Physics of Musical Sound

Class 8

Finish Chapter 5 Read Chapter 6

Homework due Friday

How Loud is a Sound?

- We detect energy
  - Measure Intensity=Energy/area/time
  - Energy $\propto$ amplitude^2.
  - Huge range of intensities
    - quietest about 10^{-12}W/m^2
    - loudest near 10^{3}W/m^2.
  - If ear responded linearly then loudest sounds would be trillions of times louder than quietest!

How Loud is a Sound?

- Ear roughly logarithmic
  - Ear more sensitive to soft sounds.
  - Alexander Graham Bell showed that the response is approximately logarithmic
- Sound Intensity Level: units Bels.
  - 1Bel very large; usually use the deciBel.
  - The SIL in deciBels is given by

$$SIL(dB) = 10 \times \log\left(\frac{SoundIntensity}{10^{-12} W/m^2}\right)$$

or

$$SoundIntensity = 10^{-12} \times 10^{\left(\frac{dB}{10}\right)}$$

Review Powers and Logs

- Basic Power Rules
  - $x^a \times x^b = x^{a+b}$ Usually want $10^a \times 10^b = 10^{a+b}$
    - E.g. $10^3 \times 10^{0.2} = 10^{3.2}$
  - $x^a / x^b = x^{a-b}$ Usually want $10^a / 10^b = 10^{a-b}$
    - E.g. $10^4 / 10^2 = 10^{4-2} = 10^2$

Review Powers and Logs

- Basic Log Rules
  - $\text{Log}(a \times b) = \text{Log}(a) + \text{Log}(b)$
  - $\text{Log}(ab) = b \times \text{Log}(a)$
    - E.g. $\text{Log}_{10}(2300) = \text{Log}_{10}(2.3)+\text{Log}_{10}(1000)$
    - E.g. $\text{Log}_{10}(2.5^2) = 2\ \text{Log}_{10}(2.5)$

