

Student Name: Tomos Williams

Student ID Number: 2319571

Module: Material Science and Building Services

Module Code: ACBA4006

Lecturer: Allan Nantel

Assignment Title: Lighting Layout, Heat and Sound

Task A

Part 1:

A production area in a factory measures 60 metres x 24 metres x 8 metres in height. The factory's work benches are set at a height of 1m above the floor level. The area's reflectance's are 0.3 for the ceiling and 0.5 for the walls. The Lighting design specifies fluorescent lamps in recessed louvre with DLOR of 50%.

A Lighting Design Lumen (LDL) output of 18,000 lumens is required.

The illumination required for the factory area is 200 lux at the working plane.

Light Loss Factor = 0.75

Calculate:

- 1) The Room Index*
- 2) The Utilisation Factor (from tables)*
- 3) The Number of lamps required*
- 4) A suitable layout (value of S) for the lamp fittings*

Answer:

- 1) The room index:**

L = 60m

W = 24m

Hm = 8m – 1 = 7m

$$RI = (L \times W) / (Hm (L+W))$$

$$RI = (60 \times 24) / (7 \times (60+24))$$

$$RI = 1440 / (7 \times 84)$$

$$RI = 1440 / 588$$

$$RI = 2.45$$

2) The utilisation factor:

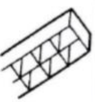
Room index = 2.45

Ceiling reflectance = 0.3

Wall reflectance = 0.5

Recessed louver

DLOR = 50%

UTILISATION FACTOR SHEET												
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	0.35	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	0.48	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
			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	0.56	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 louver 0.23 trough with optically designed reflecting surfaces		50	0.6	0.28	0.22	0.18	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

The utilisation factor = 0.46

3) The number of lamps required:

$$E = 200 \text{ lux}$$

$$A = 60\text{m} \times 24\text{m} = 1440\text{m}^2$$

$$F = 18,000 \text{ lm}$$

$$UF = 0.46$$

$$LLF = 0.75$$

$$N = E \times A / F \times UF \times LLF$$

$$N = 200 \times 1440 / 18,000 \times 0.46 \times 0.75$$

$$N = 288,000 / 6210$$

$$N = 46.38$$

I have decided to round the number of lamps up to 48 as this is a better number to work with when it comes to the lighting layout.

4) A suitable layout (value of S) for the lamp fittings:

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

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

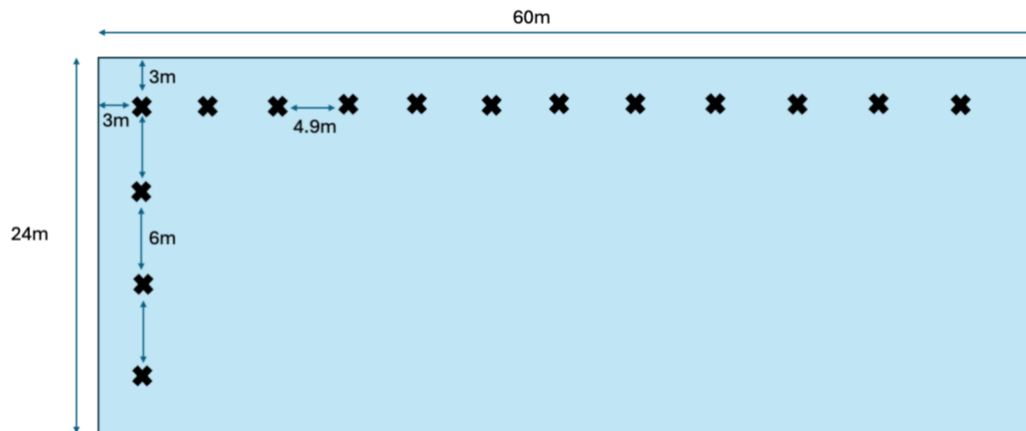
$$S_{\text{max}} = 1.5 \times 7$$

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

Therefore, the maximum distance between the lamps is 10.5 metres apart.

