ENGINEERING TRIPOS PART IIB
ELECTRICAL AND INFORMATION SCIENCES TRIPOS PART II
ENGINEERING TRIPOS PART IIA

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Friday 2 May 2003 2.30 to 4

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Module 4D11

BUILDING PHYSICS

*Answer **one** question from **each section**.*

*All questions carry the same number of marks.*

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

**You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator**

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SECTION A

1 (a) Fig. 1 shows a sectional elevation of a cubic room of internal side length 3 m, giving U-values in $\mathrm{W/m^2\,K}$ for floor, roof and walls away from the window. In winter a heating system maintains the internal temperature $T_{ei}$ at 20 °C when the external temperature is −5 °C. If the internal and external surface resistances of the glass are 0.12 and 0.08 $\mathrm{m^2\,K/W}$ respectively, and the thermal resistance of the glass itself may be neglected, what is the maximum area of double glazing that can be permitted if the total fabric heat loss is not to exceed 600 W? [30%]

(b) In summer the heating system is turned off, but electrical equipment adds 500 W of casual gains into the room. If total double-glazed window area 1.5 $\mathrm{m^2}$ has been provided, what rate of air change is required to maintain an internal air temperature no greater than 25 °C when the external temperature is 20 °C? You may assume for this example that $T_{ei} = T_{ai}$, but should discuss what differences between these two temperatures might in practice arise and how they would affect the calculations. [35%]

List other factors which might affect the desirable rate of air change, and briefly describe how the required rate might be calculated in each case. [15%]

(c) Discuss briefly what other factors might need to be considered in designing the heating and cooling systems for such a room. What steps could be taken to improve the thermal environment during the summer, without excessive use of energy? [20%]

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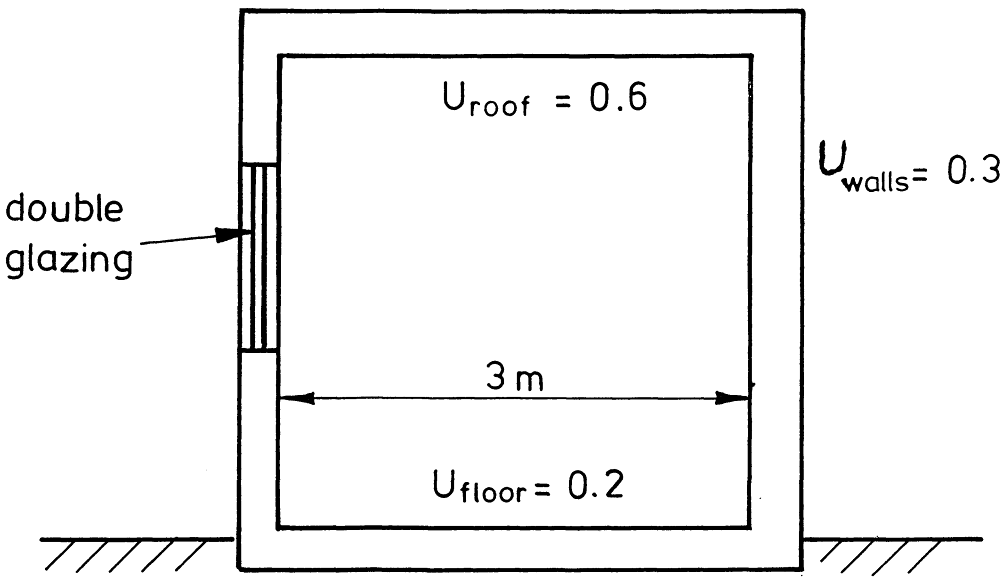


Fig. 1

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2 A sectional elevation through a bathroom is shown diagrammatically in Fig. 2.

(a) Using the formulae on the sheet of Environmental Data, and taking the coefficients of discharge (the same at the two openings) and wind pressure to have their usual symbols and meanings, show that the rate of ventilation into the room due to external wind velocity $U$ is given by

$$Q = C_d\ U\ A_w \left(C_{p1} - C_{p2}\right)^{1/2} \quad \text{where} \quad A_w{}^2 = A_1{}^2 A_2{}^2 \Big/ \left(A_1{}^2 + A_2{}^2\right).$$ [40%]

(b) What is the minimum wind velocity needed to prevent condensation on the ceiling of the bathroom given the following conditions? The U-value of the roof is 2.0 $\mathrm{W/m^2\,K}$. The temperatures outside the room are 10 °C dry bulb and 8 °C wet bulb; and the temperature inside is maintained at 20 °C dry bulb. The inside surface resistance of the ceiling is 0.1 $\mathrm{m^2\,K/W}$ and $1.0 \times 10^{-4}$ kg/s of moisture is liberated into the room. Coefficients $C_d = 0.6$, $C_{p1} = 0.8$ and $C_{p2} = -0.1$; and the effective area $A_w = 0.1\ \mathrm{m^2}$. Assume that the density of air is 1.2 $\mathrm{kg/m^3}$. [40%]

