Lighting & Acoustic Desing of an Architecture Studio at İYTE

IZMIR INSTITUTE OF TECHOLOGY
2020-2021 FALL
AR381 BUILDING PHYSICS II

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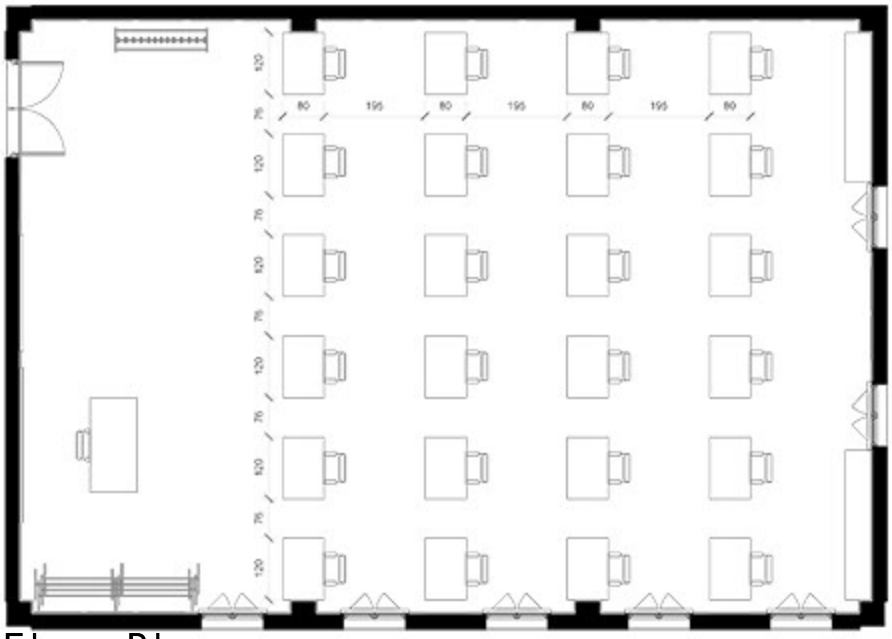


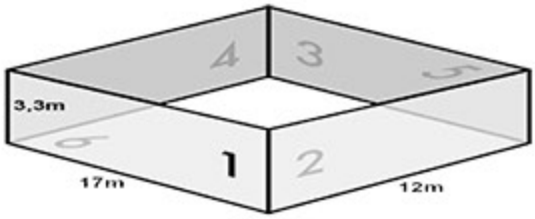
Floor Plan

Room Geometry	Rectangular
Room Lenght(m)	17,00
Room Width(m)	12,00
Room Height to Suspendend Ceiling(m)	3,30
Room Volume(m³)	673,20
Door Geometry	**Rectangular**
Door Width(m)	1,80
Door Height(m)	2,10
Door Area(m²)	3,78
Window Geometry	**Rectangular**
Window Width(m)	1,50
Window Height(m)	1,20
Window Area(m²)	1,80
Whiteboard Geometry	**Rectangular**
Whiteboard Width(m)	3,00
Whiteboard Height(m)	1,50
Whiteboard Area(m²)	4,50

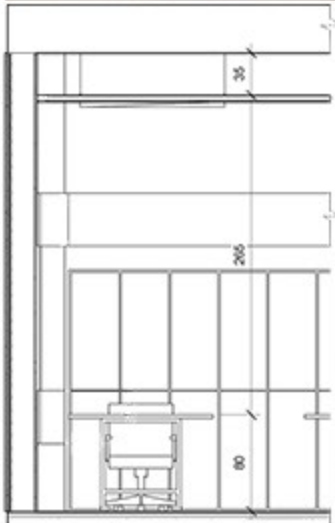
3D View 1

Total Wall Area(m²)	170,52
Total Ceiling Area(m²)	204,00
Total Floor Area(m²)	204,00
Total Door Area(m²)	3,78
Total Window Area(m²)	12,60
Total Whiteboard Area(m²)	4,50

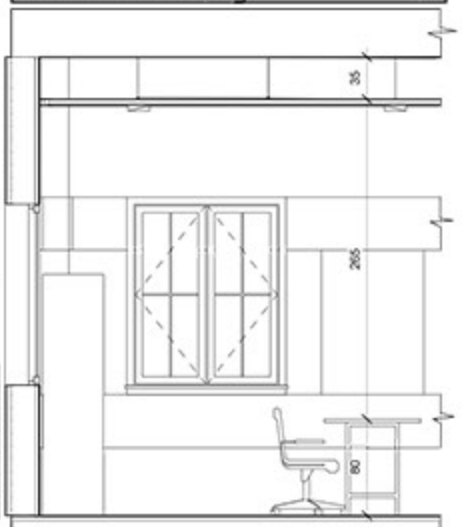
Room Geometry



NUMBER	
1	Has included nothing (just wall)
2	Has included one door and one whiteboard
3	Has included five window
4	Has included two window
5	Has included nothing (just ceiling)
6	Has included nothing (just floor)

