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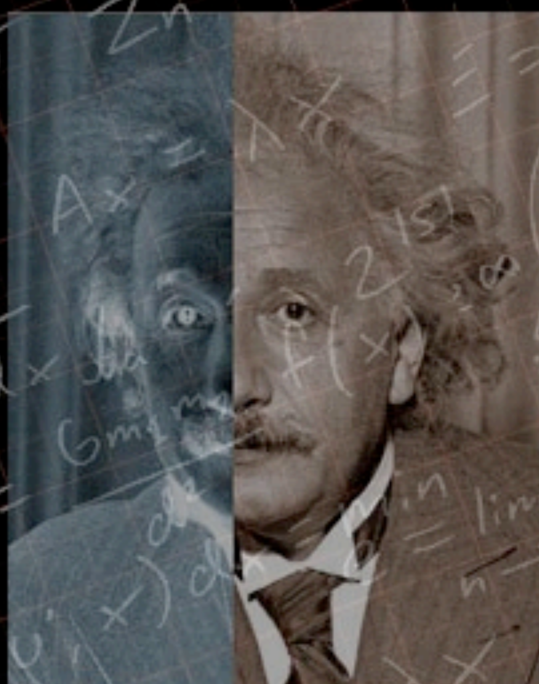


Podcast

http://vcephysics.podomatic.com/

The decibel scale

Sound intensity

- The intensity of sound decreases with the square of the distance from the source.

$$\text{Sound intensity} = \frac{power}{area}$$

$$I = \frac{P}{A} (unit = W/m^2)$$

$$I = \frac{P}{4\pi r^2}$$

$$\frac{I_2}{I_1} = \left(\frac{r_1}{r_2}\right)^2$$

Sound intensity

- eg a sound source emitting a power of 1 mW, when heard at a distance of 1 vs 2 m

$$I = \frac{P}{A} = \frac{1\times10^{-3}W}{4\pi(1m)^2} = 8\times10^{-5}W/m^2$$

$$I = \frac{P}{A} = \frac{1\times10^{-3}W}{4\pi(2m)^2} = 2\times10^{-5}W/m^2$$

Sound level: The decibel scale

- The decibel scale is a relative scale, based upon the threshold of hearing $I_0 = 10^{-12}\ W/m^2$.
- It is a logarithmic scale, an increase of 10 corresponds to 10 times the intensity.
- 20dB = 10^2 times, 30dB = 10^3 times the intensity.

$$L = 10\log\frac{I}{I_0}$$

$$I = 10^{\left(\frac{L}{10} - 12\right)}\ W/m^2$$

$$L = 10\log\frac{I}{10^{-12}}$$

Sound level calculations

- *eg* A sound has the intensity of 10^{-4} W/m^2. This is a sound level of

$$L = 10\log\frac{I}{I_o} = 10\log\frac{10^{-4}}{10^{-12}} = 10\log 10^{8} = 80\,dB$$

eg The intensity of a 45 dB sound is

$$I = 10^{\left(\frac{L}{10}-12\right)} = 10^{\left(\frac{45}{10}-12\right)} = 10^{-7.5} = 3.2\times10^{-8}\,W/m^2$$

What is the intensity of 120 dB?

$$I = 10^{\left(\frac{L}{10}-12\right)} = 10^{\left(\frac{120}{10}-12\right)} = 10^{0} = 1W/m^2$$

Some decibel measurements

Source	Intensity (W/m^2)	Sound level (dB)
Threshold of hearing	10^{-12}	0 dB
Soft whisper	10^{-10}	20 dB
Quiet conversation	10^{-8}	40 dB
Loud conversation	10^{-6}	60 dB
Highway traffic	10^{-4}	80 dB
Tractor engine	10^{-2}	100 dB
Threshold of pain (Rock concert)	10^{-0} (1)	120 dB
Jet engine (less than 50 m away)	10^{2} (100)	140 dB
Rocket launch (less than 500 m away)	10^{4} (10,000)	160 dB +

- Damage to hearing is due to both the sound level & exposure time.
- The biggest risk to hearing loss for most young people today is loud headphones!

Change in intensity

$$\Delta L = L_2 - L_1 = 10\log\frac{I_2}{I_0} - 10\log\frac{I_1}{I_0}$$

$$\Delta L = 10\log\frac{I_2}{I_1}$$

Double intensity: $\Delta L = 10\log 2 \approx +3dB$

Half intensity: $\Delta L = 10\log\frac{1}{2} = -10\log 2 \approx -3dB$

Doubling the distance from a source gives one quarter of the intensity:

