Acoustics and Ultrasonics: # Lec 2

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What we have learnt earlier

An 8-hour exposure to a sound intensity level of 90.0 dB may cause hearing damage. What energy in joules falls on a 0.800-cm-diameter eardrum so exposed?

(a) Ear trumpets were never very common, but they did aid people with hearing losses by gathering sound over a large area and concentrating it on the smaller area of the eardrum. What decibel increase does an ear trumpet produce if its sound gathering area is 900 cm^2 and the area of the eardrum is 0.500 cm^2, but the trumpet only has an efficiency of 5.00% in transmitting the sound to the eardrum? (b) Comment on the usefulness of the decibel increase found in part (a).

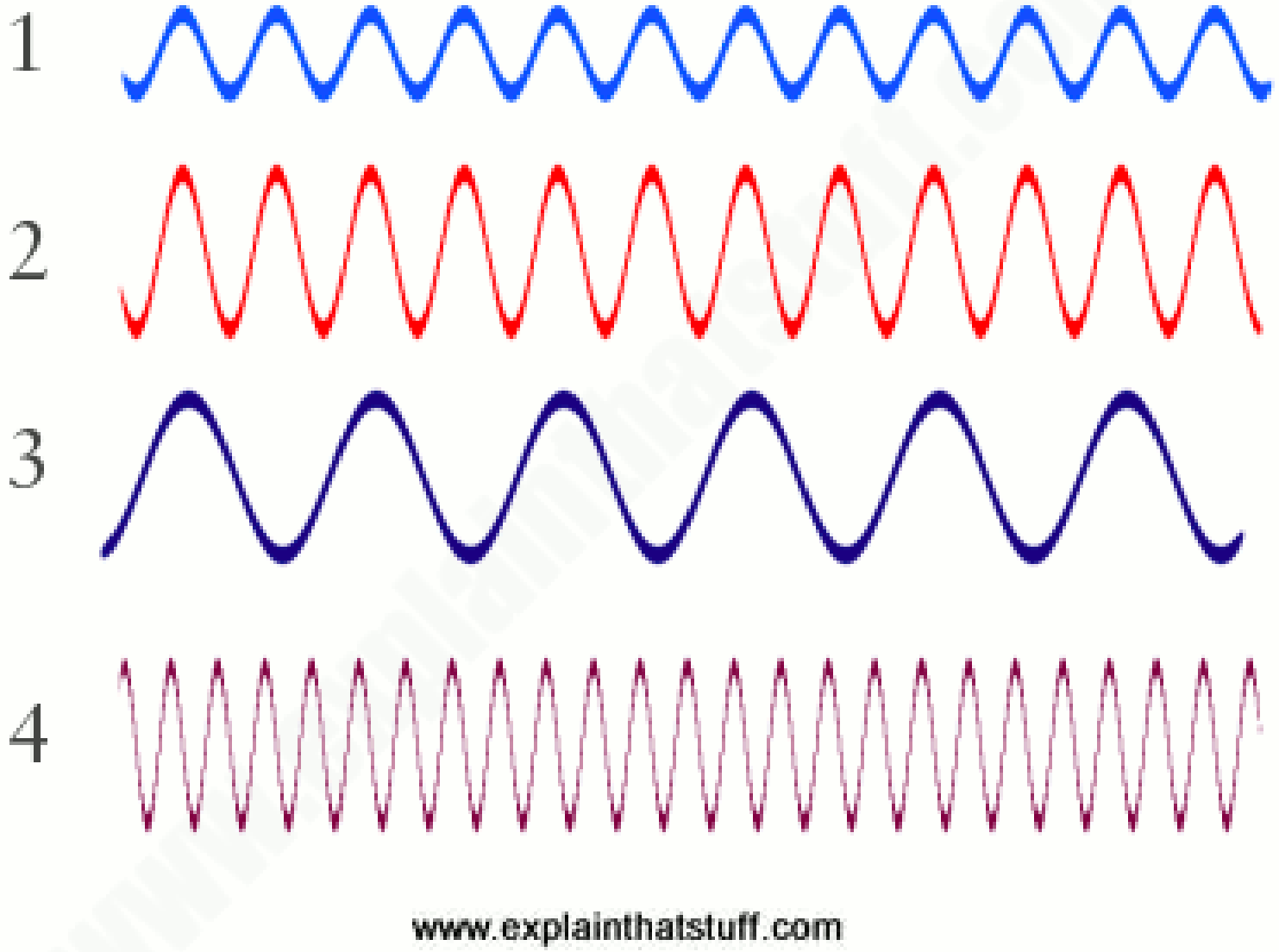
Loudspeakers can produce intense sounds with surprisingly small energy input in spite of their low efficiencies. Calculate the power input needed to produce a 90.0-dB sound intensity level for a 12.0-cm-diameter speaker that has an efficiency of 1.00%. (This value is the sound intensity level right at the speaker.)