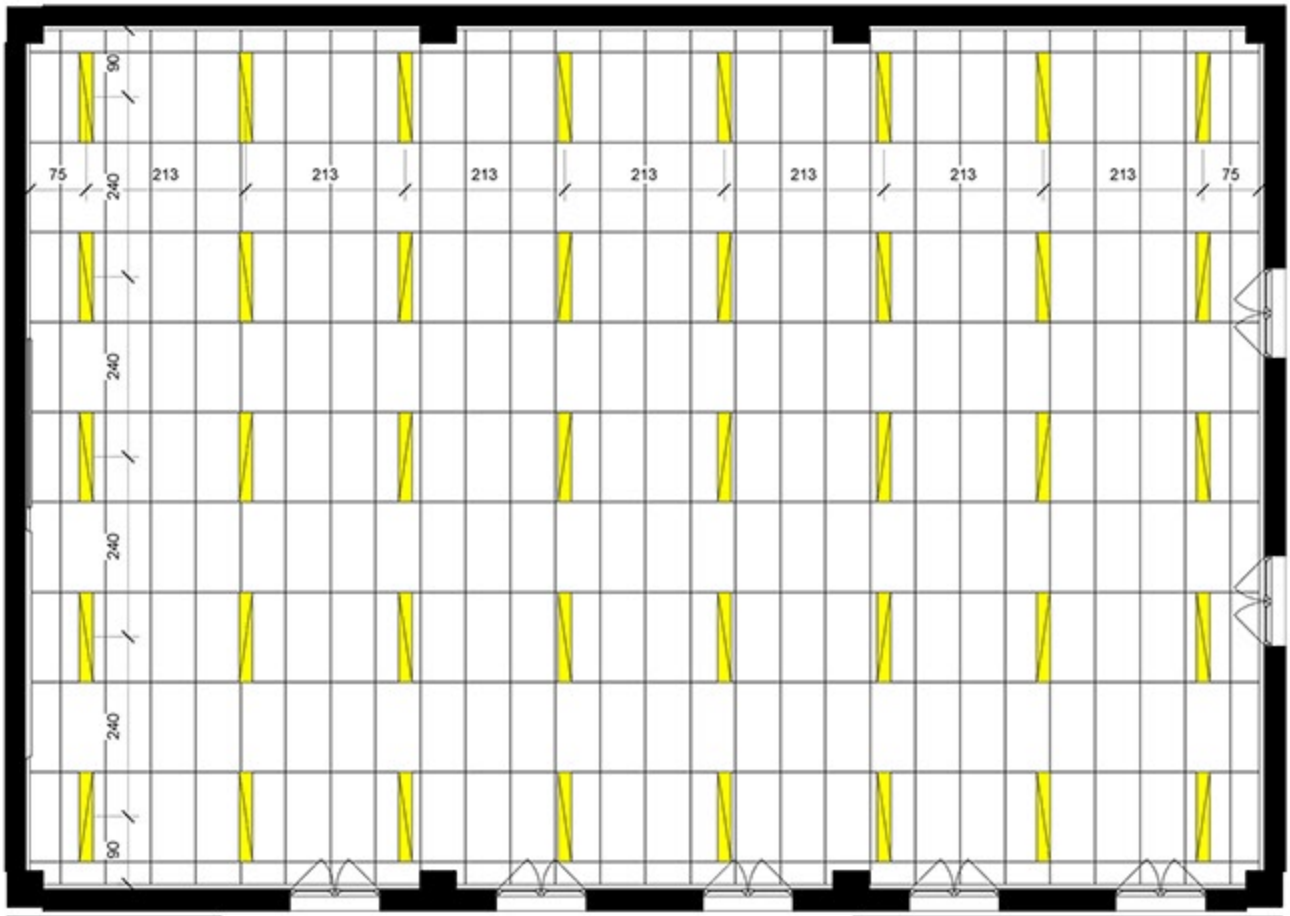


Wall 1 Section



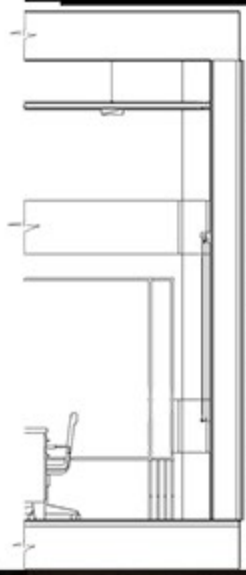
Wall 4 Section

Longitudunal Section

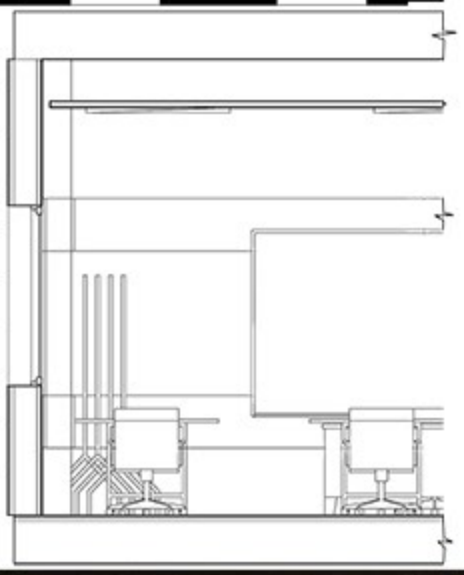


Ceeling Plan

SURFACE	MATERIAL	AREA(m²)
Wall-1	Acoustical plaster, approx. 25mm thick, 3.5 kg/m2/cm	64,60
Wall-2	Acoustical plaster, approx. 25mm thick, 3.5 kg/m2/cm	37,32
Wall-3	Acoustical plaster, approx. 25mm thick, 3.5 kg/m2/cm	55,60
Wall-4	Acoustical plaster, approx. 25mm thick, 3.5 kg/m2/cm	42,00
Wall-2	Whiteboard	4,50
Wall-2	Solid Wooden Door	3,78
Wall-3v4	Double Glazing, 2-3 mm glass, 10 mm gap	12,60
Floor	Marble Floor	175,20
Floor	Floor areas with Drawing Tables and chairs	28,80
Ceiling	Plasterboard Suspended Ceiling	204,00



