

Lighting Layout and Sound Index Calculation

Module: Material Science and Building Services

Module Code: ACBA4006

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Task A:

1. Calculation to determine required number of lights and layout for factory production area:

1) Room Index:

Calculate the Room Index value, (R.I. describes proportions of the room), using the following equation:

$$RI = \frac{(L \times W)}{(Hm(L+W))}$$

Where:

L = length of room

W = width of room

Hm = Height of luminaire measured from the working plane

(Height of factory – height of factory work bench, above floor level)

Given Values for above:

L= 60m

W=24m

Hm = (8m - 1m) = 7 m

$$\begin{aligned} \text{Room index Factor} &= \frac{(60 \times 24)}{(7(60+24))} \\ &= \frac{(1440)}{(7(84))} \\ &= \frac{1440}{588} \end{aligned}$$

$$RI = 2.45$$

$$RI = 2.5 \quad (\text{rounded up value})$$

II) Utilisation Factor:

Use the Room Index value together with values for area reflectances for the ceiling: 0.3 and for the walls: 0.5, to ascertain the Utilisation Factor, for fluorescent light fittings in recessed louvre with DLOR of 50% (see Fig 1 below).

Utilisation factor

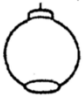
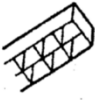
Description of fitting	Typical outline LOR	Basic downward LOR%	Ceiling	0.7			0.5			0.3		
			Walls	0.5	0.3	0.1	0.5	0.3	0.1	0.5	0.3	0.1
			Room index									
Aluminium industrial reflector, aluminium or enamel high-bay reflector		70	0.6	0.39	0.36	0.33	0.39	0.36	0.33	0.39	0.36	0.33
			0.8	0.48	0.43	0.40	0.46	0.43	0.40	0.46	0.43	0.40
			1.0	0.52	0.46	0.45	0.52	0.48	0.45	0.52	0.48	0.45
			1.25	0.56	0.52	0.50	0.56	0.53	0.49	0.56	0.52	0.42
			1.5	0.60	0.57	0.54	0.59	0.57	0.53	0.59	0.57	0.53
			2.0	0.65	0.62	0.59	0.63	0.60	0.56	0.63	0.59	0.57
			2.5	0.67	0.64	0.62	0.65	0.62	0.61	0.65	0.62	0.60
			3.0	0.69	0.66	0.64	0.67	0.64	0.63	0.67	0.64	0.62
			4.0	0.71	0.68	0.67	0.69	0.67	0.65	0.69	0.66	0.64
			5.0	0.72	0.70	0.69	0.71	0.69	0.67	0.71	0.67	0.66
Near-spherical diffuser, open beneath		50	0.6	0.28	0.22	0.18	0.25	0.20	0.17	0.22	0.18	0.16
			0.8	0.39	0.30	0.26	0.33	0.28	0.23	0.27	0.25	0.22
			1.0	0.43	0.36	0.32	0.38	0.34	0.29	0.31	0.29	0.26
			1.25	0.48	0.41	0.37	0.42	0.38	0.33	0.34	0.32	0.29
			1.5	0.52	0.46	0.41	0.46	0.41	0.37	0.37	0.35	0.32
			2.0	0.58	0.52	0.47	0.50	0.48	0.43	0.42	0.39	0.36
			2.5	0.62	0.56	0.52	0.54	0.50	0.47	0.45	0.42	0.40
			3.0	0.65	0.60	0.56	0.57	0.53	0.50	0.48	0.45	0.43
			4.0	0.68	0.64	0.61	0.60	0.58	0.54	0.51	0.48	0.46
			5.0	0.71	0.60	0.65	0.62	0.59	0.57	0.53	0.50	0.48
Recessed louvre 0.23 trough with optically designed reflecting surfaces		50	0.6	0.28	0.22	0.18	0.23	0.20	0.17	0.23	0.20	0.17
			0.8	0.34	0.31	0.28	0.33	0.30	0.28	0.33	0.30	0.28
			1.0	0.37	0.36	0.32	0.37	0.34	0.32	0.37	0.34	0.32
			1.25	0.40	0.38	0.35	0.40	0.37	0.35	0.40	0.37	0.35
			1.5	0.43	0.41	0.38	0.42	0.40	0.38	0.42	0.39	0.38
			2.0	0.46	0.44	0.42	0.45	0.43	0.41	0.44	0.42	0.41
			2.5	0.48	0.46	0.44	0.47	0.45	0.43	0.46	0.44	0.43
			3.0	0.49	0.47	0.46	0.48	0.46	0.45	0.47	0.45	0.44
			4.0	0.50	0.49	0.48	0.49	0.48	0.47	0.48	0.47	0.46
			5.0	0.51	0.50	0.49	0.50	0.49	0.48	0.49	0.48	0.47

Fig: 1 Utilisation Factor Table

From Fig: 1, Utilisation Factor = 0.46

III) Number of lamps required:

Calculate the required number of luminaires using the following equation:

$$\text{Number of Lamps (N)} = \frac{E \times A}{F \times UF \times LLF}$$

Where:

E = Lux (illumination required for factory area at the working plan)

A = Area required

F = Number of lumens required(Lighting Design Lumen (LDL) output value)

UF = Utilisation Factor

LLF = Light Loss Factor

Given values for above:

E = 200 (Lux)

A = 1440 (m²)

F = 18,000 (lumens)

UF = 0.46 (UF)

LLF = 0.75 (Light Loss Factor)

$$N = \frac{200 \times 1440}{18,000 \times 0.46 \times 0.75}$$

$$N = \frac{288,000}{6,210}$$

$$N = 46.376$$

Using 70 % rule: complete uniformity impossible in practice, acceptable standard is the minimum specified to be at least 70% of the maximum illumination level allowed)