Part 2:

See below my best fit design for the luminaire installation:



Task B:

Part 1:

Definition of Frequency and Wavelength of Sound:

The definition of the frequency of a sound is the speed of the sound's vibration, this controls the pitch of the sound. Sound is produced by vibrations that travel through air and reach the ear. Frequency is measured by the number of vibrations that happen per second. The unit used to measure frequency is Hertz (Hz). When the frequency measured is 1 Hz, this means that there has been one wave cycle per second. Whereas if the frequency measured was 20 Hz, this means that 20 wave cycles have happened during that second. The higher the frequency, the shorter and closer together the cycles are (www.designingbuildings.co.uk, 2022).

The definition of the wavelength of a sound is simply the distance that the wave has travelled before the next wave starts, measured horizontally from one peak of the wave to the other. The relationship between the wavelength and frequency is inversely proportional, because as the frequency gets higher, the wavelength decreases, and vice versa (Acoustics Today, 2015). Wavelength can be calculated using the formula λ (wavelength) = v (velocity) / f (frequency).

(a) A building's internal design and services support:

Having a good understanding of frequency and wavelength of sound is a vital part to take into consideration whilst designing a building, to create an acoustically comfortable environment and for effective service arrangements.

Depending on how a building is going to be used, different areas may need different acoustic approaches. For instance, to guarantee clarity and richness of sound, concert halls and auditoriums usually strive for excellent acoustics throughout a wide range of frequencies (ODEON Room Acoustics Software, n.d.). On the other hand, lowering low-frequency sound from machines and HVAC systems in offices can improve performance and employee comfort (Terzigni, 2008).

The way sound behaves with building elements depends on its wavelength. For example, standing waves can occur in rooms the size of multiples of a specific wavelength, which can lead to unfavourable acoustic effects like dead areas or resonance as well as uneven sound distribution. By properly placing diffusers, acoustic panels, and other sound-absorbing materials, designers can lessen the effect of standing waves (www.designingbuildings.co.uk, 2021).

Noise from electrical, plumbing, and HVAC systems might interfere with tenants' ability to work comfortably and efficiently. It is important for designers to fully understand frequencies and wavelengths, as this means they can apply suitable sound control methods such as vibration isolation mounts for machinery and duct silencers for HVAC systems. In addition, the transmission of sound can be significantly reduced by precise design of conduits, ductwork, and structural elements (Bhatia, n.d.).

(b) A partition wall's construction technique:

Partition walls have a vital part to play in separating internal rooms and ensuring privacy. To achieve efficient sound insulation, it is essential to take into consideration sound wavelength and frequency when constructing partition walls.

Depending on what type of activities are happening on either side of the partition wall this causes the sound frequencies to change. Speech, for instance, usually occurs in the mid-range frequencies, but low-frequency sounds, such as those produced by machinery or the bass in music, may also require attenuation. To preserve privacy and reduce interruptions, partition walls should be designed and built with materials that are able to dampen sound throughout a wide frequency range.

Selecting the density and thickness of the materials used to construct a partition wall has a huge affect on how well the wall will block sound. While thinner walls might be adequate for higher frequencies, thicker walls with more mass are better in attenuating low-frequency sounds with longer wavelengths. Methods like staggered stud framing or double stud construction can also aid in reducing the impact of resonance frequencies and separating sound transmission routes (Mike, 2023).

(c) The choice of insulation types available:

In order to reduce the amount of sound that travels through, ceilings, floors, and walls, insulation is essential. Sound wavelength and frequency are important factors to take into account when choosing the right insulation type.

Different types of insulation materials have ratings for their ability to absorb sound in a range of different frequencies. For instance, insulation materials such as mineral wool or foam which are usually denser may be needed to deal with lower frequencies like traffic noise or HVAC rumbling. Whereas insulation that's made from fibreglass is efficient at reducing high-frequency noises such as people talking and telephones (Baker, 2019).

The ability of insulating materials to absorb sound at particular wavelengths is influenced by their density and thickness. Selecting a thicker insulation material would prove more efficient in attenuating lower frequencies with longer wavelengths, however selecting an insulation material that is more dense would offer superior absorption over a wider range of frequencies. To provide the best sound control in environments where a larger range of frequencies need to be handled, like recording studios or home theatres, a variety of different insulation materials could be required (Baker, 2019).