(c) Discuss briefly what other factors should be considered in designing such a bathroom against condensation, and what steps might be taken to improve the situation. [20%]

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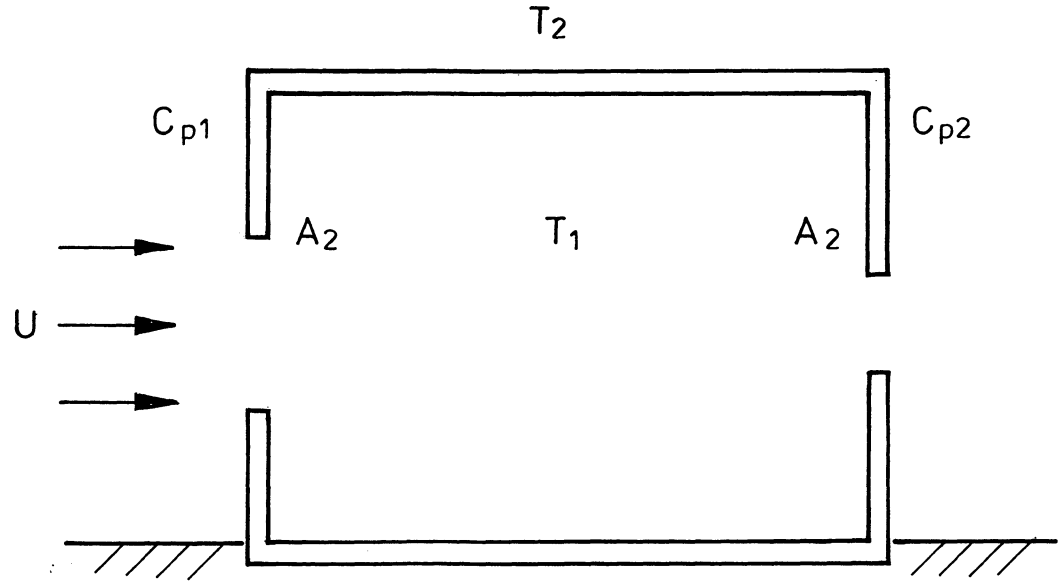


Fig. 2

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SECTION B

3 A proposed orchestral rehearsal hall is to have a volume of $3000\ m^3$. Twenty four 'cupboards', 1 m wide and 10 m tall, made from 38 mm thick medium-density fibreboard, are to be distributed around the perimeter of the room. The cupboards are to be 200 mm deep overall and filled with mineral wool, giving a mid-frequency absorption coefficient of 1.0. With the cupboard doors closed the reverberation time of the empty hall is 3.0 s.

(a) Propose rough dimensions for the hall, which is to be rectangular in plan and section, and discuss the absorption in the empty hall. [20%]

(b) Calculate the reverberation time of the empty hall with all the cupboard doors completely open: ignore for this purpose the absorption of the wall behind the cupboard doors and the thickness of the cupboards themselves, but discuss briefly whether this is reasonable. [20%]

(c) The hall is to be used for a wide variety of events. Discuss the ideal position of the cupboard doors and the resulting reverberation time for the following conditions, with the amounts of additional acoustic absorption ($m^2$) during the event shown below:

| | |
|---|---|
| drama rehearsal | 10 |
| drama performance with audience | 160 |
| orchestral rehearsal | 80 |
| orchestral performance with audience | 240 |

[40%]

(d) Explain why an acoustic engineer might well ask for the doors to the cupboards to have a curved cross-section in plan. [10%]

(e) Explain why the cupboards would be constructed from such thick and dense material. [10%]

4 (a) The specifications for the acoustic design of a large open-plan office and a lecture theatre contain the following information:

| | Open-plan office | Lecture theatre |
|---|---|---|
| Reverberation time (s) | 0.6 | 1.0 |
| Background noise level | NR40 | NR25 |
| Ceiling | absorbent throughout | absorbent rear third |
| Doors R (dB) | 25 | 40 |
| Maximum internal noise level (dBA) | 85 | 90 |

Explain the units used in the specifications, comment on the values given, and outline the reasons for the differences between the specifications for the two environments. [70%]

(b) The open-plan office is to be constructed with a raised floor and a suspended ceiling. Two adjacent individual offices for confidential discussions are to be constructed within the open-plan office. Describe the measures required to ensure adequate sound insulation between the individual and open-plan offices. [30%]

SECTION C

5 (a) Describe briefly the three components of 'daylight factor' and discuss the issues that affect optimising each component in the development of a new office. [25%]

(b) Figure 3 shows a cross-section through a typical deep-plan ground-floor office in a long 2-storey building with a glazed central atrium. The office is 3.5 m high and has similar windows on to the atrium and to level open country at the opposite end. The single central window at each end is to be 1.5 m high, covering 40% of the facade, with a sill height of 1.0 m and transparency 72%. The average internal reflectance is 45%.