N = 48 lamps

IV) Suitable layout (value of S) for the lamp fittings:

To calculate suitable layout value of S for lamp fittings (spacing between lamps)

Using equation as follows:

For fluorescent tubes in diffusing luminaires

$$S_{\max} = 1.5 \times H_m$$

Where H_m is same value calculated in step 1 to calculate RI value:

H_m = Height of luminaire measured from the working plane

(Height of factory – height of factory work bench, above floor level)

Where $H_m = (8\text{m} - 1\text{m}) = 7\text{ m}$

$S_{\text{max}} = 1.5 \times 7$

$S_{\text{max}} = 10.5\text{ m}$

To summarise a suitable layout for the lamps would be 4 x 12 luminaires, to cover the length/width of the factory production area; 4 rows x 12 luminaires, provided that distance between lamps is no greater than 10.5 m apart.

2. Lay out plan on scale drawing to demonstrate 'best fit' design for the luminaire installation for the factory floor production area:

In order to complete this, it is first necessary to establish spacing distance value for the light fittings, as follows:

Spacing:

Number of luminaires across length of factory:

Assuming each row of lights is positioned $\frac{1}{2} S$ in from each corner, using given value for length of the production area;

Using 12 luminaires along the length of the room, spacing (S_L) = $11 S_L + \frac{1}{2} S_L + \frac{1}{2} S_L = 12 S_L$, so for a room length of 60m, $S_L = 60/12 = 5m$

Number of luminaires across width of factory:

Using 4 luminaires across the width of the room, spacing (S_w) = $3 S_w + \frac{1}{2} S_w + \frac{1}{2} S_w = 4 S_w$, so for a room length of 24m, $S_w = 24/4 = 6m$.

The finished layout plan for this lighting scheme is shown in Fig: 2 below. A further plan was generated using Dialux® lighting design software, included as Appendix A, using the closest approximate specification for the luminaries, but shows an output of 245 lux, rather than the desired 200 lux; this variance is attributed to use of the closest available manufacturer's specification (LOR 62.5%) to the given luminaire parameters (LOR 50%).

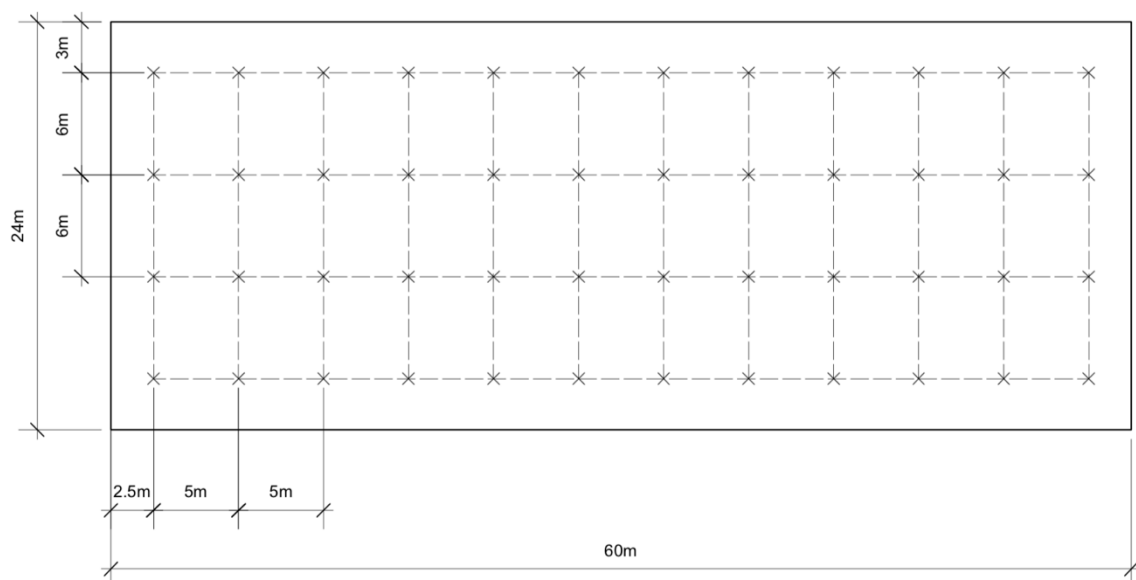


Fig: 2 Lighting layout plan to show position of luminaires for Task A

Task B

1. Calculation: Sound reduction index (R)

As the calculation concerns multiple elements in the partition, where the SRI values have been calculated using a logarithmic formula, they cannot be averaged according to area;

The following formula is then used to calculate the overall transmission co-efficient (using transmission coefficients/areas of the individual components) using the following formula:

$$\frac{T_0 = (T_1 \times A_1) + (T_2 \times A_2) + (T_3 \times A_3)}{A_1 + A_2 + A_3}$$

Where:

T_0 = Overall transmission coefficient

T_1 = transmission co-efficient for one component

(different numbers apportioned to each separate component)

A_1 = area of that component

(different numbers apportioned to each separate area of each component)

The overall sound reduction index, R, for the entire wall can then be used by using the overall transmission coefficient in the following formula:

$$R = 10 \log_{10} (1/T)$$

Units measured in decibels(dB)

Brick wall area = 20m² and contains a window of area 4m² with Sound reduction index(SRI) values of 50 dB and 10 Db respectively.