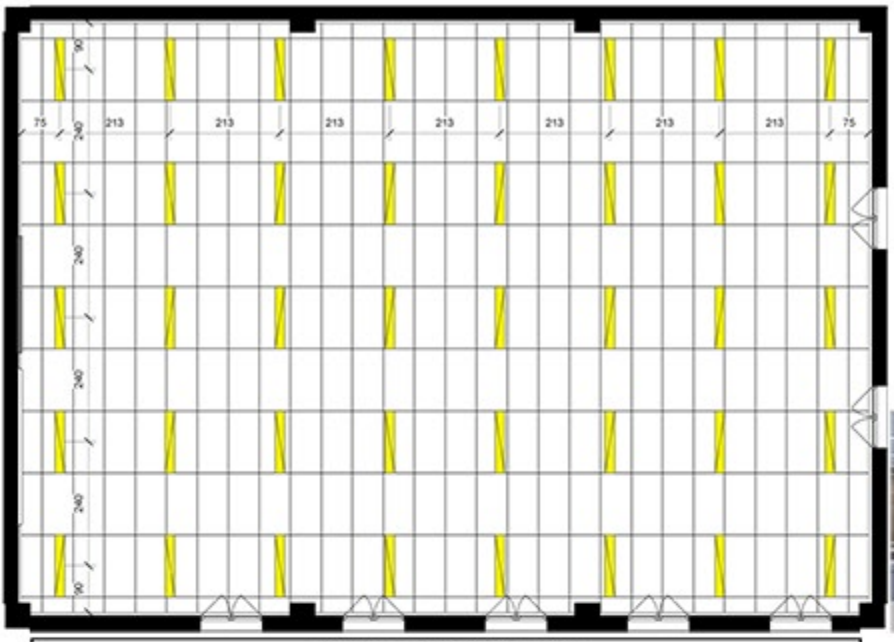
Wall 2 Section



Wall 3 Section

Transversal Section

Scenario 1



TOTAL LUMEN OUTPUT

Ewp(lux)	φ(total)	CU	LLF	Awp(m²)
500,00	205645,16	0,62	0,80	204,00

hcr(m)	2,65	Ceiling Cavity Reflectance	0,7
hfc(m)	3,80	Wall Reflectance	0,5
hcc(m)	0,35	Floor Cavity Reflectance	0,2
RCR	1,883578431 ≅2		

Number of Luminares(A)	38,80097383 ≅40

A

CCR	80%				70%				50%				30%			
WCR	70%	50%	30%	10%	70%	50%	30%	10%	50%	30%	10%		50%	30%	10%	
1	76	73	70	68	73	71	68	66	66	64	62		61	60	58	
2	70	65	60	56	67	62	58	55	58	55	52		54	52	49	
3	64	57	52	48	62	56	53	47	52	48	45		49	45	43	
4	59	51	45	41	57	50	44	40	47	42	39		44	40	37	
5	54	46	39	35	52	44	39	34	42	37	33		39	35	32	
6	50	41	35	30	48	40	34	30	37	33	29		35	31	28	
7	46	37	31	27	44	36	30	26	34	29	25		32	28	24	
8	43	33	27	23	41	32	27	23	30	26	22		29	24	21	
9	39	30	24	20	38	29	23	20	27	22	19		26	21	18	
10	36	27	21	18	35	26	21	17	25	20	17		24	19	16	
RCR	20%															

RCR

Manufacturer: Lithonia
Model: LB240A
Lamps: 2 each 4' F40T12 34W
Lumens per Lamp: 2,660
Total Lumens: 5,300

Description: This luminaire uses two 4' standard fluorescent T12 tubes, is ceiling mounted, and has a wrap around prismatic lens

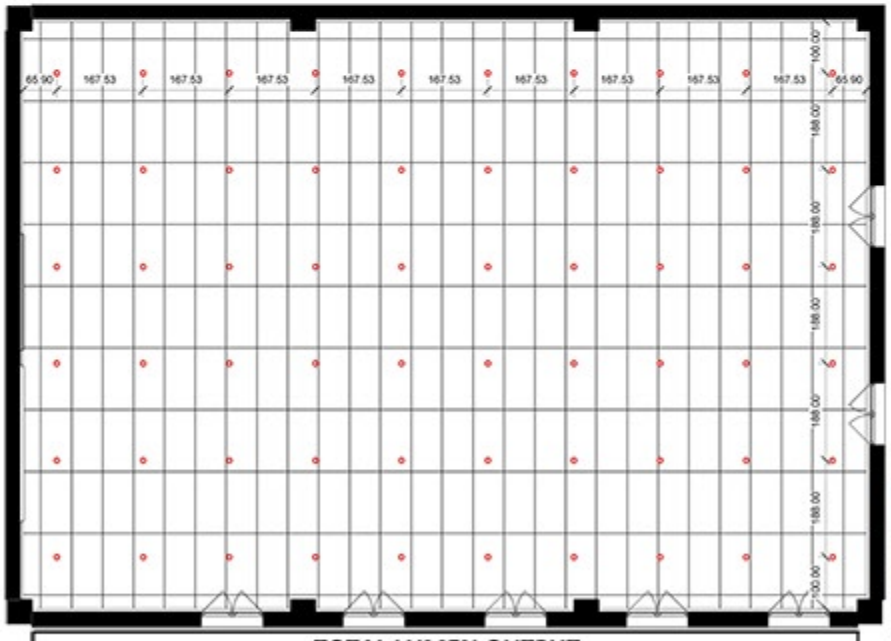
- Coefficient of utilization is based on room cavity ratio (RCR)
- RCR is five (5) times the ratio of total vertical surface area to total horizontal surface area within the room cavity, and therefore indicates the relative space proportions.

$$\text{Room-cavity Ratio, RCR} = \frac{5h_{RC}(L+W)}{L\,W}$$

Where,

- h_{RC} = Room cavity height
- L = Length of the room
- W = Width of the room

Scenario 2



TOTAL LUMEN OUTPUT

Ewp(lux)	φ(total)	CU	LLF	Awp(m²)
500,00	216101,69	0,59	0,80	204,00

hcr(m)	2,65	Ceiling Cavity Reflectance	0,7
hfc(m)	3,80	Wall Reflectance	0,5
hcc(m)	0,35	Floor Cavity Reflectance	0,2
RCR	1,883578431 ≅2		

