

Assessment 2: Materials Science and Building Services

Lighting Layout and Sound Index Calculation

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text: Aerial 12, justified, 1.5 spacing

calculations: Cambria Math 14, italic, 1.5 spacing

word count; Task B.4 = 773

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Task A

1. Lighting calculations:

1.1. Room index

$$\text{Room index} = \frac{\text{length} \times \text{width}}{\text{working height} \times (\text{length} + \text{width})}$$

Length = 60 metres

Width = 24 metres

Height = 8 metres

As the work benches are 1 metre above the floor,

Working height = 8 – 1 ∴ Working height = 7 metres

$$\therefore \text{Room index} = \frac{60 \times 24}{7 \times (60 + 24)}$$

$$\therefore \text{Room index} = \frac{1440}{7 \times (84)}$$

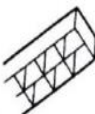
$$\therefore \text{Room index} = \frac{1440}{588}$$

$$\text{Room index} = 2.45$$

It is important to note however, that this calculation is only valid in instances where the room length is less than 4 times the width of the room and the room index is greater than 0.75 when calculated.

1.2. Utilisation factor

Utilisation factor

Description of fitting	Typical outline LOR	Basic downward LOR%	Ceiling	0.7			Reflectances			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	0.35	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	0.49	0.45	0.52	0.48	0.45	0.52	0.48	0.45
			1.25	0.56	0.53	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	0.58	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
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	0.56	0.54	0.51	0.48	0.46
Recessed louvre 0.23 trough with optically designed reflecting surfaces		50	0.6	0.28	0.25		0.23	0.28	0.25	0.23	0.28	0.25
			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

Utilisation factor = 0.46

This can be deduced from the tables via the information provided:

Fluorescent lamps: Length 1.2m, width 0.2m, at DLOR % of 50.

Using the description, it is the 3rd item down on the LHS column of the table which applies to this scenario.

Using the information that the areas reflectance's are 0.3 for the ceiling and 0.5 for the roof, we can find the exact value of the utilisation factor. Going down from the 0.5 column (value of the walls) within the 0.3 section (value of the ceiling) and moving across from the 2.5 row (the rounded value of the room index) within the correct item, these marry up at the 0.46 value thus making that the utilisation factor.

1.3. The number of lamps required

$$N = \frac{E \times A}{F \times UF \times LLF}$$

N = Number of lamps

E = Illuminance level required

A = Area at working plane height

F = Average luminous flux for each lamp

UF = Utilisation factor

LLF = Light loss factor

In this instance:

$$E = 200$$

$$A = 60 \times 24 = 1440$$

$$F = 18000$$

$$UF = 0.46$$

$$LLF = 0.75$$

$$\therefore N = \frac{200 \times 1440}{18000 \times 0.46 \times 0.75}$$

$$\therefore N = \frac{288000}{6210}$$

$$N = 46.3768116$$

$$N = 47$$

There are 47 lamps required in this instance.

1.4. A suitable layout (value of S) for the lamp fittings

For fluorescent tubes; maximum spacing between fittings =

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

Where H_m = working height

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

$$S_{max} = 10.5m$$

The suggested layout below is the 'best fit', if the maximum distance between lamps is less than 10.5 m.

As the lux value specified is at least 70% of the maximum, an additional lamp is acceptable.

To provide the best equal illuminance across all parts of the room:

