D+L

4D11 2005 Solutions

Section A

1. (a) This part is essentially bookwork. From the Data Sheet, for gravity currents etc.

velocity U, for equal area vents, is $\sqrt{g \cdot \frac{\Delta\rho}{\rho} \cdot H}$

In this case H is the height given as h and $\frac{\Delta\rho}{\rho} \simeq \frac{\Delta T}{\overline{T}}$ since to a good approximation the density change (proportional) is equal to the (proportional) temperature change (opposite sign).

Volume flow rate $Q = C_D U A$

whence $Q = C_D A \sqrt{g h \frac{\Delta T}{\overline{T}}}$ as given

where $\overline{T}$ is the mean of T_1 and T_2

(b) Evaporative cooling — almost exactly along a line of constant wet bulb temperature. (constant enthalpy)

From psychrometric chart initial moisture $\cdot 0082$

finally, at 24.25°C, $\cdot\cdot$ $\cdot 0115$

diff. $\cdot 0033$ kg/kg

Then $\Delta T = 32 - 24.25 = 7.75\ ^\circ C$

$\overline{T} = 301.12$ K

$Q = 1 \times 10 \times \sqrt{9.81 \times 30 \times \frac{7.75}{301.12}} = 27.52\ m^3/s$

density $1.2\ kg/m^3$ giving 33 kg/sec

so water sprayed in is 0.109 kg/s

D+S

2. (a) First calculate the U-value.

		W/m²K	m²K/W
internal surface			0.040
masonry 1	$\frac{0.8}{0.075}$ =	10.67 →	0.094
insulation			1.40
masonry 2	$\frac{0.8}{0.1}$ =	8.00 →	0.125
external			0.1
			1.759 m²K/W

∴ "U" value is 0.569 W/m²K

(b) total permitted kWh per annum on budget is $\frac{300}{0.08} = 3750$ kWh.

If 1940 "degree days" in year, total permitted heat loss is so many Watts / degree.

i.e. $\frac{3750 \times 10^3}{1940 \times 24} = 80.54$ W/K

less losses through roof, then 20

subtract 60.54 W/K max.

Obtain proportion x of glazing from, for 64 m² total wall,

$$60.54 = 64x \times 2.2 + 64(1-x) \times 0.569$$

$$\Rightarrow x = 0.231$$

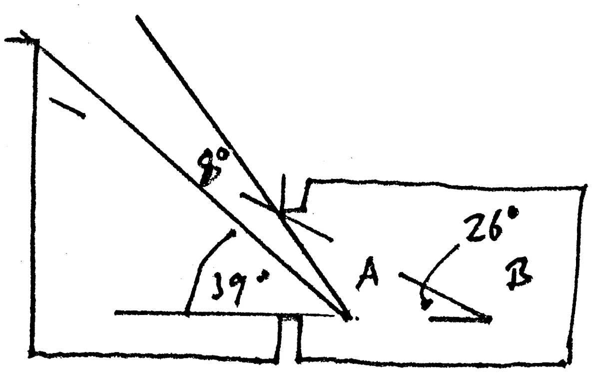
(c) Discussion of temp. profile across wall, similarly vapour pressure or moisture content across wall, hence spot where T can fall below dew point.

Section B : Lighting

3. (a) Here one needs to mention the effect on psychology and workers' health of having daylight available, the aesthetic aspects of natural light, the problem of getting artificial light to give proper colour effects, the need for a natural rhythm set by changing daylight patterns etc. — and especially, the high energy cost of artificial light in building.

For windows, obstructions reduce daylight at back of room, require more artificial light — evaluate by such means as empirical formulae for average daylight factor depending on window area, daylight protractors etc., no-sky line etc. [30%]

(b)



Using daylight protractor: for A,

sky component (long building) : 11 − 7 = 4%

externally reflected " : 7 × 0.2 = 1.4 %

short building correction factors : SC : 0.4 + 0.25 = 0.65

ERC (A) : 0.43 + 0.3 = 0.73 ERC (B) : 0 + 0.32 = 0.32

∴ direct component for A : $4 \times 0.65 + 1.4 \times 0.73$

$= 3.62\ \%$

internally-reflected component : window/surface $= 0.048$

av. reflectance 50%, nomogram, irc $= 1.5\%$ but angle of obstruction converts to 0.6%