Today's Agenda

- Loudness (contd..)
- Equal Loudness Curves

Equal loudness curve

https://www.explainthatstuff.com/sound.html



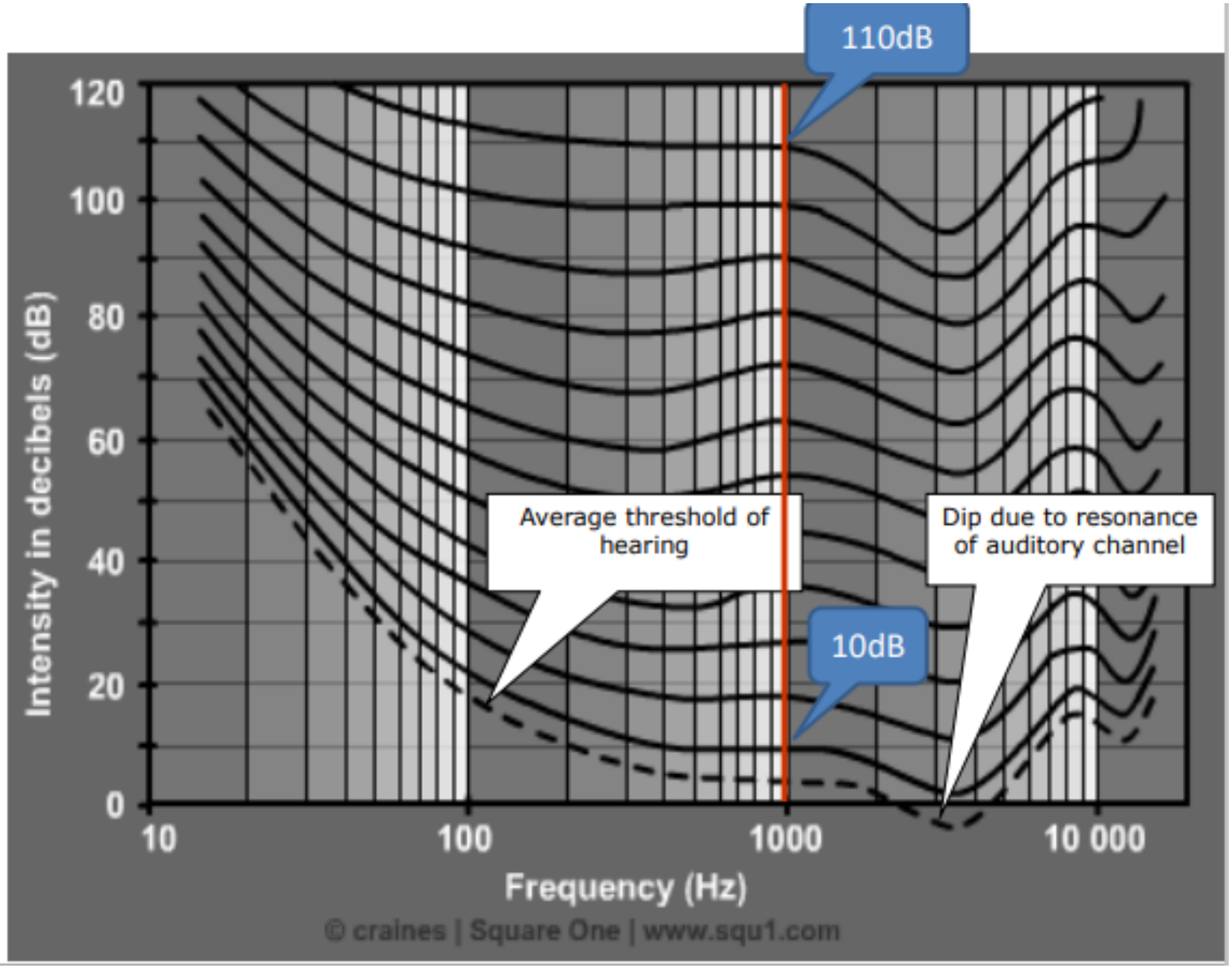
Phon is a measure of loudness and it is equal to the loudness of an equally loud 1kHz frequency note expressed in decibels.