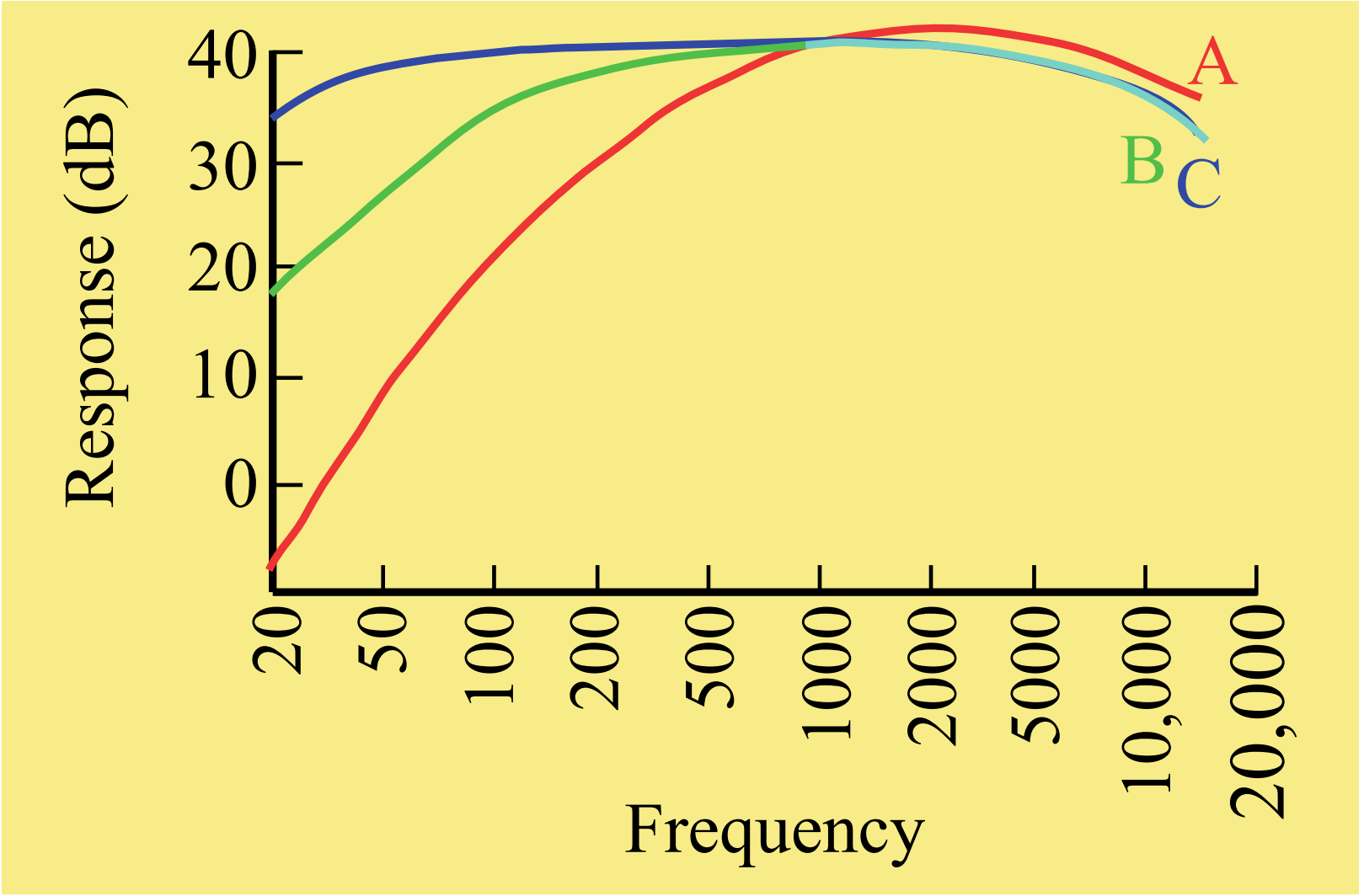
Some Sound Levels

- 0dB, $10^{-12} W/m^2$, the quietest sound possible to observe under ideal conditions
- 10dB, $10^{-11} W/m^2$, a pin drop.
- 33dB, $2x10^{-9} W/m^2$, Physics Aud. at quietest.
- 75dB, $3.2x10^{-9} W/m^2$, McEwen dining hall during a normal meal
- 100dB, $10^{-2} W/m^2$, Peak sound in a very loud classical percussion concert.

Measuring Sound Levels

- Total energy regardless of frequency.
  - Flat response.
- Because the ear is less sensitive at high frequencies and at low frequencies we often count the high and low frequencies less. Thus a given sound pressure at 50Hz will give a lower dB reading than the same sound pressure at 1000Hz.

Measuring Sound Levels



Combining Sounds 1

- When we combine two sounds we ADD the energies. There is no rule to tell us about the Log of the SUM of two numbers.
- To combine we:
  - 1) convert from SIL in dB into Sound Intensities in W/m^2
  - 2) add the Sound Intensities
  - 3) Convert the sum back into SIL