For the brickwork let

$$T_1 = ? , \quad A_1 = 20 - 4 = 16 \text{ m}^2. \quad \text{SRI} = 50 \text{ dB}$$

For the window let

$$T_2 = ? , \quad A_2 = 4 \text{ m}^2. \quad \text{SRI} = 10 \text{ dB}$$

Using **Sound reduction index (SRI)** formula and substituting:

$$R = 10 \log_{10} (1/T)$$

Brickwork value:

$$50 = 10 \log(1/ T_1)$$

$$\text{Log } 1 = 50$$

$$T_1. 10$$

$$\frac{\text{Log } 1}{T_1} = 5$$

$$\frac{1}{T_1} = 10^5$$

$$T_1 = 10^{-5}$$

$$T_1 = 0.000010$$

Window value:

$$10 = 10 \log(1/T_2)$$

$$\text{Log } \frac{1}{T_2} = \frac{10}{10.}$$

$$\frac{\text{Log } 1}{T_2} = 1$$

$$\frac{1}{T_2} = 10^1$$

$$T_2 = 10^{-1}$$

$$T_2 = 0.10$$

Using the averaging formula and substituting:

$$\frac{T_0 = (T_1 \times A_1) + (T_2 \times A_2)}{A_1 + A_2}$$

$$T_0 = \frac{(10^{-5} \times 16) + (10^{-1} \times 4)}{16+4}$$

$$T_0 = \frac{(10^{-5} \times 16) + (10^{-1} \times 4)}{16+4}$$

$$T_0 = \frac{(10^{-5} \times 16) + (10^{-1} \times 4)}{20}$$

$$T_0 = \frac{(0.00016) + (0.4)}{20}$$

$$T_0 = 0.020008$$

Using **Sound reduction index(SRI)** formula and substituting:

$$R = 10 \log_{10} (1/T)$$

$$R = 10 \log_{10} (1/ 0.020008)$$

$$R = 10(\log_{10} \times 1/ 0.020008)$$

$$R = 10 \times (\log_{10} \times 49.980008)$$

$$R = 10(1.6987)$$

$$R = 16.987$$

$$R = 17 \text{ dB (Rounded up)}$$

2. Implications of frequency and wavelength in internal sound management, partition wall construction technique and insulation choice.

Wave length and Frequency:

To address overall topic, a brief outline is first required to show the relationship between wavelength and frequency of sound waves:

In the diagram **Fig 3** below is a pictorial representation of a sound wave, where the **wavelength (λ)** perceived to be the distance between any two points on a wave, measured in meters(m). The height of the wave known as **amplitude** determines how loud/quiet the sound is see **Fig 4** and the **frequency (f)**: number of cycles of vibration per second, measured in Hertz (Hz), is perceived by the human hearing as pitch, where the higher the frequency, the higher a pitch is registered and the shorter a wavelength is observed. Examples of frequency types can be seen in **Table One** (see below).

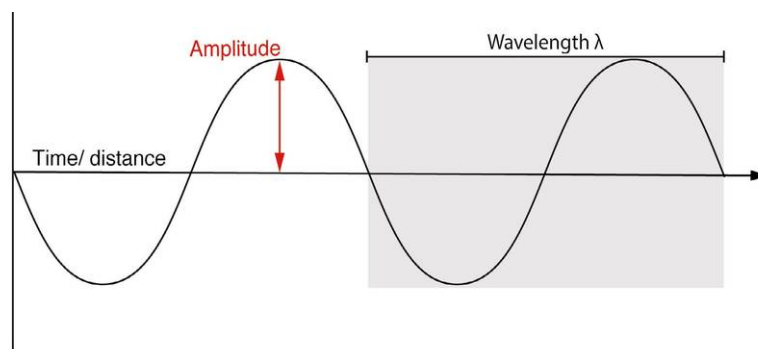
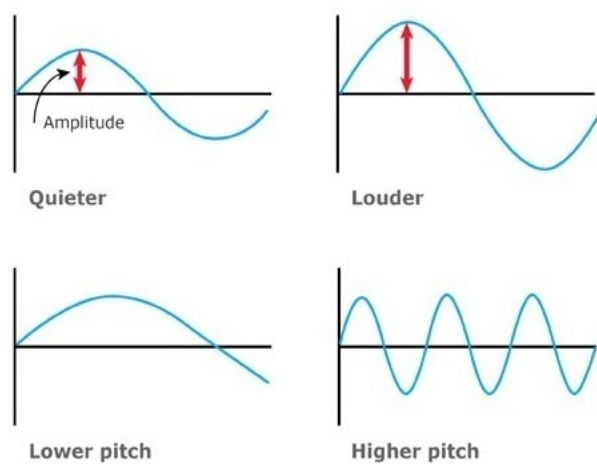


Fig: 3 Fig 3 : Diagram to show attributes of sound waves taken from (Researchgate, 2017)



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Fig: 4 Diagram to show attributes of frequency/wavelength in sound waves taken from (sciencelearn.org.nz, May 2011)

Table One: Examples of High, Middle, and Low Frequencies

Frequency Type	Range (Hz)	Example of Sound Sources
High	2000-10,000	Baby crying, Speech, Bird Song
Middle	500-2000	Human speech, poor quality
Low	10- 250	Bass system, road noise, turbines

Sound waves are perceived as a 'pressure' to the sensory organs in the human body with lower basal frequencies being most problematic to humans, (e.g. 8-100Hz), having the larger acoustic energy and exert greater effects to health. Due to the longer wavelength of lower frequencies, they are also present an issue with respect to sound insulation (i.e. a single skin brick partition would be inadequate to block out some basal notes, which could be 10-12 metres in wavelength)

Airborne and Impact Sound

Considering the previous points, **Table 2** (see below) presents a summary to explain how noise, e.g. lower basal frequencies, described previously, are transferred to buildings via 'airborne' and 'impact' sounds.