Number of Luminares(B)	60,02824859 ≅60

B

CCR	80%				70%				50%				30%			
WCR	70%	50%	30%	10%	70%	50%	30%	10%	50%	30%	10%		50%	30%	10%	
1	67	65	63	62	65	64	62	61	61	60	59		59	58	57	
2	63	60	58	55	62	59	57	55	57	55	53		55	54	52	
3	59	55	52	49	58	54	51	49	53	50	48		51	49	48	
4	56	51	47	45	55	50	47	44	49	46	44		48	45	43	
5	52	47	43	40	51	46	43	40	45	42	40		44	41	39	
6	49	43	39	36	48	43	39	36	42	38	36		41	38	36	
7	45	39	35	32	45	39	35	32	38	34	32		37	34	32	
8	42	36	32	29	42	35	31	29	35	31	29		34	31	29	
9	39	33	29	25	39	32	28	25	31	28	25		31	28	25	
10	36	29	25	23	36	29	25	23	29	25	22		28	25	23	
RCR	20%															

RCR

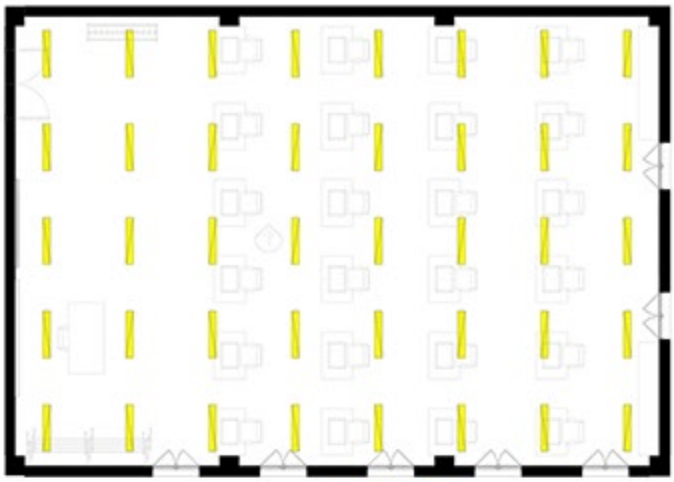
Manufacturer: Prescolite
Model: CFR826-4S2
Trim: Clear Alzak (Specular)
Lamps: 2 each 26W Double Twin
Lumens per Lamp: 1,800
Total Lumens: 3,600

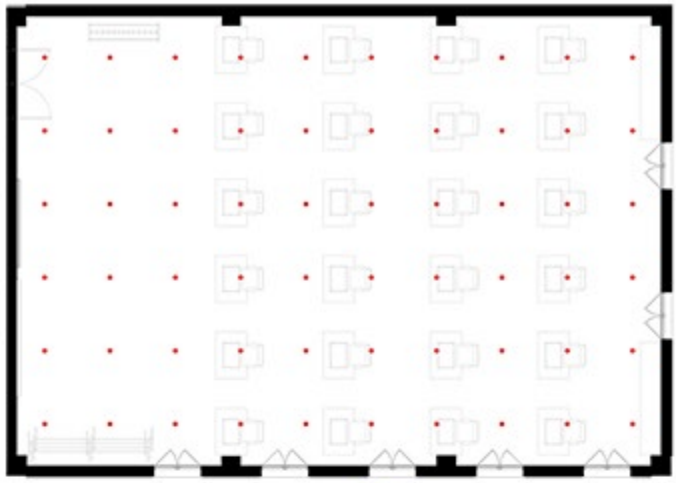
Description: This luminaire uses two horizontally positioned 26W Double Twin compact fluorescent lamps, is a recessed ceiling can, and is rated using a clear Alzak (Specular) trim. The most energy efficient and, over the long run, most cost effective luminaire design.

- By rearranging the Lumen Method equation, it is possible to find the number of luminaires required to meet a specific average illuminance level:

$$E_{WP} = \frac{\text{(lumens/lamp) x (lamps/luminaire) x (no. of luminaires) x CU x } LLF_{TOTAL}}{A_{WP}}$$

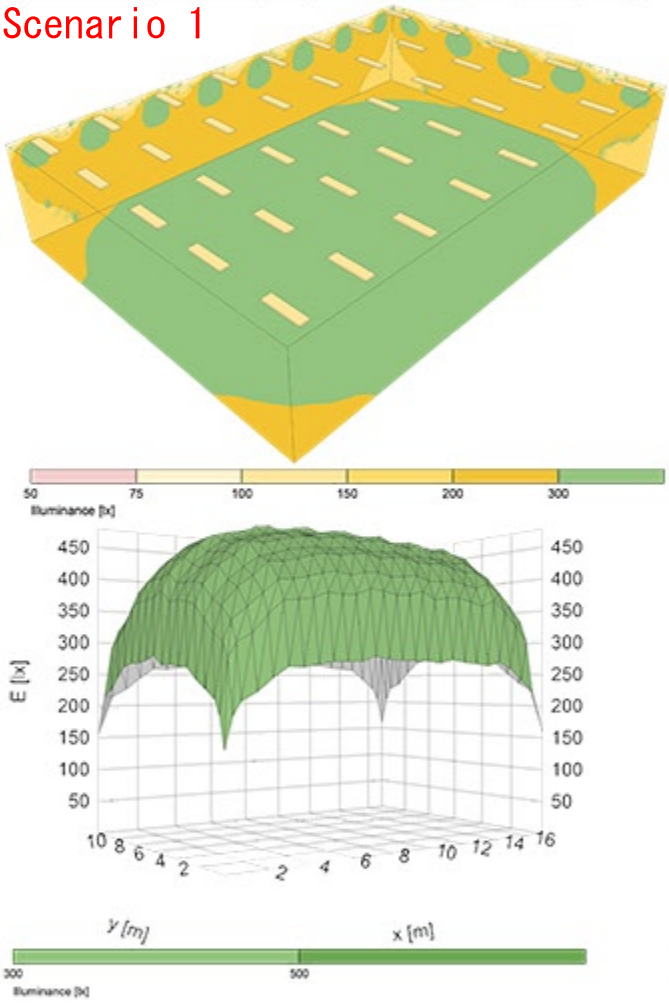
$$\text{No. of luminaires} = \frac{A_{WP} \times E_{WP}}{\text{(lumens/lamp) x (lamps/luminaires) x CU x } LLF_{TOTAL}}$$