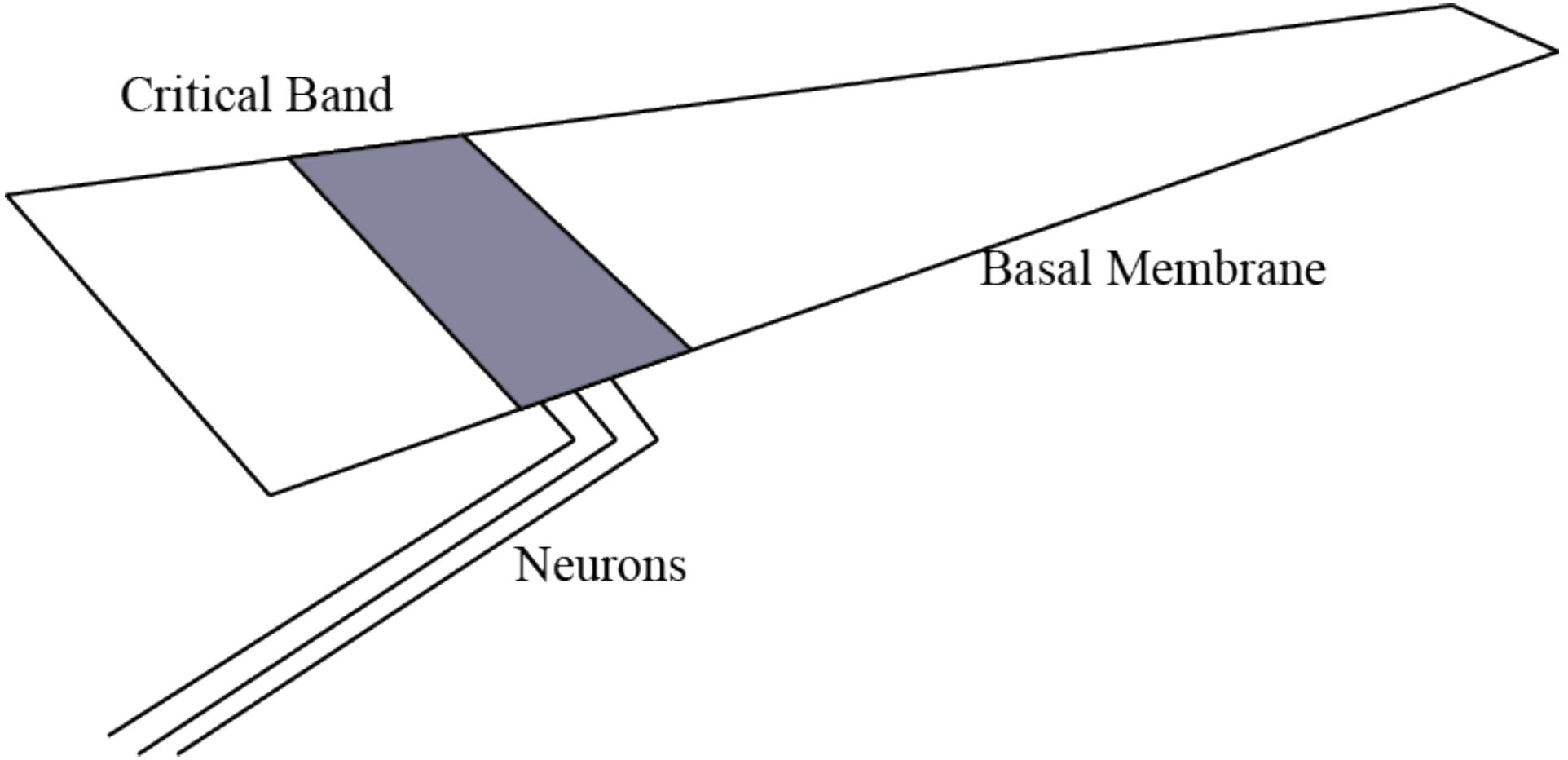
Combining Sounds 2

- For Example
  - Sound Level in room alone = 50dB.
  - Sound Level in room with water cooler = 55dB.
  - What is Sound Level from cooler alone?
  - 50dB corresponds to $SI=10^{-12}10^{5}=10^{-7}W/m^2$
  - 55dB corresponds to $SI =10^{-12}10^{5.5}=3.16x10^{-7}W/m^2$
  - Difference is $2.16x10^{-7}W/m^2$
  - Convert to $SIL=10\ Log(2.16x10^{-7}/10^{-12})$
    $= 10\ Log(2.16x10^{5})$
    = 53.3dB is sound level from cooler.

Chorus Effect

- A sine wave of amplitude A has Intensity
$$I_0 \propto A^2$$
- If I add two sine waves of amplitude A with exactly the same frequency and phase then the result has amplitude 2A and Intensity
$$I \propto (2A)^2 = 4A^2 = 4I_0$$
- If I add two equal instrumental sounds then the frequency and phase will not be the same and the new intensity is just $2\ I_0$

Critical bands



Critical Bands

- About 20 regions
- Tell by masking
  - Play pitched sound
  - Try to obscure with noise