① Phys 1402 2015-11-12 Lec 23

How is loudness related to energy?

Energy is spread in time. $\text{Power} = \frac{\text{Energy}}{\text{Time}}$

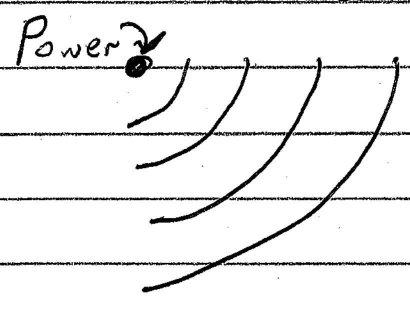
Power spreads in space. $\text{Intensity} = \frac{\text{Power}}{\text{Area}}$

Intensity is proportional to Amplitude Squared.

Why? $PE = \frac{1}{2}kx^2$ $KE = \frac{1}{2}mv^2$

Energy: J Power: $W = J/s$ $I = \frac{W}{m^2}$

Ex: Point Source: Power spreads in spheres



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

Twice as far away, I decreases by 4 X.

Decibels: Why?

- Our hearing is logarithmic. We hear ratios of loudnesses rather than deltas.

A: 10 mW/m^2 → 20 mW/m^2 Big step

B: 100 mW/m^2 → 110 mW/m^2 Small step

A is a factor of 2, B is only 1.1.

- Our ears have a HUGE dynamic range.

Barely audible: 10^{-12} W/m^2 } Factor of 10^{12} !!!...

Painfully Loud: 1 W/m^2 }

- We like adding instead

What do decibels describe?

- Ratios of energy-like quantities.
- Multiple ratios are accounted for by adding decibel levels.
- Definitions:

$$\beta = 10 \log(I/I_0)$$

$$I = I_0 \, 10^{\beta/10}$$

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β	ratio
10 dB	10
20 dB	100
30 dB	1000
120 dB	10^{12} ← Dynamic range of human ear
3 dB	$10^{0.3} = 2$
5 dB	$10^{0.5} \approx 3$
7 dB	$10^{0.7} = 5$

Level changes of less than 1 dB are generally insignificant.

1 dB $10^{0.1} = 1.25$ → 25% increase

−3 dB $10^{-0.3} = 0.5$

0 dB $10^{0} = 1$ → no change from ref.

Reference Sound $I_0 = 10^{-12}$ W/m²

60 dB 10^6 ratio $I = 10^{-6}$ W/m² Conversation

100 dB $I = 10^{-2}$ W/m² Power Tools

110 dB $I = 10^{-1}$ W/m² Loud Music

(4)

Can be used for radio waves.

0 dBm $\rightarrow$ 1 mW

-70 dBm $\rightarrow$ 10^{-7} mW = 10^{-10} W   Weak Wifi

Note: Here we only care how much power actually gets into the radio.

$$P = I A \varepsilon$$

ε ← efficiency or gain

A ← area of antenna

I ← Intensity

How many dB correspond to a 5% increase?

Factor = 1.05

log(1.05) = 0.02

level = 0.2 dB

What factor is 63 dB?

2000000

If you move 3x further away from a point source, and the sound was 80 dB, what is its level now?

$I = \frac{P}{4\pi r^2}$ $r \uparrow 3$ $I \downarrow 3^2$ -5-5 dB

Now 70 dB = I

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Polarization - transverse waves have an amplitude perpendicular to $\vec{v}$. Polarization is the direction of the oscillations.

For a horizontal light beam, polarization can be vertical or horizontal.

- Pure Vertical
- Pure Horizontal
- Pure Diagonal
- Circular
- Unpolarized - random

Most light is unpolarized.

A polarizer absorbs "undesired" light. The light that gets thru is polarized.

$$I_{out} = \frac{1}{2} I_{in} \quad \text{(unpolarized in)}$$

If the incoming light is polarized

$$I_{out} = I_{in} \cos^2\theta$$

(θ — polarization mismatch)