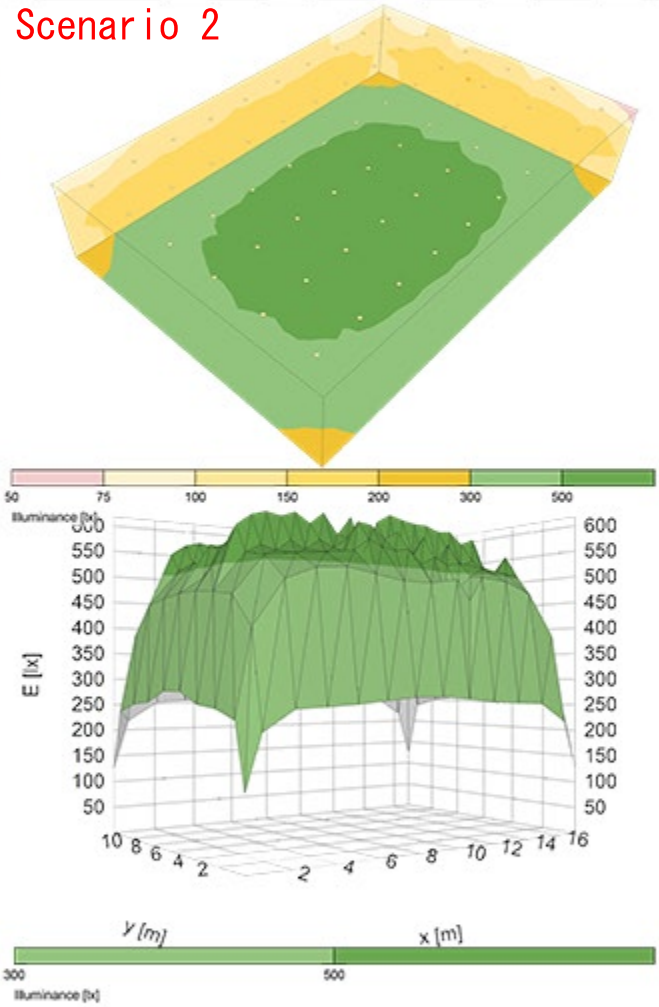




Scenario 1

Scenario 2

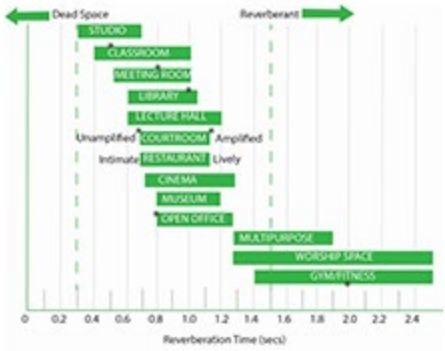




A type of luminaire should be used in the studio. If we examine the CU value, the CU value of the A-type luminaire is 0.62 while the CU value of the B type luminaire is 0.59. In other words, the efficiency of the A-type light source is higher because the absorption amount of the light emitted from the A-type luminaire is less than the light from the B type light source. In addition, the CU value of the A-type luminaire was higher, the amount of lamp required was reduced, and the same amount of light was achieved with less lamps. While 1360 W was consumed per unit time with 40 lamps in A-type lighting, 1560 W energy was consumed with 60 lamps in a B type lamp. Energy is saved with an A-type luminaire. While A type low-pressure discharge lamps are long-lasting, low-cost, and highly efficient, B type luminaires are low-cost but short-lived and their efficiency is low. The suitable RA value for classes is between 80 and 90. The RA value of A-type lighting is 80 -90 while the RA value of B type lighting is 100. RA value of A-type lighting provides sufficient lighting quality. Considering all these factors, the use of A-type luminaires will be the right choice in the studio.

Acoustic Calculations

Acoustical performance is an important consideration in the design of classrooms. Research indicates that levels of background noise and reverberation little noticed by adults, who are mature and skillful listeners, adversely affect learning environments for young children, who require optimal conditions for hearing and comprehension. Poor classroom acoustics are an additional educational barrier for all people. Optimal reverberation time range is 0.4s-1s in classrooms (showed in graph). Materials should be selected according to this range. The formula of reverberation time is RT = 0.161V/A



Scenario 1-Empty Studio

Scenario 2-Occupied Studio

FORMULA OF REVERBERATION FOR 250Hz

SCENERIO-1(EMPTY STUDIO)

SURFACE	MATERIAL	AREA(m²)	ALPHA	As
Wall-1	1	64,60	0,36	23,26
Wall-2	1	37,32	0,36	13,44
Wall-3	1	55,60	0,36	20,02
Wall-4	1	42,00	0,36	15,12
Wall-2	8	4,50	0,02	0,09
Wall-2	4	3,78	0,10	0,38
Wall-3o4	5	12,60	0,07	0,88
Floor	2	175,20	0,01	1,75
Floor	9	28,80	0,20	5,76
Ceiling	3	204,00	0,15	30,60
			TOTAL As=	111,29