Table Two: Airborne and Impact Sound Comparisons

Noise Type	Mode of travel/generation	Example of Sound Sources
Airborne	Sound travels through the air <u>before</u> reaching a partition: 'Airborne sound refers to noise produced by sources that directly set the air around them into vibration' (BS 8233:2014, E.1,p. 53)	voices,music,traffic,aircraft
Impact	Sound is generated <u>on</u> a partition: 'Impact sound refers to noise caused by sources which produce impulsive mechanical excitation of part of a building' (BS 8233:2014, E.1,p. 53)	footsteps,doors,switches,boilers

Figs 5 and 6 (see below) show not only the transfer of airborne and impact sounds through partitions, but also how sound from these sources can be indirectly transferred by 'flanking transmission'.

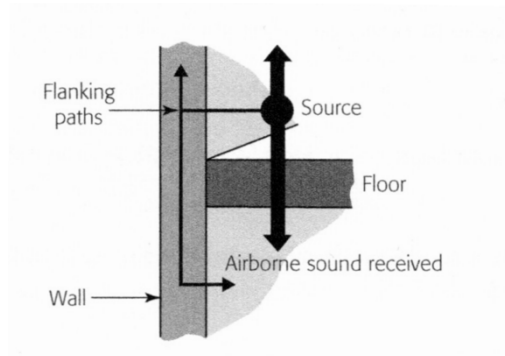


Fig: 5 Diagram to show Airborne sound transmission taken from McMullan, 2018, p.195)

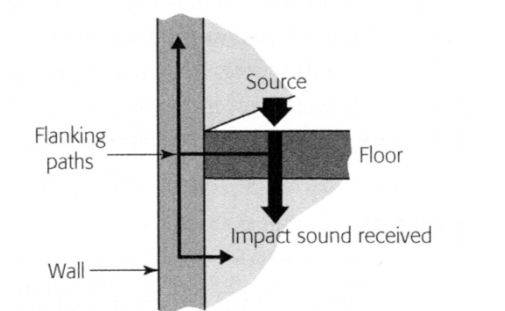


Fig: 6 Diagram to show Impact sound transmission taken from (McMullan, 2018,p.196)

Fig 7, see below, taken from (**BS 8233:2014, E.1, p. 54**) further illustrates the transmission pathway of sounds originating in one room and their extended reach. **Fig 8** also taken from **BS 8233:2014, E.1, p. 55**) is included to demonstrate the structures/detailing within the fabric of a building that typically assist 'sound leaks'.

Figure E.1 Transmission paths (via the structure) of noise originating in Room 1 (diagrammatic)

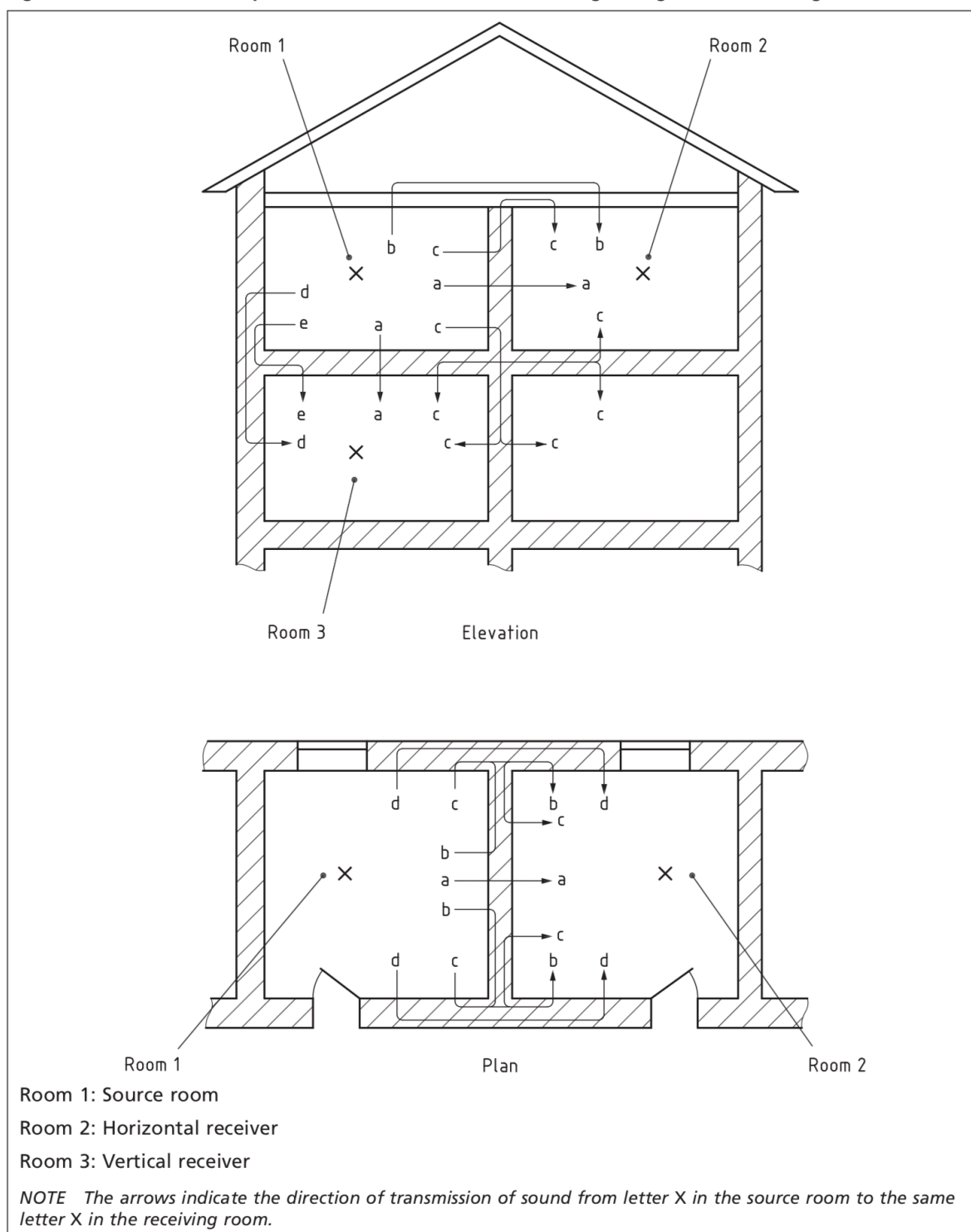


Fig: 7 Diagram to show Transmission paths (via the structure) of noise originating in Room 1 (diagrammatic) taken from, (BS 8233:2014, E.1,p. 54)

