Loughborough University

Indoor Environment
22CVB117

Semester 2 2023 | 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) Hourly operative temperatures were measured for a year in four different rooms. Which of these four rooms listed in the Table Q1 were overheated according to the CIBSE Guide A static criteria? Explain why? [6 marks]

Table Q1, Percentage of annual occupied hours at different operative temperatures

Room number	Room type	Percentage of annual occupied hours above 26 °C	Percentage of annual occupied hours between 26 °C and 28 °C	Percentage of annual occupied hours above 28 °C
1	Living room	3.5%	3%	0.5%
2	Bedroom	2%	2%	0%
3	Living room	3%	1.5%	1.5%
4	Bedroom	0.5%	0.5%	0%

b) Using the adaptive approach for assessing overheating risk in buildings, calculate the acceptable operative temperature range for a naturally ventilated building for each category below. The exponentially weighted running mean of outdoor temperature (Trm) is 18 °C. Show your working.

i) Normal level of expectation. [3 marks]

ii) High level of expectation when the space is occupied by very sensitive and fragile persons. [3 marks]

c) Describe how each of the factors below would influence overheating in buildings.

i) Urban heat island; [2 marks]
ii) Building type (e.g. flats); [2 marks]
iii) Window type and size; [2 marks]
iv) The occupants. [2 marks]

d) Describe three passive strategies that can be considered at the design stage to reduce the likelihood of overheating in UK buildings. [6 marks]

e) Dynamic thermal models are used to simulate and predict overheating.

i) What is an advantage and a disadvantage of using dynamic thermal models compared to simple early-stage checklists to assess overheating? [2 marks]

ii) Name two external errors associated with dynamic thermal models. [2 marks]

iii) Explain why is it preferable to incorporate overheating mitigation measures at design stage? [3 marks]

Continues/…

2. a) What are **FOUR** pollutants that may be emitted to the air when cooking on a gas stove? [4 marks]

b) Why do we need ventilation in buildings? Describe **TWO** ways air may enter a building via ventilation. [4 marks]

c) In mechanical ventilation systems name **ONE** attribute of the ductwork which affects the efficiency of the system. [1 mark]

d) Calculate the minimum required total window opening area for a hinged or pivot window with an opening angle of greater than or equal to 30 degrees. The floor area of the room is 13 m^2. Use Part F guidance. Include the correct units. [2 marks]

e) Calculate the required ventilation rate for a new dwelling using the overriding minimum ventilation rate in Part F. The floor area of the dwelling is 85 m^2. Include the correct units. [2 marks]

f) Estimate the infiltration rate of a building using the ASHRAE Basic infiltration estimation model. The mean indoor temperature is 21 °C. The mean outdoor temperature is 9 °C. The wind speed is 1.5 m/s. The house has a volume of 200 m^3 and an effective air leakage area of 700 cm^2. The building has three storeys. The building is sheltered by buildings immediately adjacent. See Table Q2 for stack and wind coefficients. Show your working. Report your answer to 2 decimal places. The correct units are air changes per hour (ach). [10 marks]

Table Q2, 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

Question 2 continues/…

g) Calculate the ventilation rate of a single zone building using the carbon dioxide (CO_2) decay method. The CO_2 concentration at the start of the test is 4000 ppm. At the end of the test the CO_2 concentration is 1140 ppm. The decay occurred over a 4-hour period during which time there was no additional input of CO_2. Assume homogeneous distribution of CO_2 in the space. Ambient CO_2 concentration is 430 ppm. Round your answer to two decimal places. Show your working. [10 marks]

3. a) A rectangular open-plan office has two external walls, one 10.0 m long, and a second, 6.0 m long; the office has a floor to ceiling height of 2.5 m. The external walls are constructed from layers of plasterboard, concrete blockwork, insulation, and an external render. The two remaining walls form internal partitions. The adjacent rooms, and the rooms above the office ceiling, and below the office floor are maintained at the same temperature as the office. The external façade is 25% glazed, and the office is ventilated at a rate of 1.2 ACH. The office is maintained at an internal air temperature of 21.0 ^oC when the external air temperature is 5.0 ^oC. Using the room data given here, and the thermal properties given in Table Q3, calculate:

i) the U value for the external wall construction; [8 marks]
ii) the U value of the glazing; [3 marks]
iii) the rate of steady-state heat transfer through the external wall and glazing; [6 marks]
iv) the heating demand resulting from the ventilation; [4 marks]
v) the total steady-state heating demand. [2 marks]

Table Q3, Thermal Properties of Construction Materials

Material	**Thickness (mm)**	**Conductivity (W/mk)**	**Thermal Resistance (m^2K/W)**
Internal surface	-	-	0.13
External surface	-	-	0.04
Plasterboard	12.5	0.21	-
Concrete blockwork	180.0	1.3	-
Polystyrene insulation	85.0	0.033	-
Render	13.0	0.22	
Double glazing	-	-	0.35

b) The order of the construction layers in the wall in Q3 a) is from the inside surface to the outside surface: plasterboard, concrete blockwork, insulation, and render. Explain how, and why, the thermal performance of the wall and room air might change if the order of the insulation and concrete blockwork was reversed (so that the concrete blockwork was closer to the inside surface). [10 marks]

Continues/…

4. a) A designer has specified that a room should have an acoustic rating no higher than NC 25. Table Q4a, gives the average sound pressure levels measured in the room. Using the measured data and the NC sound pressure levels given in Table Q4b:

i) evaluate the NC rating for the room. [4 marks]
ii) identify the octave bands in which the noise level must be attenuated in order to meet the NC25 criteria. [3 marks]

Table Q4a, Sound pressure level

Octave Band (Hz)	63	125	250	500	1000	2000	4000	8000
Measured sound pressure level (dB)	36	40	45	45	36	33	28	25

Table Q4b, NC values

Frequency (Hz)	**NC-25**	**NC-30**	**NC-35**	**NC-40**	**NC-45**	**NC-50**
63	54	57	60	64	67	71
125	44	48	52	56	60	64
250	37	41	45	50	54	58
500	31	35	40	45	49	54
1000	27	31	36	41	46	51
2000	24	29	34	39	44	49
4000	22	28	33	38	43	48
8000	21	27	32	37	42	47

b) A noise source is positioned in the corner of a room and emits sound energy at a rate of 0.005 W. The room is 3.0 m wide by 3.0 m long and has a height of 3.0 m. If the average sound absorption coefficient for the room is 0.5, calculate:

i) the sound power level at the noise source [1 mark]
ii) the directivity factor, Q, for the noise source [1 mark]
iii) the room constant, R [3 marks]
iv) the direct sound pressure level 2.0m from the noise source [2 marks]
v) the reverberant sound pressure level [1 mark]
vi) the total sound pressure level 2.0m from the noise source. [2 marks]

Question 4 continues/…

c) Define the term ‘daylight factor’ used in room daylighting analysis? [2 marks]

d) Define all the symbols used in average daylight factor formula given below that are required for the calculation. [3 marks]

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

e) Explain the rationale behind the traditional reference to vitamin D as the ‘sunshine vitamin’? [3 marks]

f) A source of light has a spherical intensity of 110 cd. One-quarter of the total flux emitted from the source falls at right angles onto a table measuring 2.5 m by 1 m.

Calculate:

i) The total luminous flux given out by the source. [4 marks]

ii) The illuminance produced on the surface. [4 marks]

A Beizaee
B Roberts
J Wright
S Al-Maiyah