FORMULA OF REVERBERATION	RT=0,161*V/A

	V	As	RT
FORMULA OF REVERBERATION FOR 250Hz	673,20	111,29	0,973605824

SCENERIO-2(OCCUPIED STUDIO)

SURFACE	MATERIAL	AREA(m²)	ALPHA	As
Wall-1	1	64,60	0,36	23,26
Wall-2	1	37,32	0,36	13,44
Wall-3	1	55,60	0,36	20,02
Wall-4	1	42,00	0,36	15,12
Wall-2	8	4,50	0,02	0,09
Wall-2	4	3,78	0,10	0,38
Wall-3o4	5	12,60	0,07	0,88
Floor	2	175,20	0,01	1,75
Floor	10	28,80	0,30	8,64
Ceiling	3	204,00	0,15	30,60
			TOTAL As=	114,17

FORMULA OF REVERBERATION	RT=0,161*V/A

	V	As	RT
FORMULA OF REVERBERATION FOR 250Hz	673,20	114,17	0,94933835

FORMULA OF REVERBERATION FOR 500Hz

SCENERIO-1(EMPTY STUDIO)

SURFACE	MATERIAL	AREA(m²)	ALPHA	As
Wall-1	1	64,60	0,66	42,64
Wall-2	1	37,32	0,66	24,63
Wall-3	1	55,60	0,66	36,70
Wall-4	1	42,00	0,66	27,72
Wall-2	8	4,50	0,01	0,05
Wall-2	4	3,78	0,06	0,23
Wall-3o4	5	12,60	0,05	0,63
Floor	2	175,20	0,01	1,75
Floor	9	28,80	0,10	2,88
Ceiling	3	204,00	0,10	20,40
			TOTAL As=	157,62

FORMULA OF REVERBERATION	RT=0,161*V/A

	V	As	RT
FORMULA OF REVERBERATION FOR 500Hz	673,20	157,62	0,687649175

SCENERIO-2(OCCUPIED STUDIO)

SURFACE	MATERIAL	AREA(m²)	ALPHA	As
Wall-1	1	64,60	0,66	42,64
Wall-2	1	37,32	0,66	24,63
Wall-3	1	55,60	0,66	36,70
Wall-4	1	42,00	0,66	27,72
Wall-2	8	4,50	0,01	0,05
Wall-2	4	3,78	0,06	0,23
Wall-3o4	5	12,60	0,05	0,63
Floor	2	175,20	0,01	1,75
Floor	10	28,80	0,40	11,52
Ceiling	3	204,00	0,10	20,40
			TOTAL As=	166,26

FORMULA OF REVERBERATION	RT=0,161*V/A

	V	As	RT
FORMULA OF REVERBERATION FOR 500Hz	673,20	166,26	0,651913604

FORMULA OF REVERBERATION FOR 1000Hz

SCENERIO-1(EMPTY STUDIO)

SURFACE	MATERIAL	AREA(m²)	ALPHA	As
Wall-1	1	64,60	0,65	41,99
Wall-2	1	37,32	0,65	24,26
Wall-3	1	55,60	0,65	36,14
Wall-4	1	42,00	0,65	27,30
Wall-2	8	4,50	0,01	0,05
Wall-2	4	3,78	0,08	0,30
Wall-3v4	5	12,60	0,03	0,38
Floor	2	175,20	0,02	3,50
Floor	9	28,80	0,10	2,88
Ceiling	3	204,00	0,08	16,32
			TOTAL As=	153,12

FORMULA OF REVERBERATION	RT=0,161*V/A

FORMULA OF REVERBERATION FOR 1000Hz	V	As	RT
	673,20	153,12	0,707856847

SCENERIO-2(OCCUPIED STUDIO)

SURFACE	MATERIAL	AREA(m²)	ALPHA	As
Wall-1	1	64,60	0,65	41,99
Wall-2	1	37,32	0,65	24,26
Wall-3	1	55,60	0,65	36,14
Wall-4	1	42,00	0,65	27,30
Wall-2	8	4,50	0,01	0,05
Wall-2	4	3,78	0,08	0,30
Wall-3v4	5	12,60	0,03	0,38
Floor	2	175,20	0,02	3,50
Floor	10	28,80	0,50	14,40
Ceiling	3	204,00	0,08	16,32
			TOTAL As=	165,64

FORMULA OF REVERBERATION	RT=0,161*V/A

FORMULA OF REVERBERATION FOR 1000Hz	V	As	RT
	673,20	164,64	0,658326723

FORMULA OF REVERBERATION FOR 2000Hz

SCENERIO-1(EMPTY STUDIO)

SURFACE	MATERIAL	AREA(m²)	ALPHA	As
Wall-1	1	64,60	0,62	40,05
Wall-2	1	37,32	0,62	23,14
Wall-3	1	55,60	0,62	34,47
Wall-4	1	42,00	0,62	26,04
Wall-2	8	4,50	0,01	0,05
Wall-2	4	3,78	0,10	0,38
Wall-3v4	5	12,60	0,02	0,25
Floor	2	175,20	0,02	3,50
Floor	9	28,80	0,20	5,76
Ceiling	3	204,00	0,04	8,16
			TOTAL As=	141,80

FORMULA OF REVERBERATION	RT=0,161*V/A

FORMULA OF REVERBERATION FOR 2000Hz	V	As	RT
	673,20	141,80	0,764345063

SCENERIO-2(OCCUPIED STUDIO)

SURFACE	MATERIAL	AREA(m²)	ALPHA	As
Wall-1	1	64,60	0,62	40,05
Wall-2	1	37,32	0,62	23,14
Wall-3	1	55,60	0,62	34,47
Wall-4	1	42,00	0,62	26,04
Wall-2	8	4,50	0,01	0,05
Wall-2	4	3,78	0,10	0,38
Wall-3v4	5	12,60	0,02	0,25
Floor	2	175,20	0,02	3,50
Floor	10	28,80	0,50	14,40
Ceiling	3	204,00	0,04	8,16
			TOTAL As=	150,44

