Loughborough University

Indoor Environment
23CVB117

Semester 2 2024 | In-Person Exam Paper

This examination is to take place in-person at a central University venue under exam conditions. The standard length of time for this paper is **2 hours**.

You will not be able to leave the exam hall for the first 30 or final 15 minutes of your exam. Your invigilator will collect your exam paper when you have finished.

Help during the exam

Invigilators are not able to answer queries about the content of your exam paper. Instead, please make a note of your query in your answer script to be considered during the marking process.

If you feel unwell, please raise your hand so that an invigilator can assist you.

You may use a calculator for this exam. It must comply with the University's Calculator Policy for In-Person exams, in particular that it must not be able to transmit or receive information (e.g. mobile devices and smart watches are **not** allowed).

Answer **THREE** questions.

All questions carry equal marks.

Continues/…

1. a) What is the definition of a heatwave in the UK and how are heatwaves changing due to climate change? [2 marks]

   b) State two demographic groups that are particularly vulnerable to the negative health effects of high indoor temperatures. For one of these groups discuss three reasons why they are more at risk. [5 marks]

   c) Hourly operative temperatures in a living room and a bedroom of a house were recorded for a year (365 days). The number of annual occupied hours in which operative temperatures in each room exceeded different temperature thresholds are given in Table Q1c. Show with calculations whether each room was overheated or not according to the CIBSE static criteria. Assume the occupied periods to be between 08:00 to 22:00 for the living room and between 23:00 to 07:00 for the bedroom every day of the year. [6 marks]

Table Q1c: Number of annual occupied hours in which operative temperature exceeded different temperature thresholds.

Temperature threshold (°C)	Living room	Bedroom
	Number of annual occupied hours in which operative temperature exceeded the temperature threshold	Number of annual occupied hours in which operative temperature exceeded the temperature threshold
26	100 hours	32 hours
28	65 hours	10 hours
30	35 hours	0 hours

   d) The measured daily means of the external temperatures for a location are given in Table Q1d.

      i) Calculate the exponentially weighted running mean of outdoor temperature according to BS EN 15251 for 1st July. Assume α=0.8. [3 marks]
      ii) Calculate the comfort temperature for a naturally ventilated room in an existing building in this location. [3 marks]
      iii) Calculate the suggested acceptable temperature range for this room if occupied by very sensitive persons. [3 marks]
      iv) Calculate the suggested acceptable temperature range for this room if occupied by people with a moderate level of expectation. [3 marks]

Table Q1d: Daily means of the external temperatures (°C)

Date	Daily mean of external temperature (°C)	Date	Daily mean of external temperature (°C)
24th June	21.0	**1st July**	21.5
25th June	20.5	**2nd July**	18.5
26th June	20.3	**3rd July**	19.5
27th June	19.0	**4th July**	18.5
28th June	19.5	**5th July**	18.0
29th June	20.2	**6th July**	17.5
30th June	20.5	**7th July**	17.0

Question 1 continues/…

e) Name two approaches to assess overheating risk in buildings. Discuss one advantage and one disadvantage of using each approach. [4 marks]

f) In simple terms, explain what causes overheating in dwellings and three passive strategies that can be used to reduce the likelihood of overheating in existing UK dwellings. [4 marks]

2. a) Briefly explain what is “sick building syndrome”? [3 marks]

b) Give an example of health risk associated with exposure to poor indoor air quality.

i) In the short-term
ii) In the long-term [2 marks]

c) What is the difference between infiltration and ventilation and name two of their drivers in buildings. [3 marks]

d) Compare the measurement techniques below by completing Table Q2d. You must report your answers in the answer book. [5 marks]

