2007 IIB 4D11 Dr C T Morley
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Solution to 1

(a) $\frac{1}{U} = R_i + \sum r t + R_e$

0.123 ~~1.13 × 0.~~ $\frac{1}{1.13} \times 0.14$ $\frac{1}{0.77} \times 0.1$

$\frac{1}{0.045} \times 0.1$ + 0.08 total 2.678

$\therefore$ $U = 0.373$ W/m²K

[20%]

(b) (i) casual heat gain: $10 \times \frac{10}{24} \times 100$ = 417 W

solar gain: $8 \times 207 \times 0.62$ = 1,027 W

1,447 W

$Q_c = \sum UA$ = 8 × 2.9 + 312 ~~5 × 64~~ × 0.373 = 140 ~~119~~ W/K

$Q_v = 5 \times 8 \times 64 \times \frac{1200}{3600}$ = 853 W/K

993 W/K.

$\therefore$ temp. increment = 1.46 C

$\therefore$ mean environ. temp = 18.7 + 1.46 = 20.2 C

[30%]

(ii) swing in solar gain: $8 \times 561 \times 0.44$ = 1,975 W

swing in casual gain: 1000 − 417 = 583

Q_g = 8 × 2.9 + 853 = 876 × 5.8 = 5,082

7,640 W

specific heat loss factor now

$8 \times 3.1 + 312 \times 4.6 + 853 = 2,313$ W/K

$\therefore$ swing in environ. temp $\frac{7640}{2313} = 3.30$ °C

$\therefore$ peak environ. temp : $20.2 + 3.3 = 23.5$ °C

[40%]

Getting quite hot — discuss relative to Fanger etc.

[10%]

Solution to 2

(a) (i) use equation on Data Sheet

$h = 4$

$T_i - T_o = 3$

$$\Delta p = 0.043\, h\, (T_i - T_o)$$

$$= 0.516 \text{ Pa}$$

$$A = \frac{4 \times 4}{\sqrt{32}} = 2.828 \text{ m}^2$$

$$Q = 0.827 \times 2.828 \times (0.516)^{1/2}$$

$$= \underline{1.68 \text{ m}^3/\text{s}} \qquad (= 6048 \text{ m}^3/\text{hour})$$

∴ hourly air-change rate   volume 450 m^3

is $\frac{6048}{450} = \underline{13.5}$ high!

air movement through openings : $\frac{1.68}{4} = \underline{0.42 \text{ m/s}}$

not high

Ventilation heat loss : $1.68 \times 1200 \times 3 = 6.05 \text{ kW}$ *

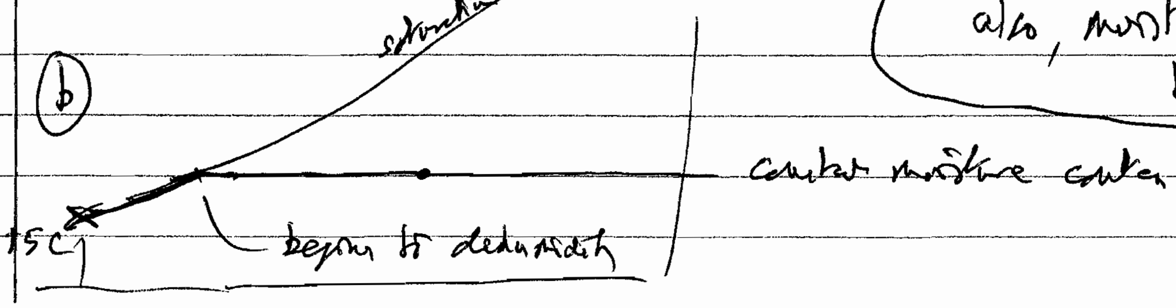
$\frac{m^3}{s}$ $\frac{J}{m^3 K}$ K

[50%]

total internal heat production is 10 kW — so actually the internal temperature would be higher than 25C db.

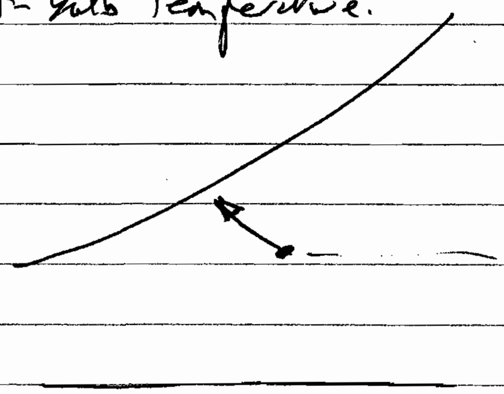
also, moisture added by people?

(b)



water-flow needed.
Look at enthalpy of air in and out.
— difference is heat extracted to water
— hence flow-rate required to keep temp-rise to 1°C
[25%]

(c) water is sprayed in at 19 C, which is exactly the wb temp. of the external air. So the air would travel along the line of constant wet-bulb temperature.



Not so effective at reducing db temp of air — and also is adding moisture.

So the cooling coil would be preferable, as it alters the db temp. of air much more, and removes moisture — which is likely to improve comfort for the students. Or, use some combined system, e.g. with bypass of some incoming air. [25%]

* This calculation uses average internal temperature — in fact the air exiting will be hotter than average, so perhaps 6K.

Solution for 3

(a) (i) $V = 14 \times 9 \times 4.5 = 567 \text{ m}^3$

$A = 2 \times 9 \times 4.5 \times 0.02 = 1.62$

$+ 14 \times 4.5 \times 0.10 = 6.3$

$14 \times 4.5 \times 0.05 \quad 3.15$

$14 \times 9 \times 0.05 \quad 6.3$

$14 \times 9 \times 0.15 \quad 18.9$

36.27 m^2

[25%]

$\therefore T = 0.16 \dfrac{V}{A} = 2.5$ secs. (very high for speech)

audience $80 \times 1 \times 0.3 = 24 \text{ m}^2 \Rightarrow T = 1.5$ s still too high.