- ✓ Saying that two sounds have equal intensity is not the same thing as saying that they have equal loudness.
- ✓ The loudness of a sound depends on the frequency of the sound and the sensitivity of the ear.
- ✓ Therefore, two different 60-decibel sounds will not in general have the same loudness.
- ✓ The loudness cannot be measured directly with a meter.
- ✓ However, the phon scale is determined by the results of experiments in which volunteers were asked to adjust the loudness of a sound at a given frequency until they judged its loudness to equal that of a 1 kHz signal.
- ✓ A sound of known intensity level is produced at the frequency 1 kHz (1 kHz being taken as the standard frequency) and then a sound at some other frequency of interest is generated.
- ✓ The intensity of the second sound is varied in intensity till the volunteers judge it to be of the same loudness as that of 1 kHz sound.
- ✓ If the intensity level of both sounds is N decibels, then the equivalent loudness is said to be N phons.
- ✓ If a given sound is perceived to be as loud as a 60 dB sound at 1000 Hz, then it is said to have a loudness of 60 phons.
- ✓ **60 phons means “as loud as a 60 dB, 1000 Hz tone”**

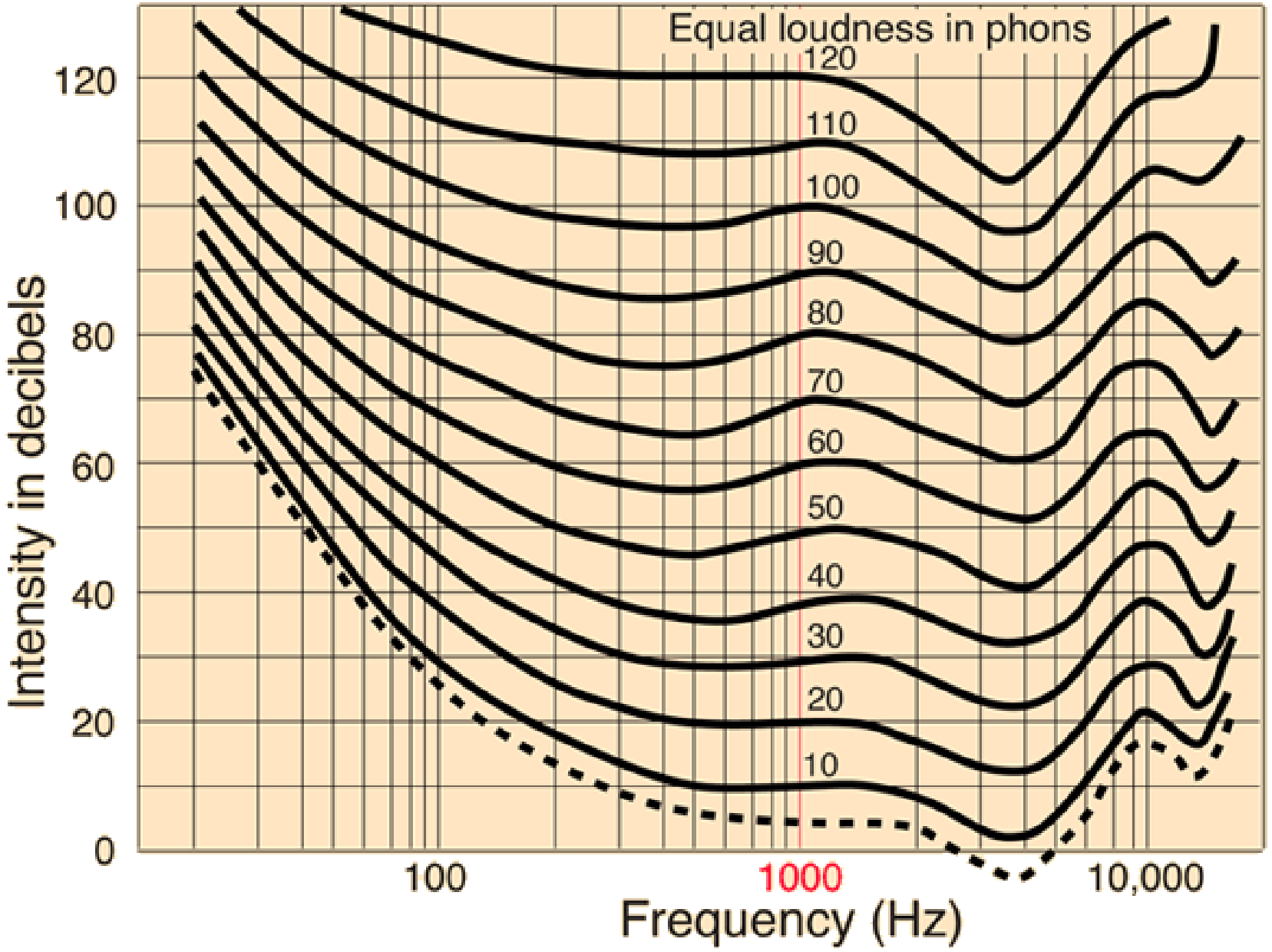
Equal loudness curve

Equal Loudness Curves

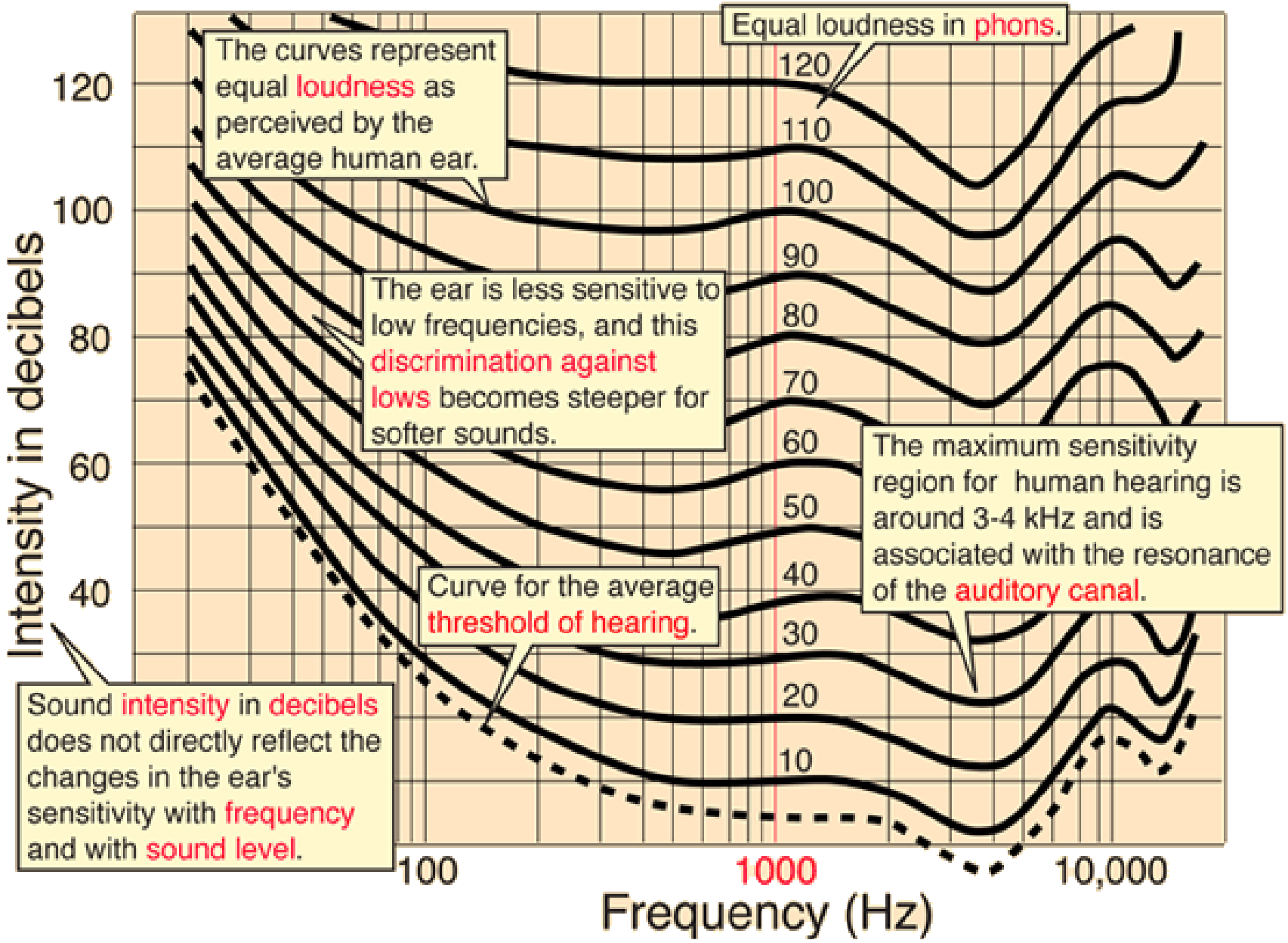
- Loudness curves capture the frequency response of our ears and its variation with increase in intensity
- Ears are more sensitive to 1-4kHz region
- At high intensities, the ears have nearly equal sensitivity to all frequencies.