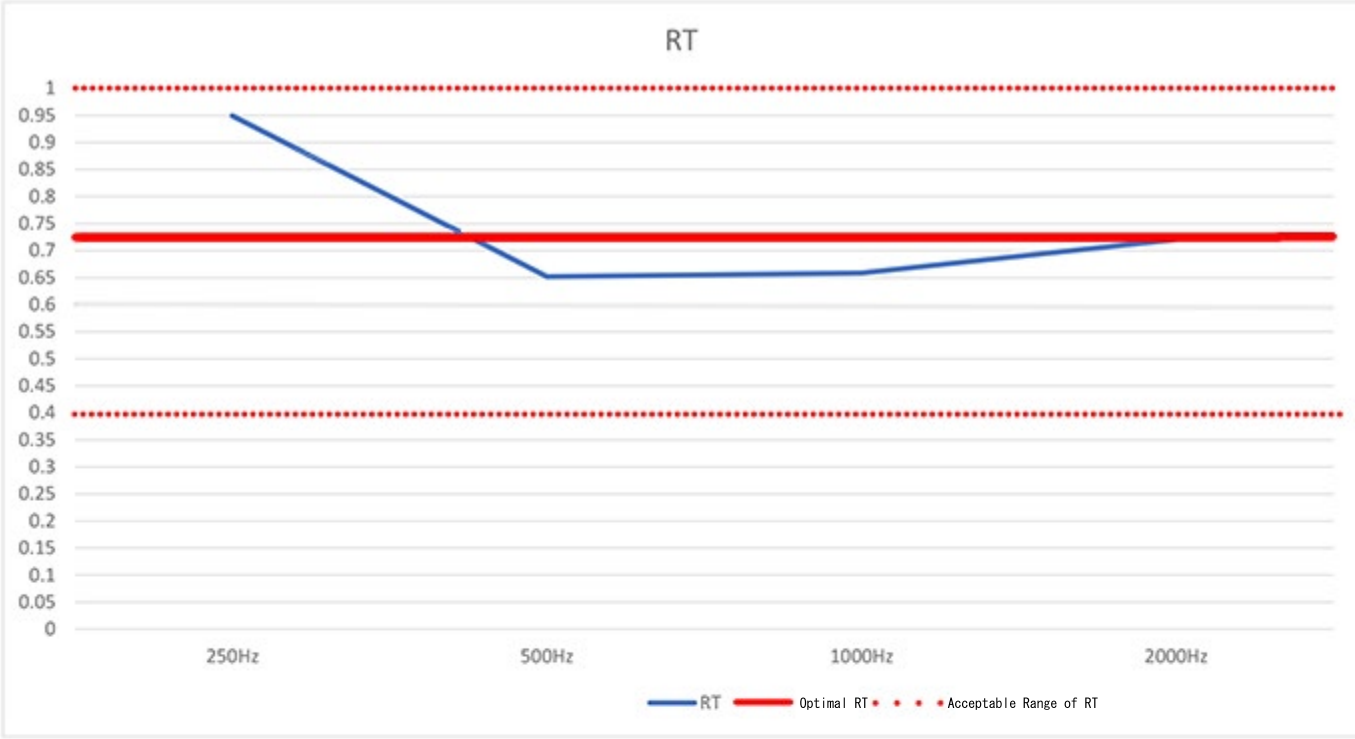
FORMULA OF REVERBERATION	RT=0,161*V/A

FORMULA OF REVERBERATION FOR 2000Hz	V	As	RT
	673,20	150,44	0,720447962

	V	As	RT
FORMULA OF REVERBERATION FOR 250Hz	673,20	111,29	0,973905824
FORMULA OF REVERBERATION FOR 500Hz	673,20	157,62	0,687649175
FORMULA OF REVERBERATION FOR 1000Hz	673,20	153,12	0,707856847
FORMULA OF REVERBERATION FOR 2000Hz	673,20	141,80	0,764345063

	V	As	RT
FORMULA OF REVERBERATION FOR 250Hz	673,20	114,17	0,94933835
FORMULA OF REVERBERATION FOR 500Hz	673,20	166,26	0,651913604
FORMULA OF REVERBERATION FOR 1000Hz	673,20	164,64	0,658326723
FORMULA OF REVERBERATION FOR 2000Hz	673,20	150,44	0,720447962