Sketch curves of total daylight factor and its various components across the 10 m depth of the office, on a line at sill height down the centre, and estimate the daylight factor at points inside the office 2.0 m from the window, (i) on to open country and (ii) on to the atrium. [55%]

(c) Suggest zones for the lighting control system in the office, and describe briefly how to estimate lighting energy use per year, in a zone with 2.5% daylight factor and simple automatic on-off switching, assuming a standard requirement of 300 lux. [20%]

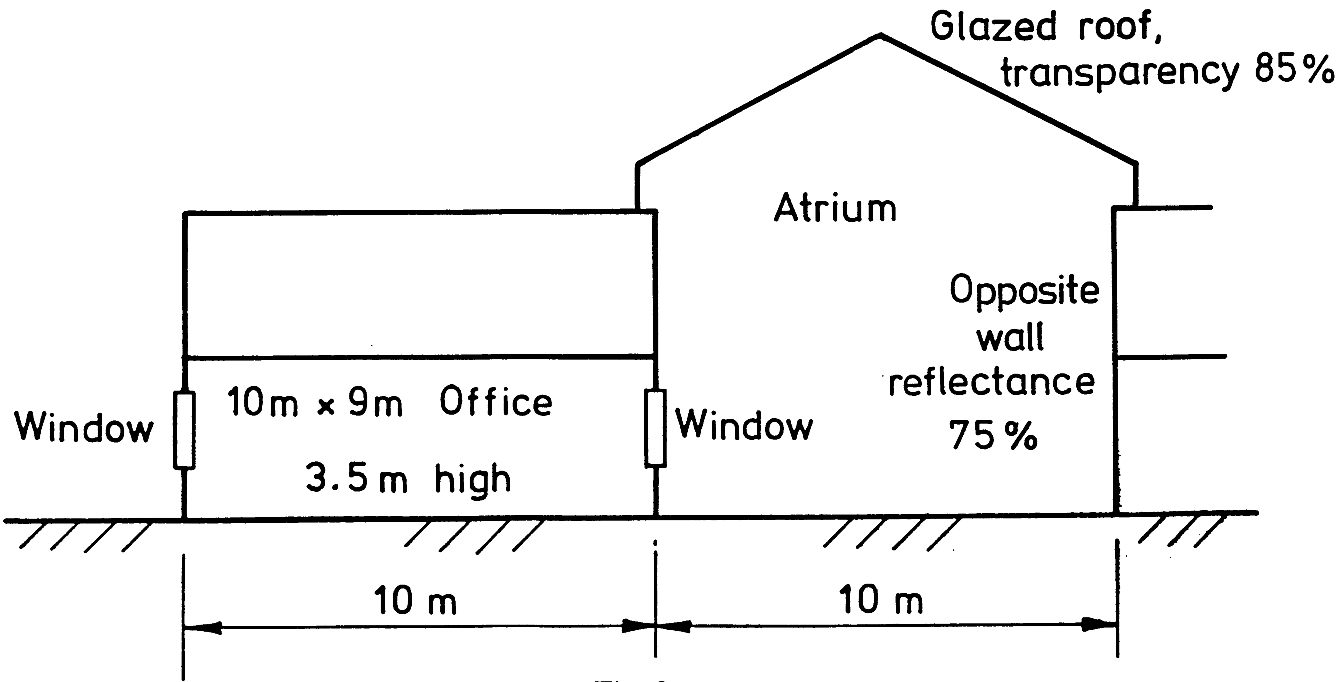


Fig. 3

6 (a) Discuss the likely differences between the lighting designs for

(i) a stockbrokers' dealing floor and

(ii) a primary school classroom.

In your answer you should consider design specifications, choice of lamps and fittings, energy efficiency, natural light, and any other relevant matters. [60%]

(b) Estimate the number of fittings required for a $10\ \text{m} \times 9\ \text{m}$ dealing floor, using typical 32 W fluorescent tubes with efficiency 85 lm/W and utilisation factor 70%. [20%]

(c) Estimate the likely lighting power requirements, in $\text{W/m}^2$, for the two main lighting strategies discussed in part (a). [20%]

**END OF PAPER**