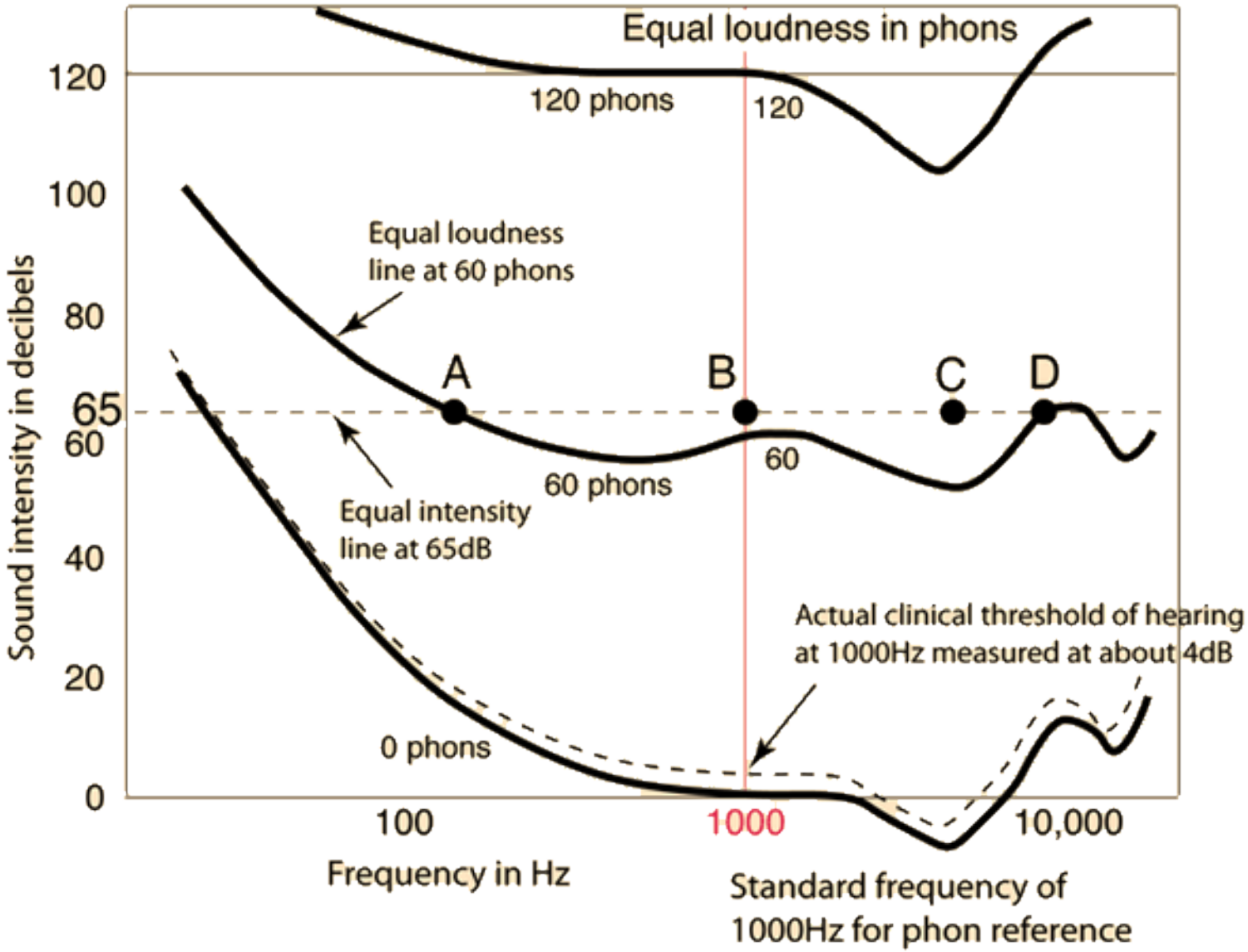
Equal loudness curve



Equal loudness curve



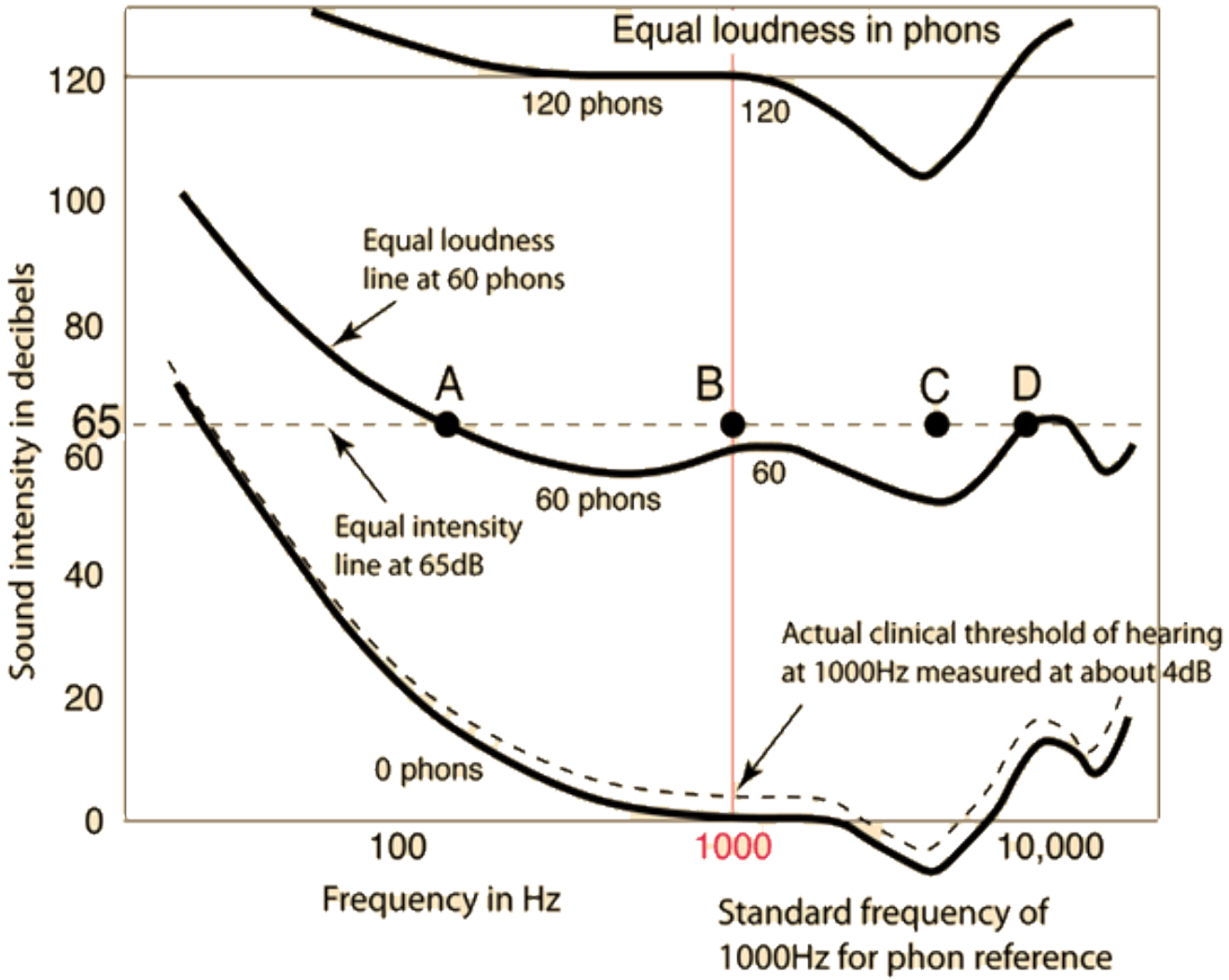
Equal loudness curve



very soft, midrange and very loud sound

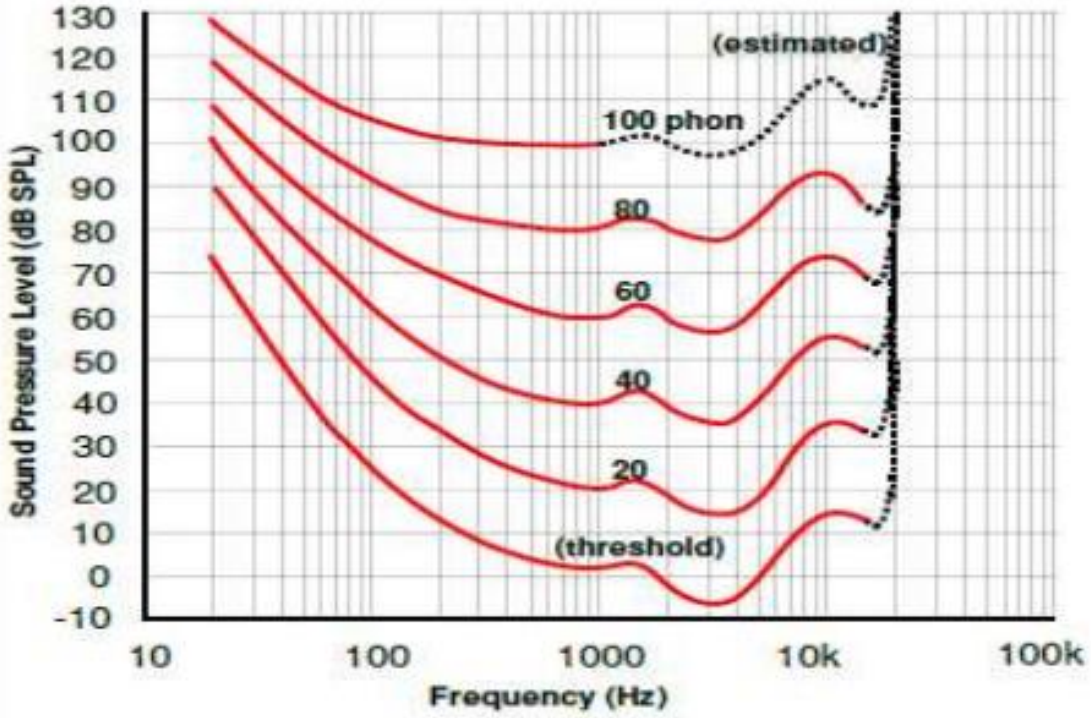
- The response to very loud sounds is much "flatter" or more uniform than the response to very soft sounds, although it still shows the prominent enhancement of sensitivity between about 2000-5000Hz associated with the ear canal resonance.
- Where the curve dips between 2000-5000Hz, this implies that less sound intensity is necessary for the ear to perceive the same loudness as a 120dB, 1000Hz tone.
- In contrast, the strong rise in the curve for 0 phons at low frequencies shows that the ear has a notable discrimination against low frequencies for very soft sounds.
- Since the vertical axis is in decibels, the flat horizontal line at 65dB represents an equal intensity at all frequencies.