In conclusion, having a good understanding of frequency and wavelength of sound is a crucial for a number of building design, construction, and insulation processes. Designers and engineers can build environments that are acoustically pleasing, structurally sound, and supportive of well-being and productivity by taking these factors into account.

Part 2:

(a) Define Thermal Transmittance and Thermal Resistance and explain the relationship between these two parameters when calculating heat loss through the building's fabric:

Thermal transmittance, most commonly known as U-value, is the rate of heat transfer through a structure divided by the difference in temperature across that structure. Essentially it measures how easily heat can flow through a structure or material. Thermal transmittance is measured using the units of watts per square meter per Kelvin ($\text{W/m}^2\text{K}$). If a building is well insulated, then its U-value will be lower. This is because it shows that the material can resist heat transfer more effectively. On the other hand, a greater U-value suggests inadequate insulation, meaning that more heat is able to travel through the material. The standard of workmanship and installation can have a great affect on thermal transmittance. When insulation isn't fitted up to a good standard this can cause gaps and cold bridges, which effectively increases the thermal transmittance higher than wanted. Heat loss from conduction, convection, and radiation is considered in thermal transmittance. (Lymath, 2015)

Various factors can influence the U-value of a material or a structure such as material thickness and composition. When evaluating the thermal performance and energy efficiency of a building, taking into consideration the U-value of building elements such as walls, roofs, windows, and doors are crucial. Often you will find that building regulations include specific U-value criteria to guarantee that the building's thermal performance is up to standard and to reduce heat loss in buildings. It is very important that architects and engineers have a good understanding and take U-values into consideration when designing and building. This is crucial as they can create better efficient environments, reduce running expenses and consume less energy.

Thermal resistance, known as R-value, is the measurement of how difficult it is for heat to be transferred through a structure or a material. The temperature difference between two points and the heat flow between them, the amount of heat flow per unit time, is the representation of thermal resistance. Simply, the higher the R-value is the more difficult it is for heat to be transferred, meaning a higher thermal resistance (Application Note Thermal Design (Basic) Basics of Thermal Resistance and Heat Dissipation, 2021). Better insulating qualities are indicated by a greater R-value, which denotes that the material or structure resists heat transfer better and lowers the rate of heat flow. In contrast, a lower R-value represents bad insulation, meaning that heat can pass through a material or structure much easier.

When calculating R-values it is important to take factors such as material, thickness, composition and conductivity into consideration. R-value is shown using the units of square meter Kelvin per watt ($\text{m}^2\text{K/W}$). When assessing the thermal performance and energy efficiency of building elements including insulation, walls, roofs, windows, and doors, R-value calculations are crucial (Designingbuildings.co.uk, 2018).

Building regulations will include different R-value requirements for different elements of the building to make sure they are energy efficient. It is essential that architects and engineers have a very good understanding of R-values so that they can design and construct buildings that have good thermal comfort, reduce energy consumption for elements such as heating and cooling, and ensure a sustainable environment.

The measurement of negative heat transfer from an interior of a building to an exterior one is called heat loss. Convection, conduction, radiation, mass transfer, or a combination of these may be to blame for this. If the temperature outside is cold, and the temperature inside is warmer, with poor building fabric thermal insulation the heat loss will be more. Usually heat loss is measured in kilowatts (kW) (Designingbuildings.co.uk 2018a).

According to building regulations appropriate measures must be taken to reduce heat gains and losses through the structure of newly constructed building and renovations to already existing buildings. You will find that there are limiting standard set by building regulations in terms of maximum U-values, which are outlined in official documents (Designingbuildings.co.uk 2018a).

Usually, the older the building is the more heat it will lose, this can be caused by poor insulating, thermal bridging, single glazing windows and air gaps. Heat loss levels depends

on the type of building, for instance a terraced house will lose more heat energy through its floor and roof rather than its walls. Whereas in a flat most of the heat loss will be through its outside walls. Having good insulation installed properly and double glazed windows can reduce the amount of heat loss in buildings (Designingbuildings.co.uk 2018a).