Figure E.2 Indirect sound leakage paths

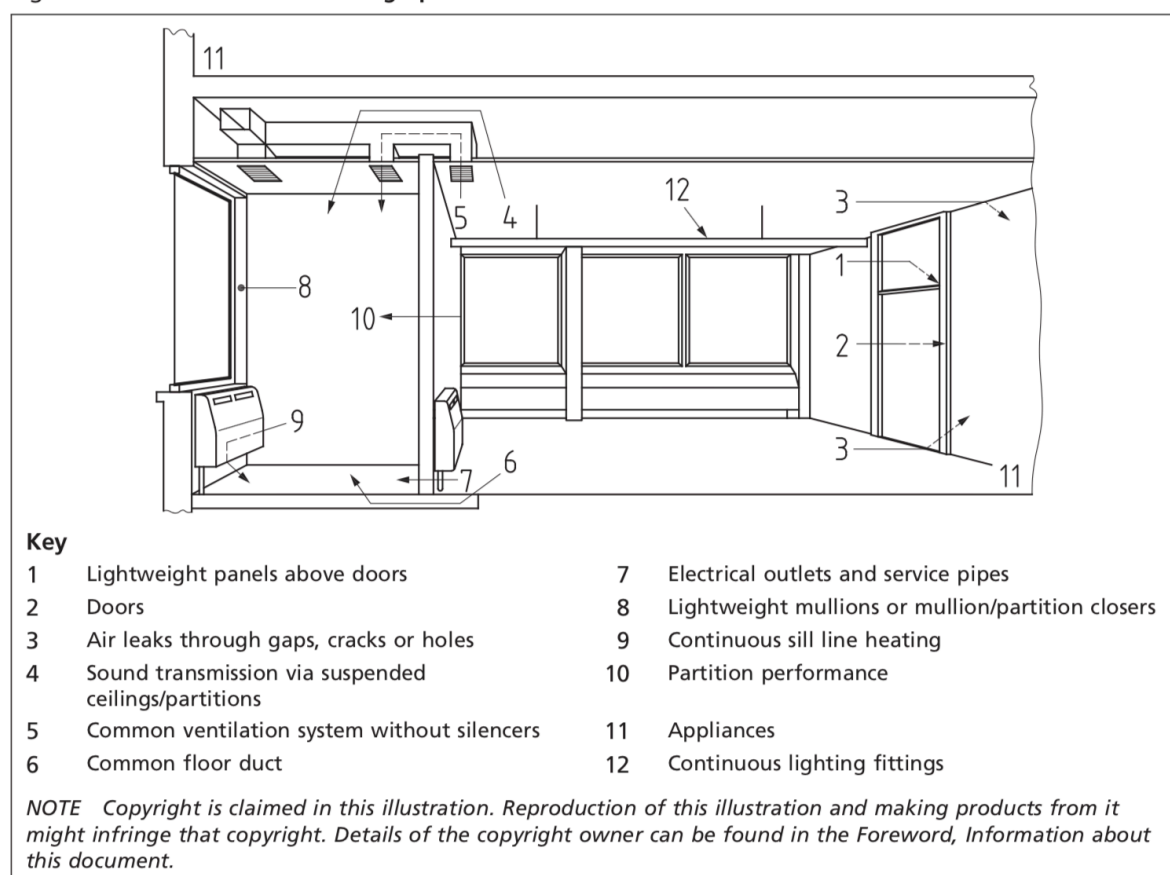


Fig: 8 Diagram to show Indirect sound leakage paths taken from (BS 8233:2014, E.2,p. 55)

Sound Insulation:

Effective sound insulation strategies to combat airborne/impact sound and accompanying flanking transmission depend on the following principles:

- 1) Heaviness (mass law)
- 2) Completeness
- 3) Flexibility
- 4) Isolation

These principles are summarised in **Table Three** (see below), along with their properties and/or governing laws, with examples of how these are applied in construction to achieve sound insulation solutions.

Fig 9 below, is also included to illustrate the 'Mass law' (referenced in Table 3) and depicts the linear relationship of sound insulation with the surface density (mass per unit area) of a single leaf partition.