Table Q2d, Tracer gas method and blower door test comparison

	Tracer gas	**Blower door**
Measurement	Ventilation and infiltration	Air permeability
Safety		
Speed		
Ease		
Influenced by weather		
Leak finder		

e) The infiltration rate of a house using the ASHRAE Basic infiltration estimation model was calculated as 1 air changes per hour. Calculate the effective leakage area at 4 Pa. The house has a volume of 150 m^3. The mean indoor temperature is 20 °C. The mean outdoor temperature is 5 °C. The wind speed is 1 m/s. The house has two storeys. The house has no obstructions or local shielding. See Table Q2e for stack and wind coefficients. Show your working. Report your answer to 2 decimal places. The correct units are in m^2. [10 marks]

Question 2 continues/…

Table Q2e, Stack and wind coefficients

	House Height (Stories)		
	One	**Two**	**Three**
Stack coefficient	0.000 145	0.000 290	0.000 435

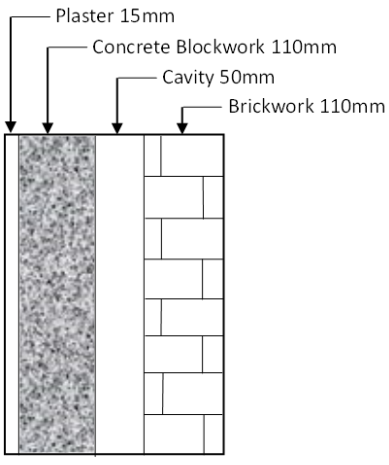
Shelter Class	**Description**
1	No obstructions or local shielding
2	Typical shelter for an isolated rural house
3	Typical shelter caused by other buildings across street
4	Typical shelter for urban buildings
5	Typical shelter produced by buildings immediately adjacent

Shelter Class (Wind coefficient)	**House Height (Stories)**		
	One	**Two**	**Three**
1	0.000 319	0.000 420	0.000 494
2	0.000 246	0.000 325	0.000 382
3	0.000 174	0.000 231	0.000 271
4	0.000 104	0.000 137	0.000 161
5	0.000 032	0.000 042	0.000 049

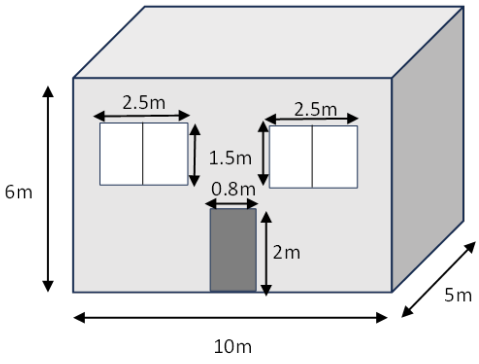
f) The ventilation rate of a single zone building using the carbon dioxide (CO_2) decay method was calculated as 0.5 air changes per hour. The CO_2 concentration at the start of the test was 4000 ppm. The decay occurred over a 3-hour period during which time there was no additional input of CO_2. Calculate the CO_2 concentration at the end of the test. Assume homogeneous distribution of CO_2 in the space. Ambient CO_2 concentration is 430 ppm. Show your working. [10 marks]

3. a) Calculate the U-value of the external wall given in Figure Q3a. Thermal properties of construction materials are given in Table Q3. [5 marks]

Figure Q3, a) external wall make up; b) building geometry.



(a)



(b)

Question 3 continues/…

Table Q3, Thermal properties of external wall

Material	Conductivity (W/mk)	Thermal Resistance (m^2K/W)
Internal surface	-	0.13
External surface	-	0.04
Plaster	0.5	-
Concrete blockwork	0.32	-
Cavity (50mm)	-	0.44
Brickwork	0.84	

b) Calculate the Heat Transfer Coefficient of the building given in Figure Q3b. The external wall's make up and properties are the same as in question 3a. There are only two windows (U-value =2.86 W/m^2K) and one door (U-value =3.33 W/m^2K) located at the front of the building. Ventilation rate is 0.75 ACH. Both the ground floor and the roof have U-values of 4 W/m^2K. [7 marks]

c) Estimate the annual gas demand for space heating of the building if it is located in the UK Midlands with an annual heating degree day of 2425 K.days and the heating is provided by a gas boiler with an efficiency of 90%. [6 marks]

d) Explain, with use of a temperature-time graph, how exposed thermal mass in office buildings can reduce summertime overheating and the need for cooling. [6 marks]

e) Name a test, and briefly describe the method, for measuring the following:
   i) The airtightness of a house
   ii) The Heat Transfer Coefficient of a house [4 marks]

f) Name two methods for predicting moisture movement in building materials. [2 marks]