Scenario 1-Empty Studio

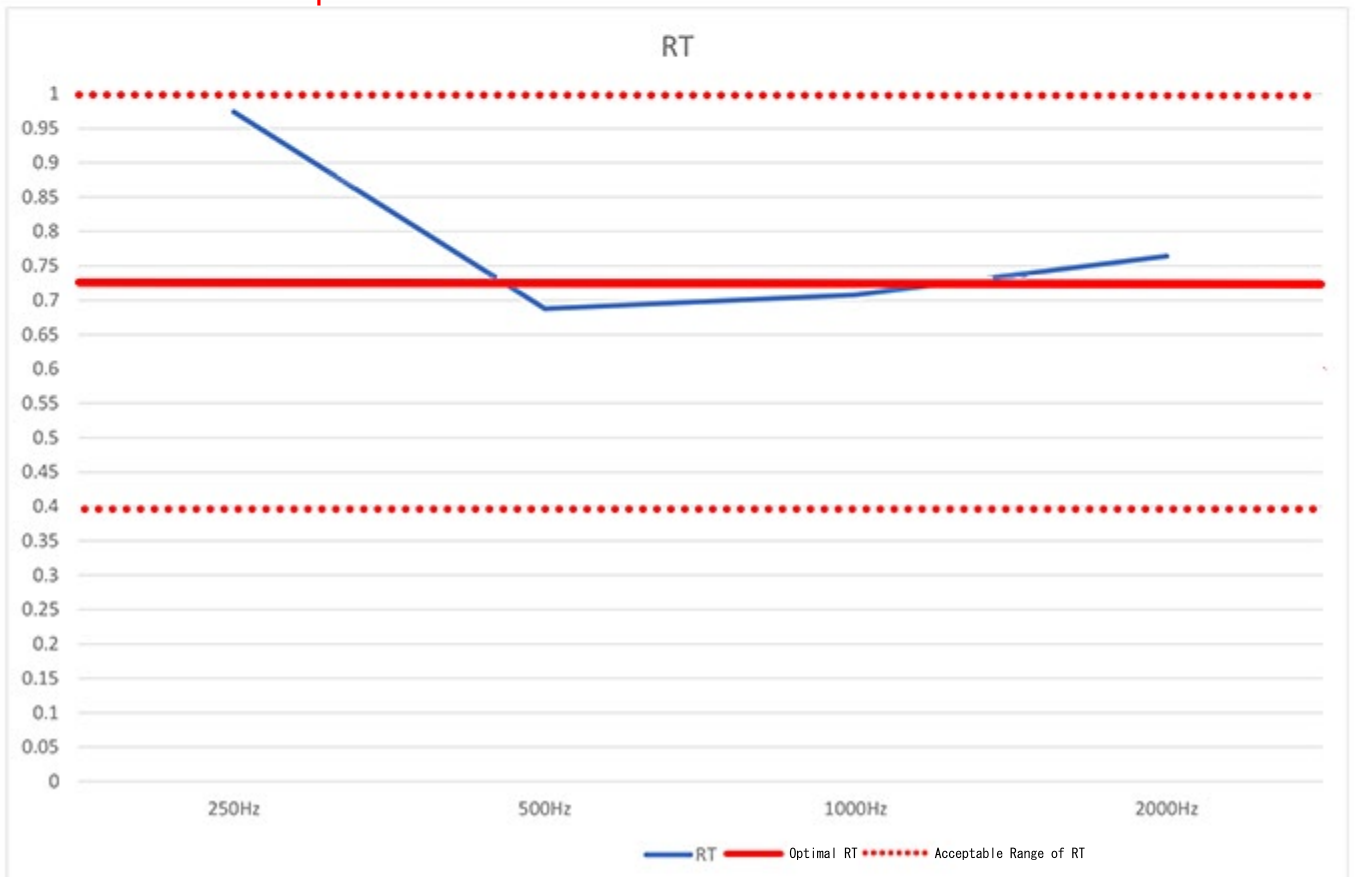


"Under the standard, the maximum reverberation time in an unoccupied, furnished classroom with a volume under 10,000 (283 m^3) cubic feet is 0.6 seconds, and 0.7 seconds for a classroom between 10,000 and 20,000 (566 m^3) cubic feet. The maximum level of background noise allowed in the same classroom is 35 decibels (dBA)." (Armsstrongceeling.com)

- Communication: `T = 0.32 * log V - 0.17`
- Speech: `T = 0.37 * log V - 0.14`

$$T=0,32*log673-0,17=\ 0,73\ s$$

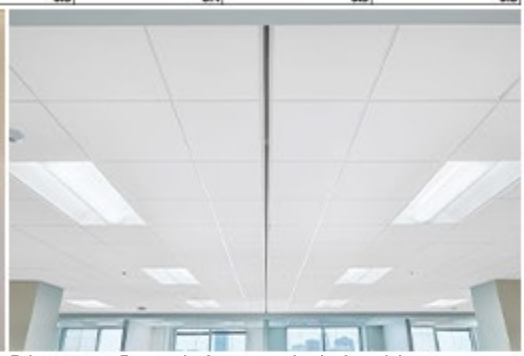
Scenario 2-Occupied Studio



NUMBER	MATERIAL	OCTAVE BAND FREQUENCY IN Hz			
		250	500	1,000	2,000
1	Acoustical plaster, approx. 25mm thick, 3.5 kg/m2/cm	0.36	0.66	0.65	0.62
2	Marble Floor	0.01	0.01	0.02	0.02
3	Plasterboard Suspended Ceiling	0.15	0.10	0.08	0.04
4	Solid Wooden Door	0.10	0.06	0.08	0.10
5	Double Glazing, 2-3 mm glass, 10 mm gap	0.07	0.05	0.03	0.02
6	Floor areas with Drawing Tables and chairs (empty)	0.20	0.10	0.10	0.20
7	Floor areas with Drawing Tables and chairs (occupied)	0.30	0.40	0.50	0.50
8	Whiteboard	0.02	0.01	0.01	0.01
9	Floor areas with Drawing Tables and chairs (empty)	0.2	0.1	0.1	0.2
10	Floor areas with Drawing Tables and chairs (occupied)	0.3	0.4	0.5	0.5

Solid Wooden Door

White Board



Plaster Board Suspended Ceeling

Acoustic Plaster

Double Glazed Window

Marble

Chair & Desk in 3D Section

Materials have been chosen to make the studio at optimal reverberation times. 250 Hz, 500 Hz, 1000 Hz, and 2000 Hz values are considered at this. Acoustical plaster at walls, double glazing glasses, marble tiles at floors, and plasterboard suspended ceiling have been used. As a result, the studio was designed to be a great space for acoustic of educational purposes.

References

https://commercial-acoustics.com/reverberation-time-graphic/

https://aia.connectedcommunity.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=16ac6d7f-5860-4b2b-a34f-e75e8a11bca5

https://cds.cern.ch/record/1251519/files/978-3-540-48830-9_BookBackMatter.pdf --- As values of material have been choosed from this book.