Equal loudness curve



- The example sounds A, B, C and D all have the same sound intensity of 65dB.
- However, this does not imply that they have the same loudness to the human ear.
- We can say that sounds A and D have the same loudness since both are on the same equal loudness curve.
- This curve passes through 60dB at 1000Hz, so we characterize all sounds on that equal loudness curve, including sounds A and D, as having a loudness of 60 phons.
- Sound B is above the 60 phon curve, so that implies that it would be perceived as louder than A or D.
- In fact, since sound B is at 1000Hz and has an intensity of 65 dB, we can say that its loudness is 65 phons.
- The perceived loudness at 1000 Hz is the reference point for defining the equal loudness curve through that point, so the numerical value of phons and dB is always the same at 1000 Hz.
- Finally, we could say that sound C at 65dB is the loudest of the four sounds since it shows the greatest displacement above the 60 phon curve.

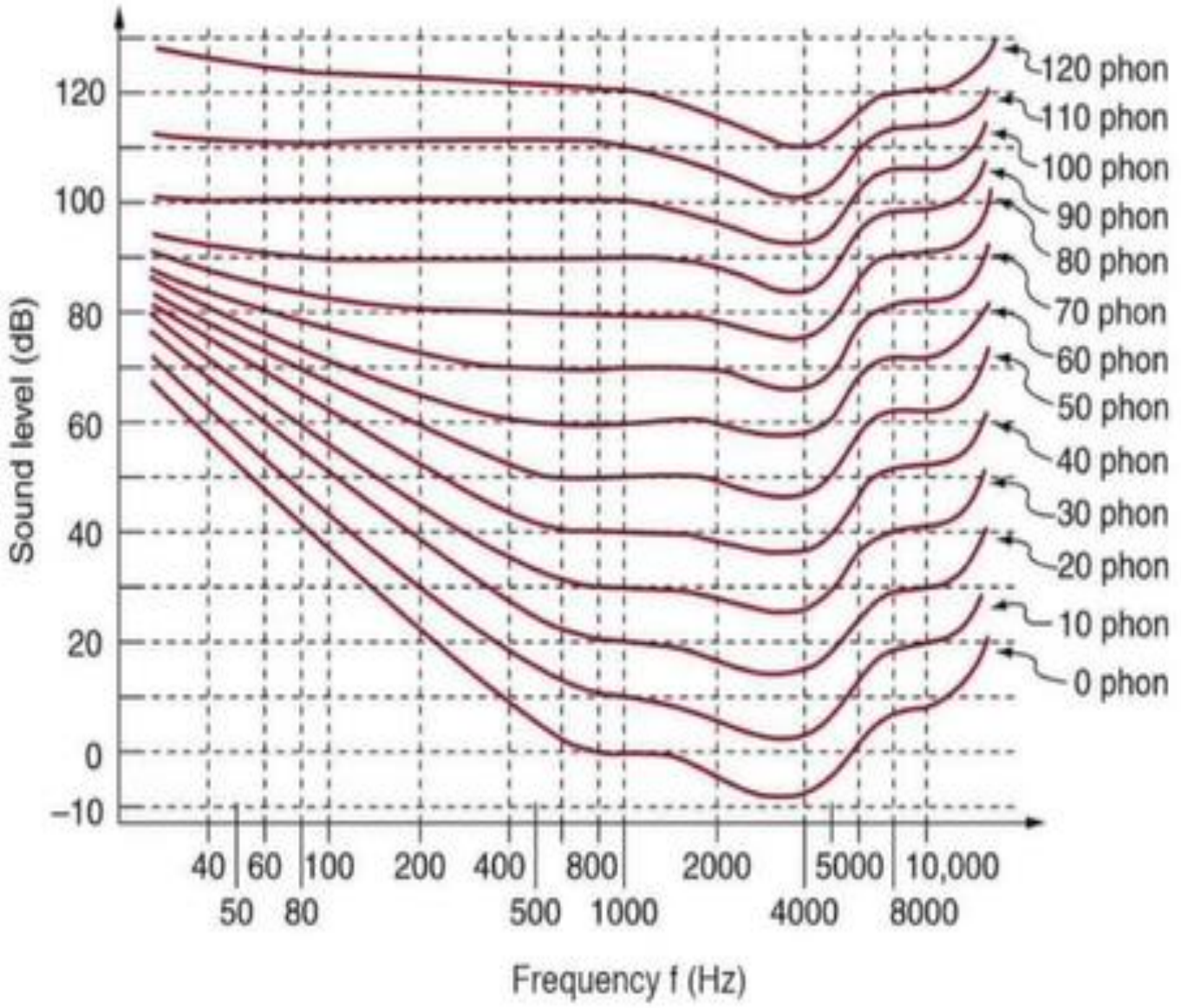
Check your learning



Answer the questions based on the given loudness curves

1. A tone at 60Hz has to be played at _____ (dB SPL) to produce a perception equal that of 1kHz at 20 (dB SPL)
2. The pressure of the tone at 70Hz should be _____ times more to produce a perception equal to that of 1KHz at 100 dB SPL
3. The difference in dB SPL between the tones at 80Hz and 40 Hz that are just audible is _____

Check your learning



A person has a hearing loss of 40 dB near 5000 Hz, due to noise exposure, and normal hearing elsewhere. How much more intense is a 5000 Hz tone than a 400 Hz tone if they are barely audible to the person?

https://www.youtube.com/watch?v=os_1HAyOxYI

