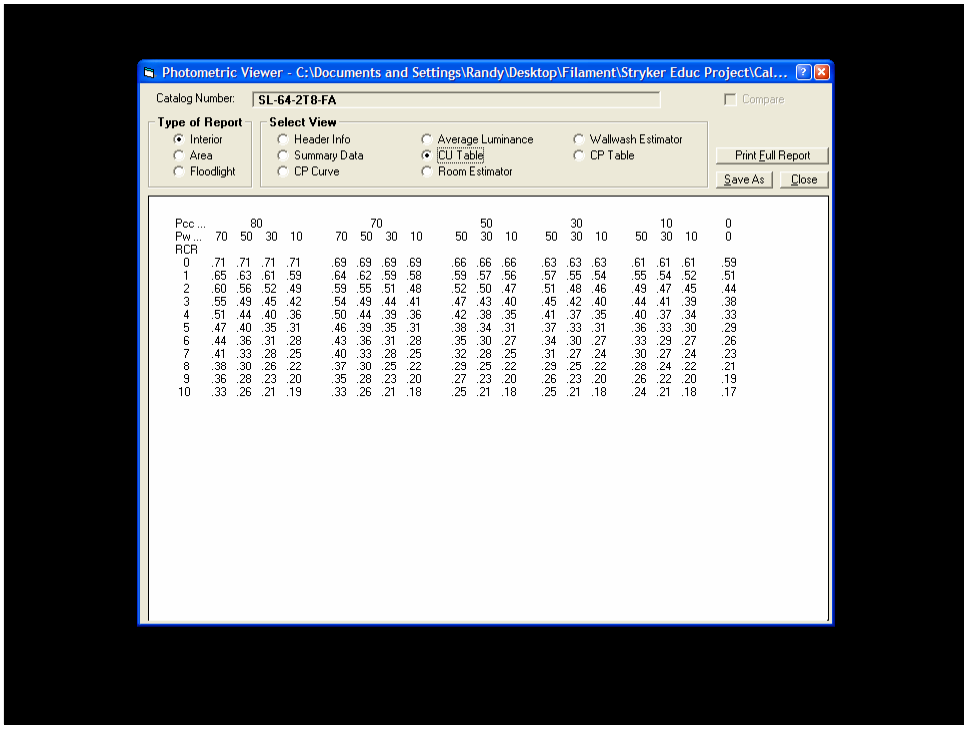
Lighting Math





Angle	0	22.5	45	67.5	90
0	1575	1575	1575	1575	1575
5	1587	1586	1582	1584	1579
10	1599	1595	1587	1586	1577
15	1597	1590	1574	1564	1551
20	1508	1497	1467	1441	1418
25	1435	1418	1371	1328	1300
30	1313	1287	1217	1151	1116
35	1213	1182	1092	1010	975
40	1077	1038	931	841	803
45	967	916	797	706	675
50	805	752	639	565	542
55	672	618	515	459	444
60	528	480	395	360	351
65	405	364	300	280	272
70	288	255	218	203	196
75	183	164	144	132	126
80	98	95	78	72	70
85	36	36	32	31	31
90	0	0	0	0	0

Lighting Math



Pcc ...	80				70				50			30			10		0
Pw ...	70	50	30	10	70	50	30	10	50	30	10	50	30	10	50	30	10	0
RCR																		
0	.71	.71	.71	.71	.69	.69	.69	.69	.66	.66	.66	.63	.63	.63	.61	.61	.61	.59
1	.65	.63	.61	.59	.64	.62	.59	.58	.59	.57	.56	.57	.55	.54	.55	.54	.52	.51
2	.60	.56	.52	.49	.59	.55	.51	.48	.52	.50	.47	.51	.48	.46	.49	.47	.45	.44
3	.55	.49	.45	.42	.54	.49	.44	.41	.47	.43	.40	.45	.42	.40	.44	.41	.39	.38
4	.51	.44	.40	.36	.50	.44	.39	.36	.42	.38	.35	.41	.37	.35	.40	.37	.34	.33
5	.47	.40	.35	.31	.46	.39	.35	.31	.38	.34	.31	.37	.33	.31	.36	.33	.30	.29
6	.44	.36	.31	.28	.43	.36	.31	.28	.35	.30	.27	.34	.30	.27	.33	.29	.27	.26
7	.41	.33	.28	.25	.40	.33	.28	.25	.32	.28	.25	.31	.27	.24	.30	.27	.24	.23
8	.38	.30	.26	.22	.37	.30	.25	.22	.29	.25	.22	.29	.25	.22	.28	.24	.22	.21
9	.36	.28	.23	.20	.35	.28	.23	.20	.27	.23	.20	.26	.23	.20	.26	.22	.20	.19
10	.33	.26	.21	.19	.33	.26	.21	.18	.25	.21	.18	.25	.21	.18	.24	.21	.18	.17