∴ total daylight factor at A is $3.62 + 0.6$, <u>say 4.2%</u>

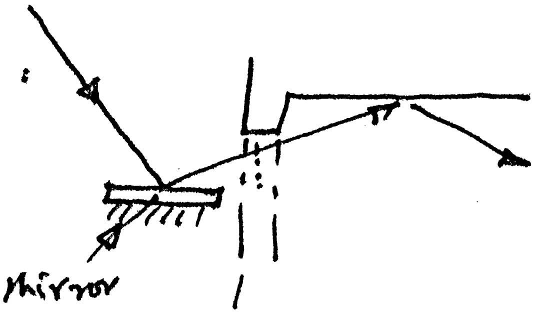
At B, no sky component (obstruction too tall)

externally reflected $2.6 \times 0.2 = 0.52$ [40%]

internal, 1.5% converted to 0.5% $= 0.5$

total <u>1.0%</u> say.

(c) Light shelf :



light from more vertical directions (brighter sky) is reflected into top of room through top of window reflects from (hopefully high reflectance) ceiling — then round room to back. Somewhat outweighed by obstruction to other light — but that from lower angles less bright. Efficacy — discuss in terms of daylight factor, average for room etc

[30%]

D76

4.(a) Output : $K = 10\times 12 / (2.1\times 22) = 2.6$

$\therefore U = 0.72$

Useful output per luminaire is $4400\times 0.72\times 0.8$
$= 2534$ lumens

Required illuminance 500 lux, area 120 m^2

$\therefore$ required lumens 60,000

$\therefore$ no. of luminaires $= \dfrac{60,000}{2,534} = 23.7$

say $\underline{\underline{24}}$

Four rows of six, parallel

(b) Daylight needed for correct illuminance is $\dfrac{500}{0.04} = 12,500$ lux

In March, from sheet 70% exceedance

Switch lights in room automatically according to a daylight sensor outside.

Energy saved during March: 60 lumens/Watt

$$0.7 \times \frac{24\times 4400}{60} \times \left[60\times 60\times \underbrace{8\tfrac{1}{2}}_{\text{hours / working day}} \times \underbrace{22}_{\text{days in month, working}}\right] = \underline{\underline{830\text{ MJ}}}$$

$= \underline{230 \text{ kWh}}$

(c) Museum, and especially art gallery design. Much affected by deterioration of e.g. water colours by light, provoking chemical deterioration of the colours. So need low light levels throughout on paintings, and lower levels for public walking areas, so that the exhibits look good by contrast. Natural light gives better colour rendering — so tendency to have schemes with diffuse daylight on exhibits, level controlled by blinds etc.

Used to think that max. illuminance mattered — so limit to say 150 lux. More recently, realize that it is the light fall integrated over a time period say one year which matters — so can have brighter light for shorter periods.

Typical museum design, well-lit foyer, entrance, sculpture galleries — but darkened areas for paintings, no windows etc.

Section C.

5. (a) This is mainly bookwork. In a room with long reverberation time, sound is reflected back from walls etc and persists. But speech intelligibility requires high frequency sound — persisting echoes can interfere with arriving direct sound, causing confusion, loss of sense. RT measured by having a persistent incoherent noise source in room, suddenly switching off, measuring time for sound pressure level to decay by 60 dB. (or you might time for say 30 dB and extrapolate) — several frequencies. Ideal RT for speech is given on Data Sheet as 1.0 s — contrast to longer times better for music, opera etc (to give richer sound). Other characteristics considered — shape of room (to avoid flutter echoes), early decay time (for first 10dB × 6), early energy fraction (within 50ms of direct sound) etc. Insulation to neighbouring rooms?

