FUNDAMENTAL AUDITORY FUNCTIONS

1. Loudness
   - Physical attribute of sound is intensity
   - Perceptual attribute is loudness

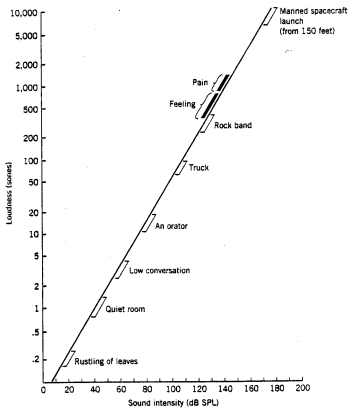


Figure 13.2 Relationship between intensity level (decibels) and loudness (sones). Note that in this function a 10-dB increase in the intensity scale increases loudness by a factor of 2. Loudness and intensity are scaled logarithmically. (*Source:* From Lindsay & Norman, 1977, p. 161. Reprinted by permission of the publisher.)

   a) Sones

   - Unit of measure used to describe subjective loudness of sounds of differing intensity
   - 1 sone = loudness of 1000 Hz tone at 40 dB SPL
   - From graph (s349) we see # of sones (perceived loudness) doubles every 10 dB of intensity
   - Compare +6 dB intensity means doubling intensity, and +10 dB intensity means ~tripling intensity)
   - So as you triple intensity, you only double the perceived loudness

   b) Frequency dependence of loudness

   - Due to the mechanics of the basilar membrane, the arrangement and number of hair cells, and the auditory pathway (including cortical areas) perception of loudness differs for sounds of different frequencies
   - Can see this in threshold plots

c) Equal-loudness contours

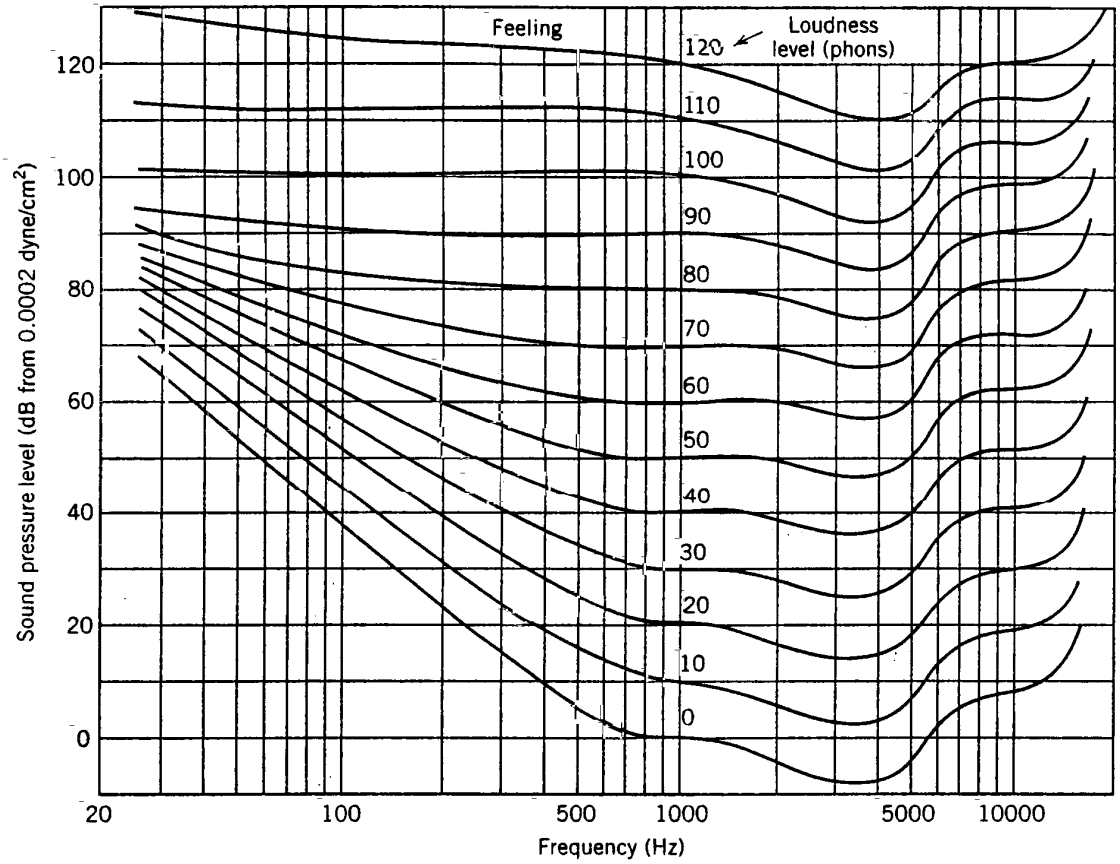


figure 13.3 Equal-loudness contours. The bottom curve—0 phons—shows the absolute sensitivity of the ear as a function of frequency. Tones with intensity and frequency values that lie below the 0 phon curve are not audible. (*Source:* Revised from H. Fletcher and W. A. Munson, Loudness, its definition, measurement, and calculation, *Journal of the Acoustical Society of America, 5,* 1933, pp. 82–108. Reprinted by permission of the American Institute of Physics.)