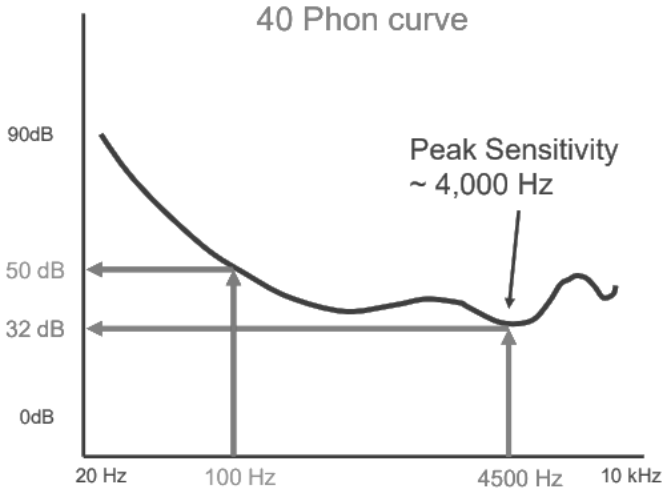
g) Explain three problems that can be caused by excessive moisture in buildings. Include one problem related to water in each of its three phases: solid, liquid and gas. [3 marks]

4. a) Explain the term "Noise Rating (NR)" as used in room acoustics analysis. [3 marks]

b) Explain the equal loudness curve shown in Figure Q4 and what it represents. [3 marks]

Question 4 continues/…

Figure Q4, 40 Phon equal loudness curve



c) A large HVAC fan is located at the ceiling surface of a room and emits sound energy at a rate of 0.1 W. The room is 10.0 m wide by 5.0 m long and has a height of 6.0 m. If (at a particular frequency), the average sound absorption coefficient for the room is 0.15, calculate:

i) The sound power level of the noise source. [2 marks]
ii) The directivity factor, Q, for the noise source. [1 mark]
iii) The room constant, R. [2 marks]
iv) The direct sound pressure level 3.5m from the noise source. [2 marks]
v) The reverberant sound pressure level. [2 marks]
vi) The total sound pressure level. [2 marks]

d) The benefits of daylight which are numerous, have been covered in the second semester of this module. Briefly discuss **two** of the principal benefits of daylight in relation to health, wellbeing, and energy use. You can refer to any of the aspects covered in the class, or to the content discussed in Chapter 2 ‘Daylighting’ of the SLL (Society of Light and Lighting) Handbook. [3 marks]

e) In the context of the issue of climate emergency and the increasing events of heatwaves. ‘shading’ has been described as an urban necessity. List and define **four types** of the **rigid screens** commonly used in buildings. [4 marks]

f) A group of students calculated the average daylight factor of one of their classrooms using the equation below. They calculated the average daylight factor at 1.5%.

i) Define all the symbols used in the equation below. [3 marks]

$$\overline{DF} = \frac{TW\theta M}{A\left(1 - R^2\right)}$$

Question 4 continues/…

ii) Discuss whether the above percentage calculated is satisfactory with the reference to the British Standard. You can paraphrase or quote the standard in writing your response. [2 marks]

g) A luminaire has a luminous intensity of 1500 candela and acts a point source. Calculate the illuminance produced on surfaces at the following distances:

i) at 2.5 m distance from the luminaire [2 marks]
ii) at 5 m distance from the luminaire [2 marks]

A Beizaee
S Al-Maiyah