

# Math 5: Music and Sound. Midterm 1

2 hours, 7 questions, 55 points total

Please show your working and pay attention to the indicated number of points available per question. The last page has useful information.

1. [8 points]

(a) What is the frequency of the pitch  $E\flat_6$  in the equal-tempered system?

(b) What musical pitch is the frequency 350 Hz nearest, and what is the error from this pitch in *cents*?

(c) Construct the frequency ratio between E and C in the Pythagorean C major (diatonic) scale. (Briefly show working)



3. [7 points] Sketch spectrograms on the axes provided which could realistically match the following sounds. Feel free to explain any features in words too:

(a) A pure tone rising in pitch but getting quieter, then followed by a hissing sound (no apparent pitch)



(b) A musical note with harsh timbre which is a periodic signal, followed by a bell-like note with no definite pitch.



4. [5 points] A bell produces the following partials all at roughly equal amplitudes: 302, 781, 1168, 1560, 2964. What 'strike tone' frequency is perceived, and why?

5. [11 points] A tuning fork is struck and produces a pure sinusoid at 300 Hz. A listener is a distance 2 meters from the tuning fork.

(a) Initially the tuning fork radiates 0.005 W acoustic power in all directions. What intensity in dB does the listener hear?

(b) The Q-factor of the tuning fork is 1000. What is the decay time?

(c) How long since it was struck with the above initial strength does it take until the intensity at the listener reaches the lower threshold of human hearing which is about  $10^{-10}$  W/m<sup>2</sup> at 300 Hz? (careful, not  $10^{-12}$  W/m<sup>2</sup>)

(d) If mass is added to the prongs of the tuning fork so that their *effective* mass doubles (viewing the fork as a mass-spring oscillator), what frequency does the fork sound now?

6. [7 points + bonus]

- (a) Draw a space-time diagram showing why a flutter echo is heard by a listener standing beside a wall a distance  $L$  from another wall, when they produce a short sound such as a clap. Label the walls and any sound pulses.

(b) What period of signal is heard if the spacing between the walls is  $L = 10$  meters?

- (c) BONUS: If the listener instead stands *half way* between the walls, what periodicity is heard?  
(draw a space-time diagram)



## Useful information

$$\omega = 2\pi f$$

$$c = f\lambda$$

$$\text{dB} = 10 \log_{10} \frac{I}{10^{-12} \text{W/m}^2}$$

$$Q = \pi \frac{\tau}{T}$$

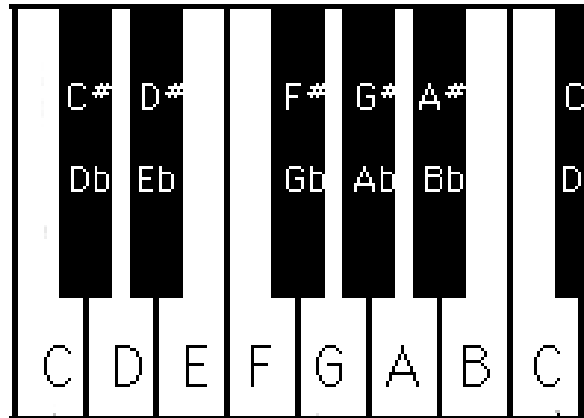
$$\frac{f_{\text{obs}}}{f} = \frac{1}{1 - v/c} \quad \text{or} \quad 1 + v/c$$

$$\sin(a + b) = \sin a \cos b + \cos a \sin b$$

$$\sin a + \sin b = 2 \cos\left(\frac{a - b}{2}\right) \sin\left(\frac{a + b}{2}\right)$$

Intervals by number of semitones:

1. minor second
2. whole tone (major second)
3. minor third
4. major third
5. perfect fourth
6. tritone (augmented fourth)
7. perfect fifth
8. minor sixth
9. major sixth
10. minor seventh
11. major seventh
12. octave



The standard musical pitch A4 is 440 Hz

You can use the speed of sound as 340 m/s.