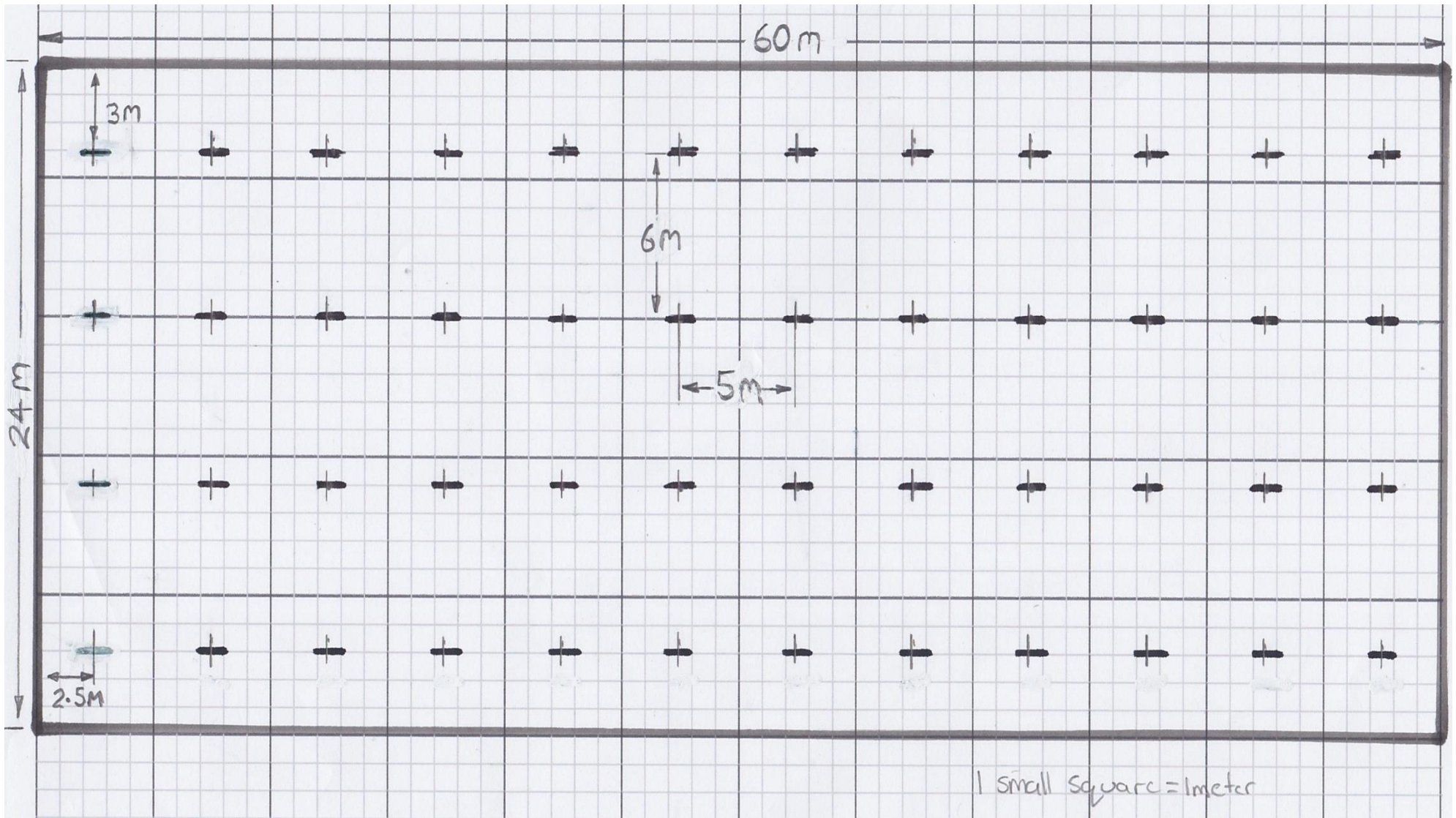
48 lamps will be used at 4 rows of 12.

At distances of:

Length; centre intervals at 5m, edges at 2.5m

Width; centre intervals at 6m, edges at 3m.

2. Plan layout scale drawing of the factory floor design for the luminaire installation. (figure 2. Lighting design)



Task B

3. Sound calculations: Overall sound reduction index (dB) for the entire wall.

Brick:

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

Where T = Transmission Coefficient for the partition under test.

$$50 = 10 \times (\log_{10}(1/T1))$$

$$5 = \log_{10} (1/T1)$$

$$1/T1 = 10^5$$

$$T1 = 10^{-5}$$

$$= 0.000010$$

Window:

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

$$10 = 10 \times (\log_{10}(1/T1))$$

$$1 = \log_{10} (1/T1)$$

$$1/T1 = 10^1$$

$$T1 = 10^{-1}$$

$$= 0.10$$

$$T0 = \frac{(T1 \times A1) + (T2 \times A2)}{A1 + A2}$$

$$A1 + A2$$

$$= \frac{(10^{-5} \times 18) + (10^{-1} \times 2)}{18 + 2}$$

$$18 + 2$$

$$= \frac{0.00018 + 0.2}{20}$$

$$20$$

$$\text{Average transmission coefficient} = 0.010009$$

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

$$= 10 \times (\log_{10} (1/0.010009))$$

$$= 10 \times (\log_{10} (99.91008093))$$

$$= 10 \times 1.9996$$

$$SRI = 20 \text{ dB}$$

4. The implications of sound wavelength and frequency in building.

4.1. General

From a building fabric perspective, sounds can be impact or airborne, defined by the source producing the sound. Impact sounds are created when the fabric of a structure is vibrated by direct contact. Such sources of noise should be given particular attention in industrial or commercial building. Airborne sound only sets the structural fabric vibrating in unison when the emitted sound wave reaches the enclosing structural fabric. The vibrations set up, transmit the sound to adjacent rooms.

