NO BOOKS OR NOTES ARE ALLOWED. PLEASE DO YOUR OWN WORK!

Potentially Useful Formulae

\[ f_n = nf_1 \quad \frac{L}{\lambda_0} = \frac{(A/A_0)^2}{1} \quad v = \frac{d}{t} \quad p = \frac{F}{s} \quad v_{20} = 344 \text{ m/s} \]

\[ \beta = 10 \log \frac{L}{\lambda_0} \quad \frac{L}{\lambda_0} = 10^{\beta/10} \quad v_T = \left[344 + 0.6(T - 20^0)\right] \text{ m/s} \]

\[ SIL_c = SIL_1 + 10 \log(1 - 10^{(\beta_2 - \beta_1)/10}) \]
\[ SIL_c = SIL_1 + 10 \log \left\{1 + 10^{(\beta_2 - \beta_1)/10} \pm 2(10^{(\beta_2 - \beta_1)/20})\right\} \]

\[ \log 2 = 0.3 \quad \log 4 = 0.6 \quad p = \frac{1}{f} \quad f = \frac{1}{2\pi} \sqrt{\frac{k}{m}} \text{ Simple Harmonic Motion} \]

\[ |L_2 - L_1| = n\lambda \quad n = 0, 1, 2, ... \]

\[ |L_2 - L_1| = (n + \frac{1}{2})\lambda \quad n = 0, 1, 2, ... \]

\[ P = \frac{E}{t} \quad I = \frac{P}{S} \]

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1a) Sketch the steady state response of a linear oscillator to a simple harmonic (sinusoidal) driving force as a function of frequency. Please do this for light and heavy damping, and indicate on your sketch which is which.

1b) Give four examples of resonance. Identify what provides the driving force and why the response is frequency dependent.
2a) The two frequencies 300 Hz and 400 Hz are sounded together. Give the simplest heterodyne components which are present if they are loud enough to make the ear’s response nonlinear.

2b) What is the fundamental of the harmonic series to which these frequencies belong? When you consider only the original frequencies and the simplest heterodyne components, which harmonics are missing?

2c) Please indicate the first 16 harmonics of the harmonic series based on C2 on the musical staff below. Indicate which are “badly out of tune” with our usual convention of pitches.
3a) How is intensity related to the amplitude of a wave?

3b) What is the approximate resulting sound level for two sounds which have the individual Sound Intensity Levels of 20 and 90 dB? Please briefly explain your answer. (Hint: Tell what the relative intensities are)

3c) What is the resulting sound level if two incoherent sounds with identical SILs of 60 dB are sounded together.

3d) Answer 3c if the sounds are coherent.
4.) The Fletcher-Munson Curves are shown below. Also shown is the response of our Hi Fi amp to a constant amplitude input signal as a function of frequency. In the first photo, the amplifier the bass and treble controls were set to zero, and the loudness control was off which resulted in the lower trace. The flat line shows that the amplifier is quite linear. The vertical scale covers 100 db, and the horizontal scale covers 10 kHz. To separate the traces, the volume control was then turned up slightly and the loudness control was turned on. The resulting response is given by the upper curve. This implies that low, and high frequencies (to a lesser extent) were “boosted” by the amplifier to a level higher than was present in the “original” sound.

The second photo shows a smaller frequency range, zero to 2000 Hz. No adjustment was made to the volume control this time so that you can see the relative separations of the two curves. At the lowest frequency the difference between loudness off and on is about 10 dB.
4a. Using the F-M curves explain the basic features of the loudness function on the amplifier.

4b. Tell how music would sound when played at a low SPL with, and without the loudness control in use.
4c. Why are we lucky that the ear has much less sensitivity at low frequencies than at high ones.

4d) Explain why the pitch of the alarm on wrist watches is around 4000 Hz.
5a) The piano keyboard covers a frequency range of 27.5 Hz to 4186 Hz for the fundamental pitch of the harmonic series associated with the notes. Tell why it makes no sense musicall to continue beyond 4 kHz.

5b.) Tell why the player must strike a bass key harder than a treble one to achieve the same loudness.

5c. Why is it good that the damping on the basilar membrane is large. (Hint: if it were not, what implications would this have on hearing?)
5d) Define: Place theory

Fundamental Tracking

basilar membrane
6a) Consider a glass vase suspended at rest 2 m (approximately 6 feet) off the ground. Is its energy kinetic or potential?

6b) Suppose it is dropped from this height. Is its energy kinetic or potential just before it hits the floor?

6c) What happens to this energy after the vase hits the floor?