Figure E.3 Mass law curve

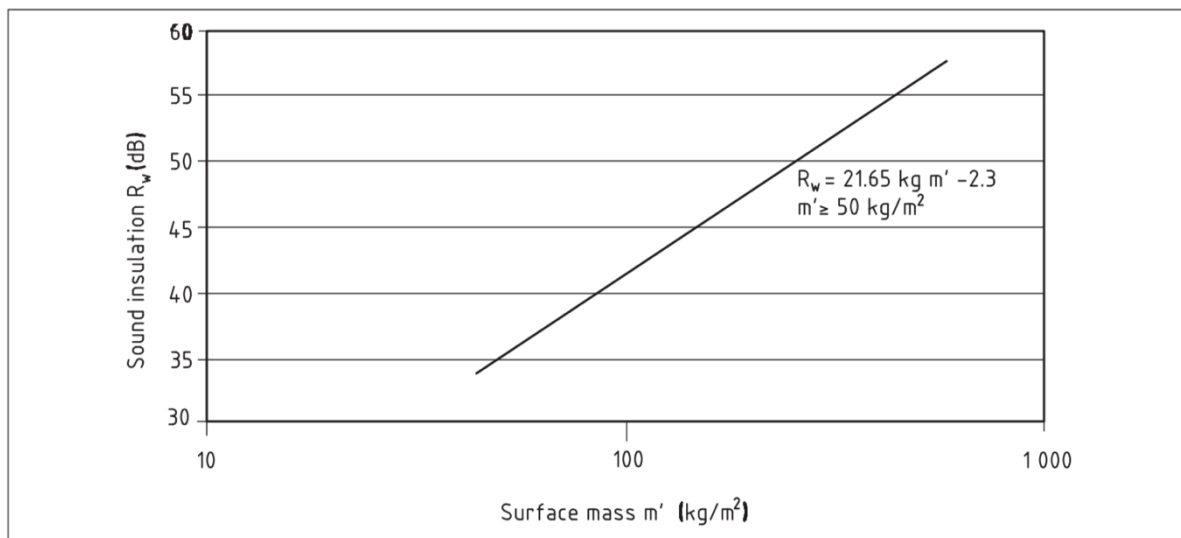


Fig: 9 Diagram to show Mass Law Curve (BS 8233:2014, E.3,p. 55)

Further guidance on standards, measurements, and example specifications for sound insulation, can be found in the Approved Document E to the Building Regulations (Wales) which are formed from building codes and legislation; **Fig 10** below, is taken from this document and shows examples of recommended sound insulation solutions, for masonry single skin/cavity, and timber frame cavity wall partitions.

Fig 11 also below, is included to show further details of how the requirements for sound insulation can be met by adopting 'standard approved constructions' for a block and timber partitions, (McMullans, 2018, p.206).

Table Three: Summary of Sound Management Insulation principles and their properties and construction implications.

Sound Insulation principle	Properties: Governing attributes or laws	Implications for Construction: Insulation choice and/or technique
Heaviness	A material with a heavy weight and high mass transmits less sound energy, due to high	Techniques for increasing sound insulation involve

	density restricting size of sound vibrations inside material, such that final face of structure, e.g. inside of wall of room, vibrates with less movement than in light weight materials(e.g. timber frame). Vibrations ,and amplitude of sound waves re radiated in air is restricted, lowers loudness of the sound but does not effect the pitch/frequency. Governed by the Mass Law: (See Fig 9 below to see diagram to show effects of Mass law) States that the sound insulation of a single leaf partition has a linear relationship with the surface density(mass per unit area) of the partition.	increasing thickness of masonry, plaster and glass: E.g. Composite brickwork-plastered, but must be bonded. Approved Document E of the Building Regulations 2010(Welsh Government,2010) gives guidance on: measuring/specifying standards for sound insulation for the building envelope internal walls and floors i.e. walls require insulation against airborne sound/floors require insulation for both airborne/impact sound. (See Fig 10 to see examples of insulation requirements for separating wall structures) Sound insulation increases by 5 dB whenever the mass is doubled.
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		Sound insulation increases by amount 5 dB whenever the frequency is doubled.
Completeness	Areas of reduced insulation/small gaps in construction of wall have far greater effect on overall insulation- completeness depends on airtightness and uniformity: Airtightness: Presence of gaps becomes more significant as insulation against airborne sound is increased e.g. Brick wall with hole/crack at 0.1% of the total area of the wall, average SRI of wall is reduced from 50 dB to 30 dB. Uniformity: Overall sound insulation is reduced by small areas of poor insulation: E.G. 25 % of half brick wall, occupied by unsealed door reduces SRI of the wall from 45 dB to 23 dB: in summary; final sound insulation is affected by relative areas, but reduced overall by the insulation of the	Air gaps(see Fig 8 above) can occur because of poorly constructed seals around partitions or joins with : Floors Ceilings Windows Doors Service Pipes and ducts Avoid use of materials porous enough to pass sound via small holes- brick/block work must therefore be sealed/plastered. Doors/openable windows should also be airtight when fastened. Improve the insulation of the worst areas first and consider reduction of openings in some circumstances e.g. walls facing noisy roads should contain the minimum of

	poorer component(s) than by the better insulated areas.	openings/should also be well insulated.
Flexibility	Stiffness is physical property of a partition, depends on factors of the properties of the materials- elasticity and also the fixing of the partition. High stiffness results in loss of insulation at certain frequencies- that result in coincidence and resonance effects. These effects interfere with the Mass law. Resonance: Loss of insulation occurs if the incident sound waves have same frequency as natural frequency of the partition; the vibrations increase in the structure and are passed to the air, lowering efficacy of the insulation. Resonant frequencies are low usually and can cause issues in air spaces of cavity construction.	Flexible(non- stiff) materials combined with high mass are best for high sound insulation, but flexibility not best structural property in a wall/floor. Considerations to mitigate could be, i.e. cavity constructions must be sufficiently wide for the air to be flexible. Otherwise resonance and coincidence effects can cause the insulation to be reduced at certain frequencies”