The U-value is the reciprocal of the R-value. The relationship between the U-value and R-value is inverse, which means $U=1/R$, $R=1/U$. The parameters of both the U-value and R-value are very important when it comes to calculating the heat loss through a building's fabric.

To calculate the rate of heat loss through a building's fabric for any temperature difference between the faces, the U value is multiplied by the area and the temperature differences. As shown in the equation below:

Heat loss = U value x Area x Temperature difference

$$P = U \times A \times (\theta_1 - \theta_2)$$

The units for the calculation of heat loss are Watts.

The affect this has on insulation is that better insulation is demonstrated by lower U-values and higher R-values. Therefore, lesser heat loss is achieved by structures or materials with higher R-values. On the other hand, higher U-values and lower R-values indicate inadequate insulation and increased heat loss.

In conclusion, it is critical to fully understand the inverse relationship between thermal transmittance (U-value) and thermal resistance (R-value) when evaluating heat loss through a building's fabric. Greater heat loss and poorer insulation are indicated by higher U-values and lower R-values, whereas lower U-values and higher R-values indicate better insulation.

- (b) Illustrate, by means of your own supporting diagram, how Thermal Conductivity is measured, and explain why 'material type' and 'distance' are contributory factors in this calculation.**

Thermal conductivity, known as K-value or lambda, is the measure of the rate that temperature differences travel through a material under specified conditions. A material is more effective as an insulator when its thermal conductivity is lower because it slows down the rate at which temperature differences pass through it. In general, less energy is needed to keep interior conditions comfortable the lower the building's fabric thermal conductivity is. Thermal conductivity is measured in watts per meter kelvin (W/mK) (Designingbuildings.co.uk, 2016).

The coefficient of thermal conductivity (lambda or K-value) is measured at the rate of heat flow in watts across a thickness of 1m of material for a temperature difference of 1 degree Kelvin and a surface area of 1 metre squared. This can be shown in the following equation:

$$\text{Rate of heat flow (conductivity)} = H / t = \lambda \times A \times (\theta_1 - \theta_2) / d$$

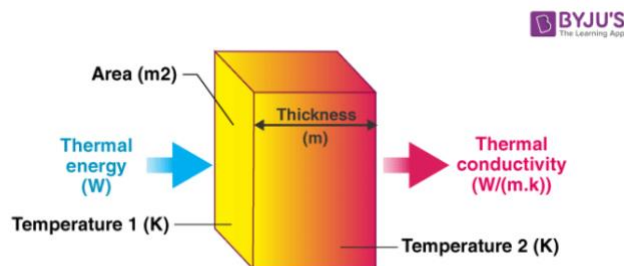
H/t = rate of heat flow (conductivity) between the faces ($J/s = \text{Watt}$)

λ = coefficient of thermal conductivity for that material (Watt/mK)

A = cross sectional area of the sample (metres squared)

$(\theta_1 - \theta_2)$ = temperature difference between the faces (degrees Celsius or kelvin)

D = distance between the faces (m)



(BYJU'S, 2016)

Above is a diagram of how thermal conductivity is measured. To set up this measurement a constant heat source is applied to one end of the material being tested. Temperature sensors are then placed along the material at regular intervals. Insulation is provided at the sides of the material to ensure no heat is lost. A thermal guard is placed between the heat source and the material being tested to stop any direct contact between them. The experiment is conducted in a controlled environment to stop any effects on the heat transfer.

The measurement process is fairly simple as the difference in temperature is calculated by recording the temperatures at the different sensors. This information is then applied in the rate of heat flow formula shown above the diagram.

Materials influence thermal conductivity because of their molecular and atomic structures being different. Higher thermal conductivity materials facilitate easier heat movement, while lower thermal conductivity materials obstruct heat flow. Consequently, the measured thermal conductivity is directly influenced by the kind of material being examined (Team Xometry, 2023).

The rate of heat transmission is dependent on the distance between the temperature sensors and the heat source being applied. Shorter distances can cause temperature gradients to be steeper, which accelerates heat transfer and increases thermal conductivity. On the other hand, a greater distance lowers the temperature gradient, which slows down heat transfer and lowers the thermal conductivity. Thermal conductivity is therefore

influenced by the distance between the heat source and the temperature sensors (Goering, 2010).

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