$$\Delta L = 10\log\frac{1}{4} = -10\log 4 \approx -6dB$$

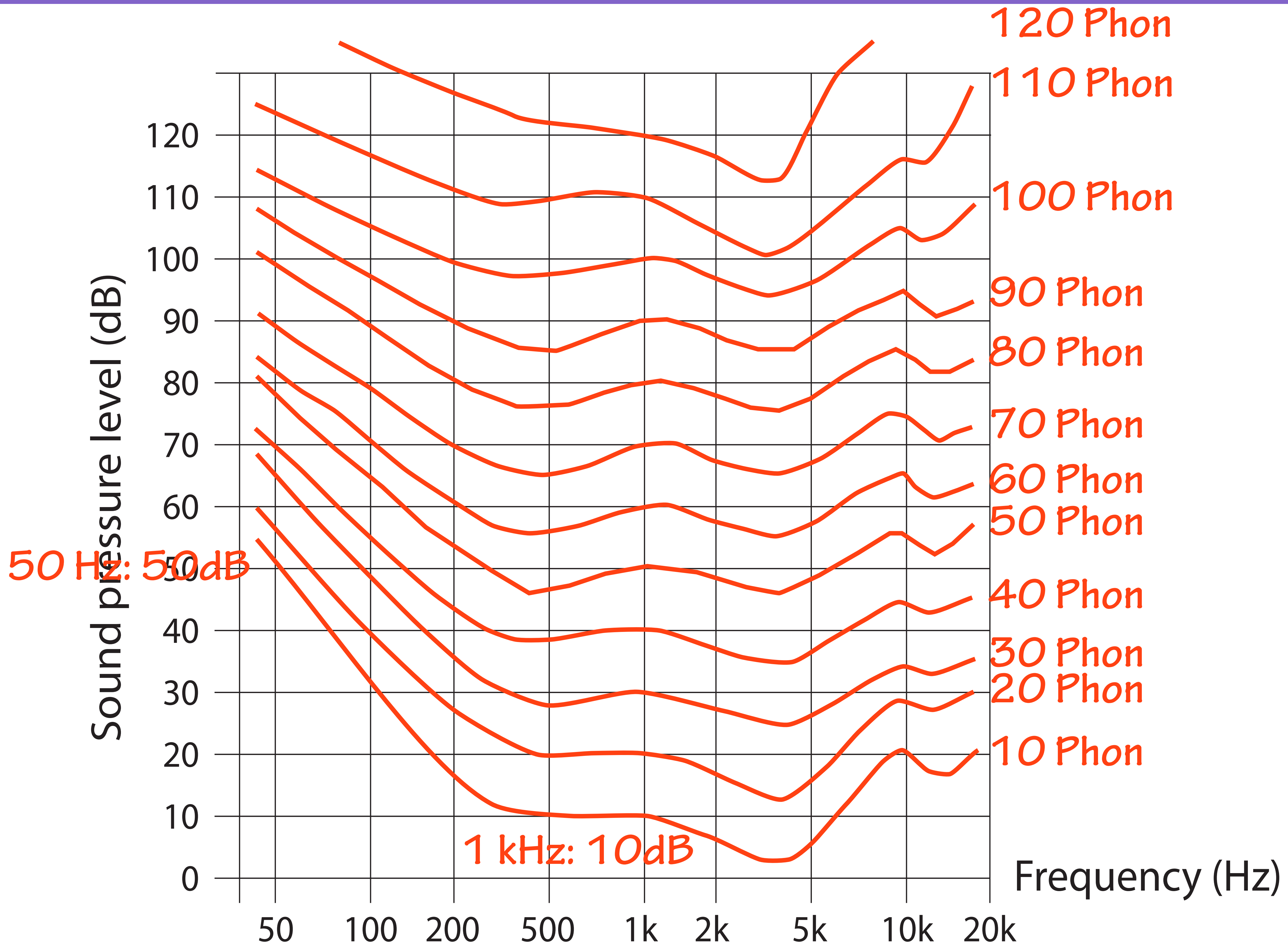
Human Hearing

- The human ear can hear sounds from ~20 Hz → 20 kHz
- Our ears are most responsive to frequencies ~2-3 kHz
- As we age, we lose sensitivity to the higher frequencies.
- The dBA & Phon scales is weighted so that a reading is of equal perceived loudness regardless of frequency.

The phon scale

- The phon scale shows how human ears respond to sounds at different frequencies.
- Different frequencies at the same Phon level are perceived to be equally loud.
- Based on the perception of 1kHz at different intensities.
- Sounds at 2 - 3 kHz are generally the loudest to our ears.
- At higher intensities, the dB differences between perceived equally loud sounds are less.

The phon scale



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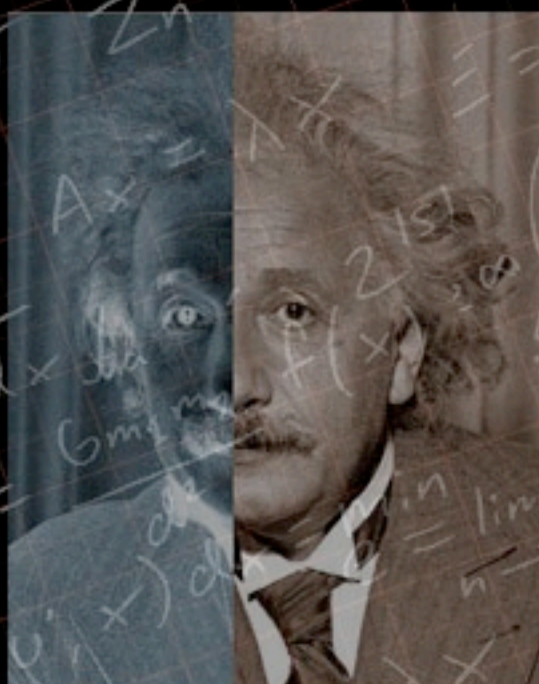

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