In task B3 above we determined the level of insulation required to mitigate airborne sound through a composite partition, but what effect does sound at varying frequencies (and corresponding wavelength) have on our ability to insulate a partitioned room?

Short wavelength sounds are easier to absorb, whereas sounds with greater wavelengths i.e., low-frequency sounds, typically below 500Hz, are more difficult to absorb. Low frequency sound waves transfer less energy to the medium they are traveling through, causing fewer vibrations in the material (including air) means they can pass through more easily and travel greater distances than high frequency waves.

When sound energy from the source strikes a room boundary, it is either reflected, absorbed by, or transmitted through the boundary. Heavyweight construction of boundaries offers good insulation; it is hard to vibrate a heavy wall. The **Mass Law** states that: 'the sound insulation of a single leaf partition rises in proportion to its mass'. (Nantel, 2022)

4.2. Resonance in building fabric

All objects and systems have a natural frequency, when an incident sound matches this frequency resonance occurs. Resonance causes an increase in the vibration of objects or systems and transfers this to surrounding air. In the most extreme cases this can cause damage. When this occurs in the fabric of a building there is a resulting loss of sound insulation. Resonant frequencies of building fabric are usually quite low and most likely to cause vibrational (even rattling) problems in the air spaces of cavity walls. (McMullan, 2007)

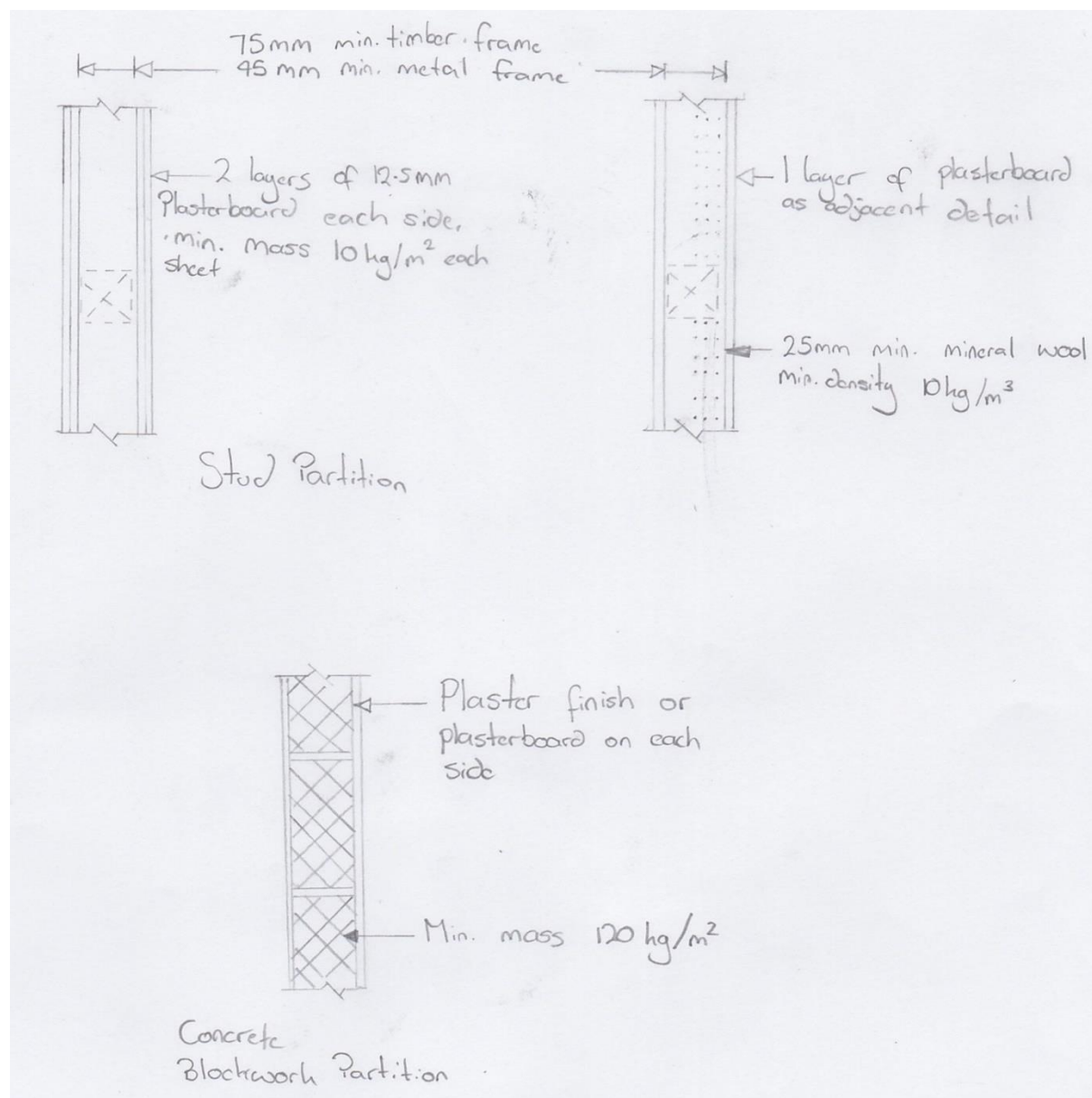
4.3. Partition wall construction techniques