A stethoscope gathers sound into its diaphragm of area 12.56 cm^2 and concentrates it onto both ears with a total area of 0.8 cm^2, with an efficiency of 50%. What is the gain in decibel offered by the construction of the stethoscope? If the intensity coupled onto the diaphragm of stethoscope is 100 times more than that into equivalent area in air what is the overall gain in decibel offered by the stethoscope?

Check below

https://www.youtube.com/watch?v=go7IDMzx9Kk&list=PL_3h4GvKc6GAF47v9nOZxfnEkCcLTobZh&index=28

Check your learning

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Given A_{steth} =12.56 cm^2, A_{ears} = 0.8 cm^2 Transfer efficency of stethoscope =0.5
Let P be the acoustic power that is incident on the stethoscope ,
Intensity at stethoscope, $I_{steth} = P/A_{steth,,}$ (1)
50% of the power incident on the stethoscope diaphragm is conveyed to the ears, so power incident on the ears =0.5 P
Intensity at the ears, $I_{ears} = (0.5 \times P)/A_{ears,} = (0.5x\ I_{steth}\ xA_{steth})/\ A_{ear}$ (2)

Gain in dB due to construction of stethoscope = $\mathbf{10 \log (I_{ear}/I_{steth})} = 10 \log (0.5 \times A_{steth}/ A_{ear})$

$= 10 \log (0.5 \times 12.56/0.8) = 8.95$ dB

Check below

https://www.youtube.com/watch?v=go7IDMzx9Kk&list=PL_3h4GvKc6GAF47v9nOZxfnEkCcLTobZh&index=28

Check your learning

State Weber Fechner's law. Discuss equal loudness curves and its variation from threshold of audibility to threshold of pain with relevant diagrams

Please check below problems

https://www.youtube.com/watch?v=a6fjiTlZkbE&list=PL_3h4GvKc6GAF47v9nOZxfnEkCcLTobZh&index=27

https://www.youtube.com/watch?v=go7IDMzx9Kk&list=PL_3h4GvKc6GAF47v9nOZxfnEkCcLTobZh&index=28

https://www.youtube.com/watch?v=k96QOKfRY7c&list=PL_3h4GvKc6GAF47v9nOZxfnEkCcLTobZh&index=30