Today, we will:

- Finish our discussion of **Section 3.4 – Hearing and Noise**
- Do some example problems
- Discuss **Section 3.5 – Thermal Comfort and Heat Stress**
- Do some example problems

Example

Given: The noise level of a factory machine is 85 dB at 10 m in free space. = calibrated

To do: Estimate the sound pressure level at a distance of 4.0 ft away when the machine sits in the corner of the building, and all walls are concrete.

Solution:

- First, calc L_p of the machine

Let "c" = calibrated

@ $r_c = 10$ m, $L_{p_c} = 85$ dB @ $Q_c = 1$ (free space)

Eq. 3-27 → $$L_W = L_{p_c} + 20\log_{10}\left(\frac{r_c}{r_0}\right) - 10\log_{10} Q_c + 11.0 \quad (1)$$

L_W = constant, fixed for the acoustic power of the noise source

- Now at the given r

Eq 3-27 $$L_p = L_W - 20\log_{10}\left(\frac{r}{r_0}\right) + 10\log_{10} Q - 11.0$$

- Plug in Eq. 1 for L_W

$$L_p = L_{p_c} + 20\log_{10}\left(\frac{r_c}{r_0}\right) - 10\log_{10} Q_c + 11.0$$
$$- 20\log_{10}\left(\frac{r}{r_0}\right) + 10\log_{10} Q - 11.0$$

Recall $\log(ab) = \log a + \log b$; $\log\left(\frac{a}{b}\right) = \log a - \log b$

So, ☆ $$L_p = L_{p_c} + 20\log_{10}\left(\frac{r_c}{r}\right) - 10\log_{10}\left(\frac{Q_c}{Q}\right)$$

Ans. in variable form

· Plug in #'s → get

$$L_p = 85\,dB + 20\log_{10}\left(\frac{10\,m}{1.219\,m}\right) - 10\log_{10}\left(\frac{1}{8}\right)$$

$$\boxed{L_p = 112.31\,dB}$$

ALWAYS ROUND OFF FINAL dB ANSWER TO CLOSEST dB

$$\boxed{L_p = 112.\,dB}$$

Note: $L_p = fnc(r)$, but $L_W \neq fnc(r)$

SEC. 3.4.4 Sound from Multiple Sources

Note: Since $L_p = L_I$, all eq's for L_I also apply to L_p

Eq. 3.70 →

$$\boxed{L_p = 10\log_{10}\left[\sum_j 10^{\left(\frac{L_{p,j}}{10}\right)}\right]} \;\ast$$

Where $L_{p,j}$ = sound pressure level of sound source j by itself

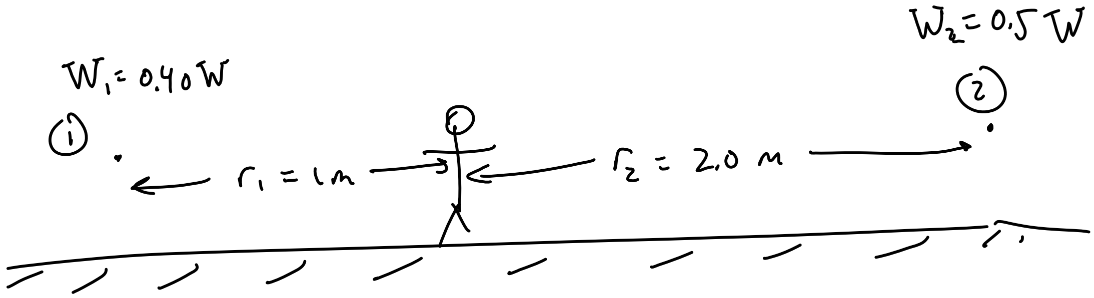
Example

Given: A man stands between two noisy machines on a concrete floor with no walls nearby.

- Machine 1 has an acoustic power of 0.40 W, and is 1.0 m away to the man's right.
- Machine 2 has an acoustic power of 0.50 W, and is 2.0 m away to the man's left.

To do: Estimate the sound pressure level at the man's ears.

Solution:



- Calc $L_{W_1} = 10\log_{10}\left(\frac{W_1}{W_0}\right) = 10\log_{10}\left(\frac{0.40 \text{ W}}{10^{-12} \text{ W}}\right) = \underline{116.02 \text{ dB}}$

$L_{W_2} = 10\log_{10}\left(\frac{0.50 \text{ W}}{10^{-12} \text{ W}}\right) = \underline{117.00 \text{ dB}}$

- Eq 3-27 with $\underline{Q = 2}$ $(Q_1 = Q_2 = 2)$

$$L_{p_1} = L_{W_1} + 10\log_{10} Q_1 - 11.0 - 20\log_{10}\frac{r_1}{r_0}$$

(L_{W_1} = 116.02 dB; Q_1 = 2; r_1 = 1.0 m; r_0 = 1.0 m)

$L_{p_1} = \underline{108.03 \text{ dB}}$

Similarly $L_{p_2} = \underline{102.98 \text{ dB}}$

Eq. 3-30 →

$$L_{p_{total}} = 10\log_{10}\left[10^{10.803} + 10^{10.298}\right]$$

($\frac{108.03}{10}$ = 10.803; $\frac{102.98}{10}$ = 10.298)