(b) for $T = 1.1$ s, need $1.1 = 0.16 \times \dfrac{567}{A}$

$\therefore A = 82.5 \text{ m}^2$

$\therefore$ extra (in empty hall) 46 m^2 [15%]

area of back wall: 40 m^2 only

so even if coeff. nearly 1, need more than whole wall.

Also better to have reflection from front part of ceiling — remove acoustic plaster

— to provide say double height to ceiling

3.5m × 9m · plus 4m near rear of side wall.

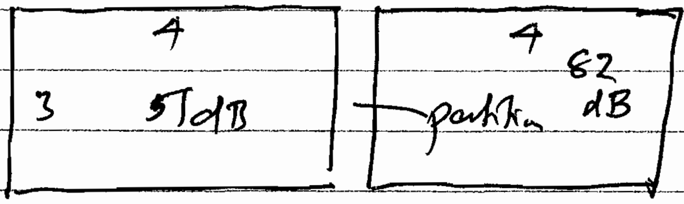
Extra absorption on floor not possible.

? control according to audience [40%]

(c) This refers to first part of lecture course, about the reverberation time of large spaces — e.g. gothic cathedrals, development of chant on one note to improve intelligibility, shoebox halls with better musical characteristics (RT about 2s) and plenty of reflections etc. [20%]

Solution for 4

(a)



equation $\Delta(SPL) = R - 10\log(S/A)$ (Dix Steel)

$$S = 4\times3 = 12\,m^2$$

$$A = 0.2\,(4\times12 + 2\times16) = 16\,m^2$$

$$\Delta(SPL) = 82 - 57 = 31\,dB$$

$$\therefore\ R = 29.75\,dB$$

[38%]

(b) Assumptions: that all sound transmitted between source and receiving rooms is going through the partition – i.e. ignore any flanking paths, through ceiling, floor, ducts etc. Also, white noise being used, incoherent – no coincidence with any natural frequency of the partition.

derivation $R = 10\log\left(\frac{1}{\tau}\right)$ where τ is transmission coeff. (transmitted / incident intensity)

equation follows from considering sound coming through partition being absorbed in receiving room. To allow for door, need to find its transmission coeff and that of rest of wall – hence stress on "average" τ, weighted by areas of the different materials, hence modified R. [35%]

(c) This refers to the lecture by Lewers on the different requirements of different spaces. Meeting room – everyone there to hear clearly, but reasonable sound insulation provided by walls, so probably no need for background noise. Open-plan office – do not wish to hear distant conversations – maybe have reasonable background noise generated to mask distant sounds. For unwalled space within office, probably have partitions, and perhaps a reflector above the meeting table, to keep wanted sound in, and reinforced – while hopefully damping down unwanted sound from the rest of the office. [40%]

Solution to 5

(a) 'Daylight factor' is the ratio of illuminance (in lux) on the horizontal working plane in a room, to the simultaneous illuminance on the horizontal plane due to an unobstructed overcast sky outside. It gives a guide to the use of daylight/natural light in a room — deep rooms having less daylight at the back away from windows. Can be used to help lighting design, topping up daylight with artificial light etc — as to facade, can be used to consider the effect of deep reveals to windows, light shelves, anti-solar-gain blinds etc. [20%]

(b) Daylight factor at a point is hard to calculate (sky component, externally-reflected component, internally-reflected etc) — we need to study whole room to get proper idea — especially if windows on more than one side. More precision, but more effort. Simple formulae for average daylight factor rather crude, take no account of depth/shape of room, reflectance from external obstruction etc.

[20%]

(c) $DF_{ave} = TWdM / (1 - r^2) A_i$

in this case $T = 0.72$, $W = 5.4\ m^2$ $d = 53°$

$M = 0.8$ $r = 0.5$ $\Rightarrow DF_{ave} = \underline{\underline{1.76\%}}$

$A_i = 2 \times 1.75 \times 4.8 + 3 (1.75 \times 2 + 4.8 + 1.8)$
$= 125\ m^2$

[20%]

(d) 300 lux internal, @ 1.76% requires 17,000 lux outside.

$89 + 86 + 82 + 71 + 78 + 57 \times 2 + 27 + 22 + 6 + 4 + 1$

$= \underline{\underline{78\%}}$

[20%]

(e) Altering DF_{ave} without altering total window area:

(i) raise and lengthen window: max length 4.8 m
∴ depth 1.125 ⇒ 56° (only 6% improvement)

(ii) raise maintenance factor — i.e. clean windows

(iii) increase internal reflectance: e.g. to 60% gives 17% better

(iv) have relatively shallower room for same area — may not be possible.

etc.

[20%]

Solution to 6

This question is about the conflict between the need for illumination, to help people view and appreciate art — usually measured in lux on surface — and the fact that light energy can cause deterioration of the exhibits (e.g. loss of colour in water-colour paintings). So architects have struggled with how to resolve this problem. The final lecture by Prof. Steemers is devoted entirely to this matter.

(a) Discussion reasons why light can cause deterioration — and whether it is the maximum intensity, or integral over time which matters. Need also to consider the requirements for display — low background light, so contrast with exhibits even if actual light level on the art is low to limit deterioration. Daylight good for appreciation. [30%]

(b) Two strategies — (i) entirely artificial light, hardly any daylight, special lights on exhibits — with examples: and (ii) using some daylight, because of the better colour rendering and psychological benefits, with special ways of lighting exhibits all carefully engineered. [40%]

(e) More of a historical question — may not appeal to engineers. But they can bring examples from history to bear — all covered in first lecture by Steemers [30%]