The following designs are provided by UK Building Regulations, Approved Document E. (Building Regulations, 2010) & (Chudley & Greeno, 2013),

Completeness is a prominent characteristic of our wall design. An airtight structure gives good sound insulation. Any gap that allows air to pass will allow sound to pass.

Isolation is another recognised method of reducing noise. A minimum of physical contact between two surfaces or rooms provides the highest insulation. We can partially achieve this in practice by our air gap or glass fibre gap, but this is sometimes compromised by studwork or other fixings.

figure 3. Partition wall construction designs, (insulation of 40dB)



4.4. Insulation material choice for our partition wall.

The objective of our boundary insulation design is to meet regulations whilst maximising absorption and minimising weight and cost. The internal partition walls in figure 3 are designed to insulate against airborne sound. Whereas floors are also insulated against impact sound by integration of resilient layers and separation of floors in each room.

The sound-absorbing characteristics of materials vary significantly with frequency.

All materials have an absorption coefficient, which is a measure of the amount of sound absorption provided by a particular type of surface. Different materials and constructions have different coefficients e.g., a surface that absorbs 40% of the incident sound energy has an absorption coefficient of 0.4. The coefficient for the materials also varies with the frequency of the incident sound.

Table 1. Material sound absorption coefficient

Material	Absorption coefficient at low frequency 250Hz	Absorption coefficient at medium frequency 1000Hz	Absorption coefficient at high frequency 4000Hz
Plasterboard (Nantel, 2022)	0.1	0.03	0.03
Concrete block (Nantel, 2022)	0.05	0.7	0.8
Mineral wool 25mm (Rockwool, 2022)	0.2	0.85	0.9

As an individual layer, it is the mineral wool which provides the best overall sound insulation properties at all frequencies. Low frequencies penetrate the concrete block; however, it is extremely effective at medium and higher frequencies. The plasterboard, with a lot less mass performs poorly when standing alone but of course would never be used as a single layer.

Taking onboard the **Mass Law**, the simplest way to insulate would be to increase the thickness of the wall. However, this isn't the most effective solution from an engineering or economical point of view.

The objective of sound insulation in our wall is to reduce the transmitted sound to an acceptable level right across the whole frequency spectrum. Our stud and blockwork wall designs present a combination of these materials that satisfy engineering and economic objectives. Each system presented having an increased overall sound absorption coefficient and corresponding sound reduction index that meets the required regulations.

5. List of references

(All references were accessed April/May 2022) (in alphabetic order)

(Building Regulations, 2010) UK Building Regulations. Approved Document E - Resistance to the Passage of Sound, section 6 rooms for residential purposes page 65. and Section 0 Performance Table 2 page 13 available at <https://www.gov.uk/government/collections/approved-documents>

(Chudley & Greeno, 2013), Construction Handbook, Abingdon, Routledge.

(McMullan, 2007) Environmental Science in Building, London, Palgrave Macmillan.

(Nantel, 2022) UWTSD notes from lectures and presentations, Artificial Lighting & Sound.

(Rockwool, 2022) Mineral Wool 25mm, Rockwool RWA45 Acoustic Insulation Slab 25mm, available at <https://www.rockwool.com/uk/>