(b) Volume 700 m^3 plan 14m × 8m so height 6.25m

Sabine's Law $T = 0.16 \dfrac{V}{A}$

∴ with only absorption on ceiling

at 63 Hz $A_c = \dfrac{0.16 \times 700}{2.2} = 51\ m^2$

at 520 Hz $53.3\ m^2$

(i.e. about 46% absorption coefficient)

panel 0.5 at 63 Hz 0.25 at 520 Hz A_1
porous 0.1 1.0 A_2

∴ for ideal 1.0 s at 63 Hz we require

$$51 + 0.5A_1 + 0.1A_2 = 0.16 \times \frac{700}{1.0} = 112$$

at 500 Hz. $$53.3 + 0.25A_1 + A_2 = 112$$

$$\therefore \quad 5A_1 + A_2 = 610$$

$$0.25A_1 + A_2 = 58.7$$

$$\Rightarrow \quad A_1 = 116\ \text{m}^2 \qquad A_2 = 30.0\ \text{m}^2$$

panel porous

Back wall has area 50 m², side walls each 87.5 m² — so there is room for the 150 m² absorption (just about).

Suggest putting absorption at rear of room, to reduce echoes from back wall taking a long time to arrive, mixed panel and porous, floor to ceiling, rear part of side walls also (avoiding doors etc).

At 63 Hz, $$\bar{\alpha} = \frac{51 + 0.5 \times 116 + 0.1 \times 30}{500} = 0.224$$

absorption $$A = -500 \times \ln(0.776) = 126.8$$

$$\therefore \quad RT = 0.16 \times \frac{700}{126.8} = 0.88\ \text{s}$$

500 Hz. $$\bar{\alpha} = \frac{53.3 + 0.25 \times 116 + 1 \times 30}{500} = 0.224$$

similar.

So according to Eyring we have somewhat too much added absorption — could adjust figures somewhat.

N.B. Mention absorption by audience, empty seating etc — not so far included in the calculations.

6. (a) This is mainly bookwork. For a single source in open air, the sound level will fall off by the inverse square law, as in this question.

$$SPL = SWL - 10 \log 4\pi - 20 \log_{10} r$$

as on data sheet.

For multiple sources in open air, would need to combine the SPL's from each

$$SPL = 10 \log_{10} (I/I_0) \quad \text{where } I = \overline{p}^2/\rho c$$

and so depends on the mean square pressure variation. For <u>incoherent</u> sound, add mean square pressures

i.e. $SPL = 10 \log_{10} ((I_1 + I_2 + I_3)/I_0)$ etc.

Inside a large room, there will be reflections from the walls, multiple ones — which far from the source will dominate the sound, so it will not fall off with distance. Within the so-called "room radius" the direct sound will still predominate — quite close to the source. Direct sound still falling off as inverse square law, added to background due to reverberation.

[30%]

(b) If one unit produces 75 dBA, the addition of a second identical unit will increase sound level by $10 \log 2 = 3$ dB, to 78 dBA. at 10 m distance.

What is noise level at 80 m, without the barrier, say X

$$78 = (SWL - 10\log 4\pi) - 20\log 10 \quad \text{at } 10\text{m}$$

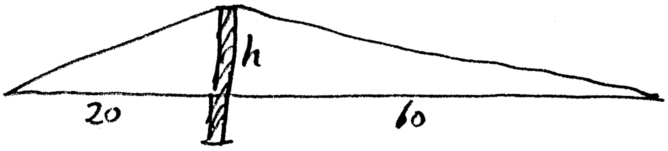
$$X = (SWL - 10\log 4\pi) - 20\log 80 \quad \text{at } 80\text{m}$$

$$\therefore 78 - X = 20\log 80 - 20\log 10 = 18.06$$

$$\text{so } \underline{X \approx 60 \text{ dBA}}$$

So the barrier needs to produce an attenuation of 15 dB to satisfy the criterion given, i.e. it needs to create a path difference of 0.8 m.

There are several possibilities: e.g. in elevation



trial and error: guess $h = 4$ m path 80.53
5 m 80.82 ✓

so this needs a barrier 6.2 m high.

Try 40 m away: $h = 5.7$ m high. ∴ barrier 6.9 m

10 m away: $h = 4$ m path 80.9 barrier about <u>5 m</u>

Then need to consider situation in plan: barrier needs to be 2h wide.

So at 10 m away, a barrier about 8 m long and 5 m high would do the trick

— barriers nearer the source seem to be better.

What about noise reflected to neighbours on other side?

Contract for <u>mass</u> — maybe soil mound, trees etc.