$= 109.21$ dB

or $\boxed{L_{p_{total}} = 109. \text{ dB}}$

Sound does not add up linearly, does not = average

(because of the logarithms in the eq's)

Section 3.4.5 – Noise Standards – see Table 3.5 in the text:

Table 3.5 ACGIH and OSHA noise limit standards for the workplace (from Internet websites and US Office of the Federal Register, 1988).

sound intensity (dBA)	ACGIH exposure time (hr)	OSHA exposure time (hr)
80	24	32
82	16	24.3
85	8	16
88	4	10.6
90	-	8
91	2	7
92	-	6
94	1	4.6
95	-	4
97	0.5	3
100	0.25	2
102	-	1.5
105	-	1
110	-	0.5
115	-	0.25 or less

85 dB @ 8 hr = ACGIH standard

change time by factor of 2 with every 3 dB change

90 dB @ 8 hr = OSHA standard

change time by factor of 2 with every 5 dB change

OSHA defines

$$E_n = \text{sound exposure parameter} = \sum_j \frac{t_j}{t_{j,\,\text{permitted}}}$$

As with air pollution, if $E_n > 1 \rightarrow$ violation

$E_n < 1 \rightarrow$ okay – no violation

[very similar to what we did with multiple chemical exposure in air pollution analysis]

SEC. 3.5 THERMAL COMFORT & HEAT STRESS

We are "homeotherms" → we maintain a constant body core temperature

Normal body core $T = 98.6\,°F = 37.0\,°C$

- hypothermia → body is too cold (core $T < 96°F$)
- hyperthermia → . . . . . hot (core $T > 105°F$)

Metabolism → chemical reactions inside the body occur
"Burn" food like fuel & release energy

$\dot{M}$ = metabolic rate $\{\dot{M}\}$ = power

units are W (watt)
or $\frac{kcal}{hr}$

[kilocalorie = Calorie = 1000 calories]

Conversion: $1\ W = 0.86\ \frac{kcal}{hr}$

$\dot{M}_b$ = basal metabolic rate ⇒ When a person is laying down, resting, but not sleeping

"Typical person" = 70 kg male in good health

$\dot{M}_b = 84.\ W$

Some typical metabolic rates (for "average" 70-kg man) – see Table 3.6 in the text:

Table 3.6 Metabolic rate as a function of physical activity for a 70 kg adult man (abstracted from ASHRAE, 1997).

activity	**metabolic rate (W)**	**metabolic rate (kcal/hr)**
sleeping	72	62
seated, quiet	108	93
standing, relaxed	126	108
walking about the office	180	155
seated, heavy limb movement	234	201
flying a combat aircraft	252	217
walking on level surface at 1.2 m/s	270	232
housecleaning	284	244
driving a heavy vehicle	333	286
calisthenics/exercise	369	317
heavy machine work	423	364
handling 50-kg bags	423	364
playing tennis	432	372
playing basketball	657	565
heavy exercise	900	774

e.g. Average man burns $\simeq 100 \frac{kcal}{hr}$ avg. for 24 hrs

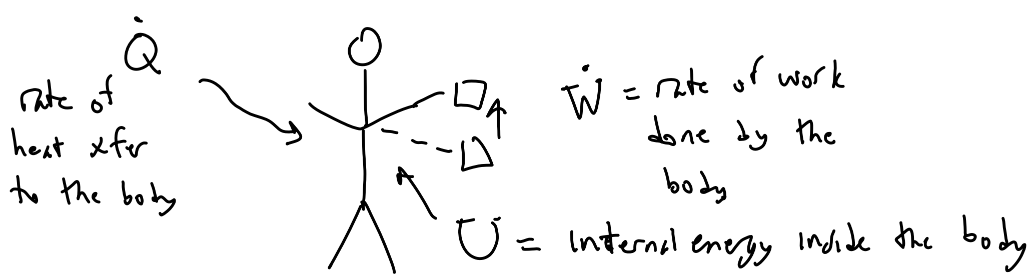
requires 2400 kcal of food per day

E.g. 175 lbm man walking around the office

$$\dot{M} = \frac{155 \frac{kcal}{hr}}{154\ lbm}(175\ lbm) = \boxed{176 \frac{kcal}{hr}}$$

(70 kg = 154 lbm)

Sec. 3.5.2 Thermodynamics of the Human Body



1st law of thermo: $\frac{dU}{dt} = \dot{Q} - \dot{W}$

Ignore → combine with $\dot{M}$

We lump $\dot{W}$ into $\dot{M}$

Use $\frac{dU}{dt} = -\dot{M}$

∴ we use the $\dot{M}$ from the table @ various activity levels

$\dot{M} + \dot{Q} = 0$

☆ Must be balanced for steady state

☆ $\dot{Q}$ must be < 0 (Heat from the body) since $\dot{M} > 0$ in order to remain @ constant body temperature

How do we gain or lose heat?

- Conduction $\dot{Q}_{cond}$ — usually negligible
- Convection $\dot{Q}_{conv}$ — usually ⊖, can be ⊕
- Radiation $\dot{Q}_{rad}$ — ⊕ or ⊖
- Respiration $\dot{Q}_{res}$ — usually ⊖, can be ⊕
- Evaporation $\dot{Q}_{evap}$ (sweating) → always ⊖

Next time → we will look @ Equations for these heat transfer rates.