	Coincidence: Loss of insulation by coincidence caused by bending flexural vibrations that can occur along length of a partition, sound wave frequency and bending wave frequency coincide at the critical frequency. Sound insulation remains constant and less than stated by Mass law above this critical frequency- greatest losses in double leaf constructions e.g. cavity walls or hollow blocks.	
Isolation	Sound insulation can be ruined by strong flanking transmission via rigid links, i.e. single nail/ rigid cavity tie. This can be mitigated by application of discontinuous construction techniques; can be effective in reduction of transmission of sound through a structure- conversion of sound to 'different wave motions' at the junction of	Sound insulation ruined by strong flanking transmission via rigid links, i.e. single nail/ rigid cavity tie. Strategies for mitigation can involve for example, air cavities in windows/floating floors/use of carpets on floors/resilient mountings for vibrating

	different materials, energy is lost- useful insulation gained. Useful to note here that: Sound Absorption: reduction of sound energy reflected by the surfaces of a room, although not in the scope of this task, should be mentioned briefly with regard to using this principle to control noise reflected from ceilings/floor, ducts, corridors of industrial buildings	machines/fixings of windows. Sound insulation of insulating panels, i.e wall with multiple leaves will improve matters by absorbing reflections inside the cavities.
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Diagram 2.1 Types of separating wall

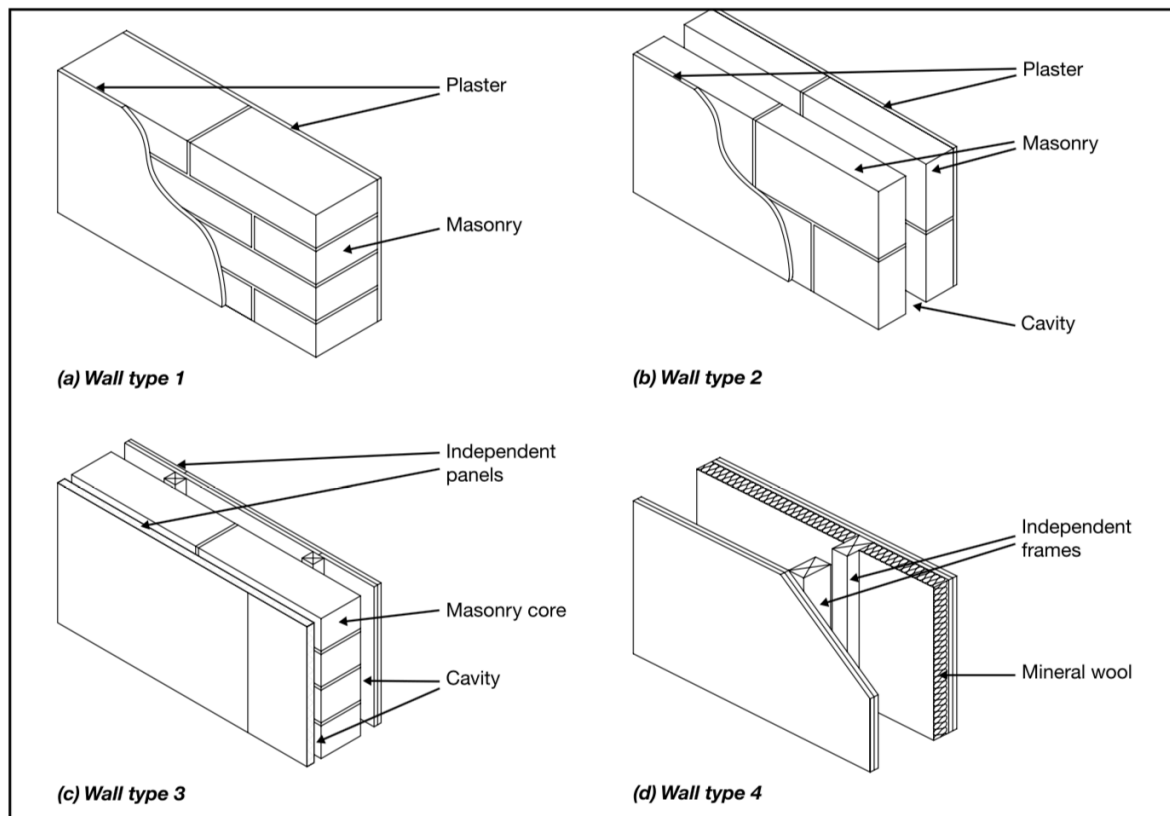


Fig: 10 Diagram to show types of separating wall (Welsh Government, 2010, p.30)

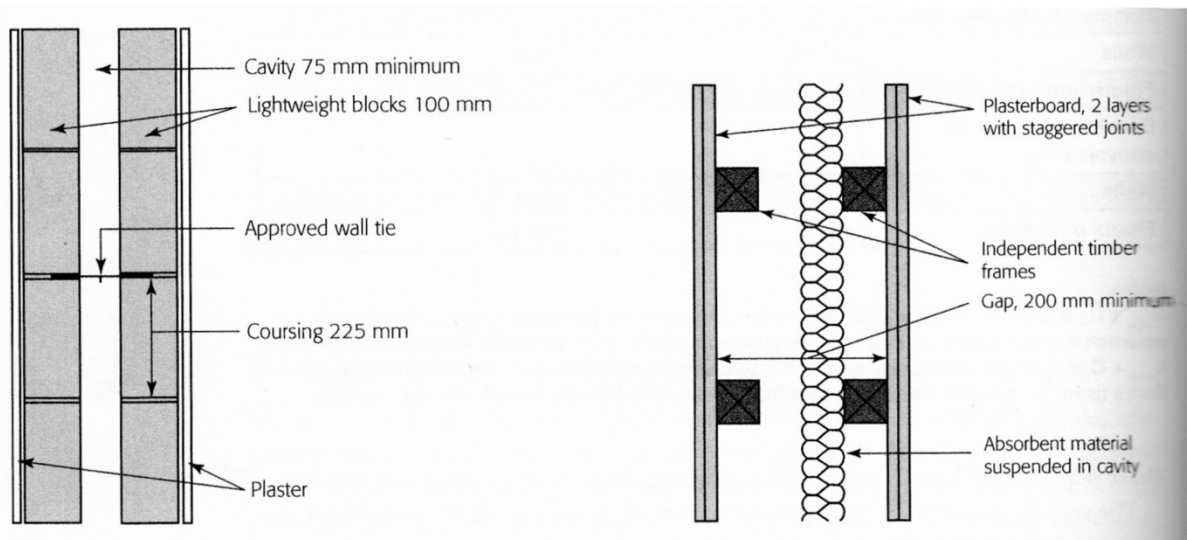


Fig: 11 Diagram to Show Sound Insulation Standards to meet building regulation requirements in a Block Cavity Wall and Timber Frame Wall Construction (McMullans, 2019, p.206)