2. Pitch

a) Discrimination (JND)

b) Mel scale

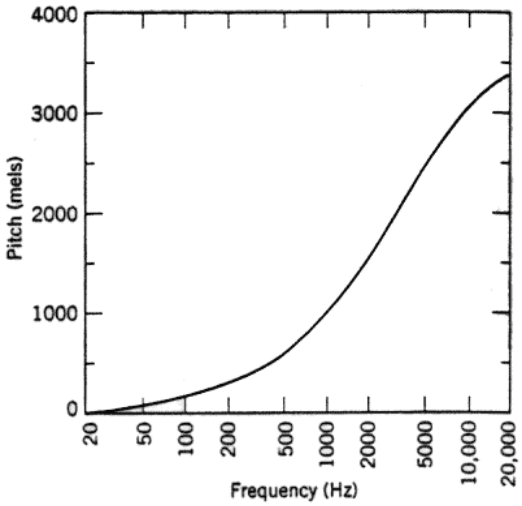


figure 13.4 The frequency–pitch function. Pitch in mels is plotted against frequency (in Hz). The curve shows how the perceived pitch of a tone varies with its frequency. Observe that pitch increases more rapidly than frequency for tones below 1000 Hz but less rapidly for tones above 1000 Hz. (Frequency is plotted on a logarithmic scale. *Source:* After Stevens & Volkmann, 1940.)

c) Intensity affects pitch

i. For low tones

ii. For high tones

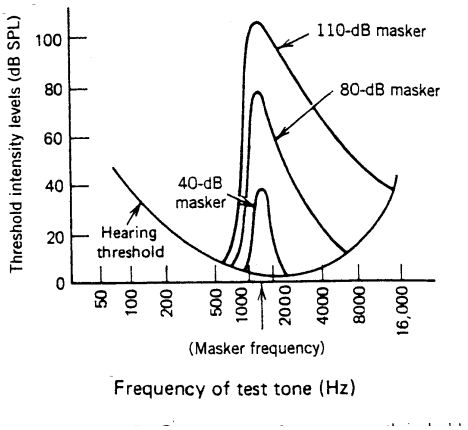
3. Multiple frequencies stimulation

How common is it to hear two sounds very close in frequency, in the real world?

a) Beats

b) Masking

- Asymmetry of frequency effects in masking

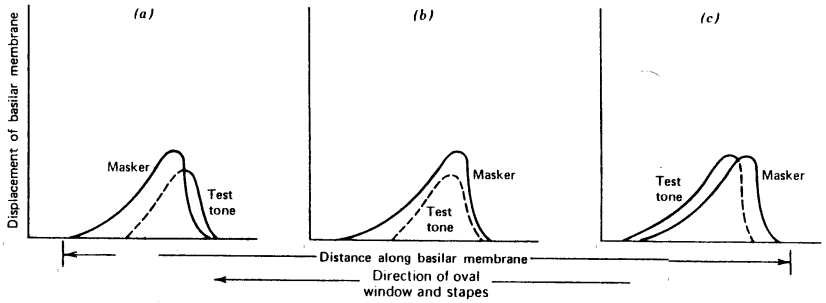


- Simultaneous masking

- Forward masking

- Backward masking

- "Line busy" hypothesis



4. Threshold shifts

a) Auditory fatigue

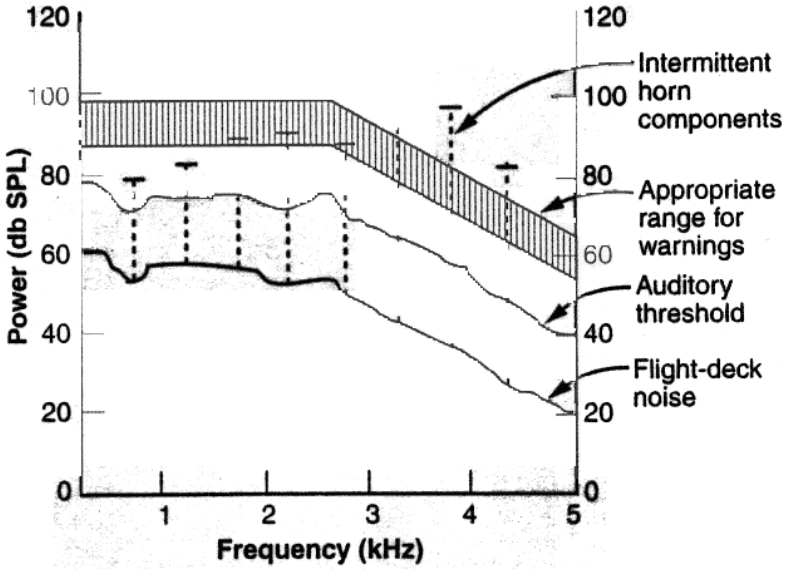
b) Threshold shift

i. Temporary

ii. Permanent

c) Adaptation

5. Warning tones and masking



a) Consider frequency of the masking (background) noise

b) Make each component of the warning ~15 dB above background <u>at that frequency</u>

c) Use multiple frequencies

d) Each component, and total sound, not to exceed danger levels