Appendix A

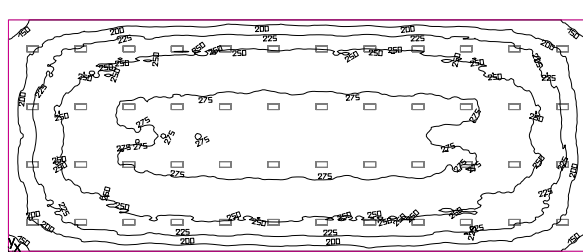
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06/04/2020

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

DIALux

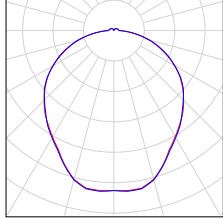
Room 1



Clearance height: 8.000 m, Reflection factors: Ceiling 30.0%, Walls 50.0%, Floor 20.0%, Maintenance factor: 0.80

Workplane

Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1 Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 1.000 m, Wall zone: 0.000 m	244 (≥ 200)	127	287	0.52	0.44

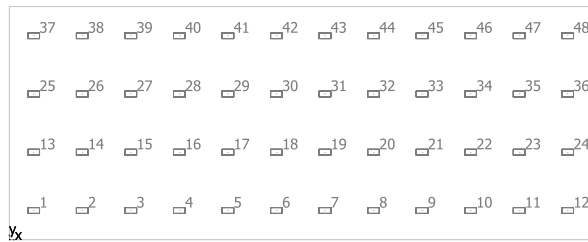
Quantity	Luminaire (Luminous emittance)		
48	Whitecroft Lighting - HYP428 HYGIENE Luminous emittance 1 Fitting: 1x@FT5/49W/865/GE/LL/SL1/30, 1x@FT5/49W/865/GE/LL/SL1/30, 1x@FT5/49W/865/GE/LL/SL1/30, 1x@FT5/49W/865/GE/LL/SL1/30 Light output ratio: 62.46% Lamp luminous flux: 18600 lm Luminaire luminous flux: 11617 lm Power: 208.0 W Luminous efficacy: 55.9 lm/W Colourimetric data 1x@FT5/49W/865/GE/LL/SL1/30: CCT 6400 K, CRI -		

Total lamp luminous flux: 892800 lm, Total luminaire luminous flux: 557616 lm, Total Load: 9984.0 W, Luminous efficacy: 55.9 lm/W

Lighting power density: 6.93 W/m² = 2.84 W/m²/100 lx (Floor area of room 1440.00 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 27450 kWh/a of maximum 50450 kWh/a

Room 1



Whitecroft Lighting HYGP428 HYGIENE

No.	X [m]	Y [m]	Mounting height [m]	Maintenance factor
1	2.500	3.000	8.106	0.80
2	7.500	3.000	8.106	0.80
3	12.500	3.000	8.106	0.80
4	17.500	3.000	8.106	0.80
5	22.500	3.000	8.106	0.80
6	27.500	3.000	8.106	0.80
7	32.500	3.000	8.106	0.80
8	37.500	3.000	8.106	0.80
9	42.500	3.000	8.106	0.80
10	47.500	3.000	8.106	0.80
11	52.500	3.000	8.106	0.80
12	57.500	3.000	8.106	0.80
13	2.500	9.000	8.106	0.80
14	7.500	9.000	8.106	0.80
15	12.500	9.000	8.106	0.80
16	17.500	9.000	8.106	0.80
17	22.500	9.000	8.106	0.80
18	27.500	9.000	8.106	0.80
19	32.500	9.000	8.106	0.80
20	37.500	9.000	8.106	0.80
21	42.500	9.000	8.106	0.80
22	47.500	9.000	8.106	0.80
23	52.500	9.000	8.106	0.80
24	57.500	9.000	8.106	0.80
25	2.500	15.000	8.106	0.80
26	7.500	15.000	8.106	0.80
27	12.500	15.000	8.106	0.80
28	17.500	15.000	8.106	0.80
29	22.500	15.000	8.106	0.80
30	27.500	15.000	8.106	0.80
31	32.500	15.000	8.106	0.80
32	37.500	15.000	8.106	0.80
33	42.500	15.000	8.106	0.80
34	47.500	15.000	8.106	0.80
35	52.500	15.000	8.106	0.80
36	57.500	15.000	8.106	0.80
37	2.500	21.000	8.106	0.80

No.	X [m]	Y [m]	Mounting height [m]	Maintenance factor
38	7.500	21.000	8.106	0.80
39	12.500	21.000	8.106	0.80
40	17.500	21.000	8.106	0.80
41	22.500	21.000	8.106	0.80
42	27.500	21.000	8.106	0.80
43	32.500	21.000	8.106	0.80
44	37.500	21.000	8.106	0.80
45	42.500	21.000	8.106	0.80
46	47.500	21.000	8.106	0.80
47	52.500	21.000	8.106	0.80
48	57.500	21.000	8.106	0.80

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