

# THE SCIENCE OF MUSIC

## EXERCISES FOR CHAPTER 11

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**11.1** Here are some properties of air and helium gas:

Gas	Density ( $\text{kg/m}^3$ )	Bulk modulus ( $\text{N/m}^2$ )
air	1.23	$1.42 \times 10^5$
helium	0.179	$1.01 \times 10^5$

- Based on these figures and Eq. (1.16), calculate the speed of sound in air. How does your result compare with the known speed of sound, 343 m/s?
- What would the speed of sound be on a planet with a helium atmosphere?
- An organ pipe plays the note C4 on Earth. What note would it play on the planet with the helium atmosphere?

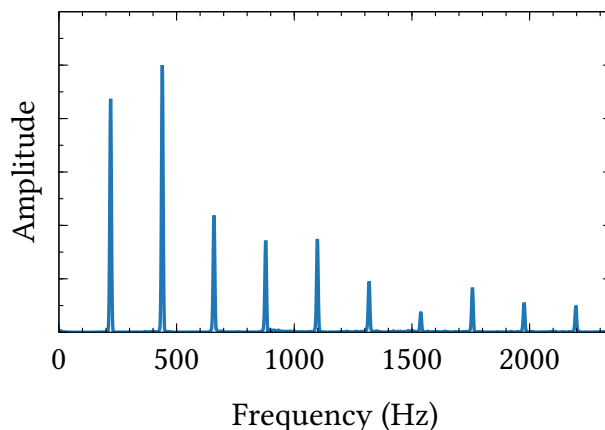
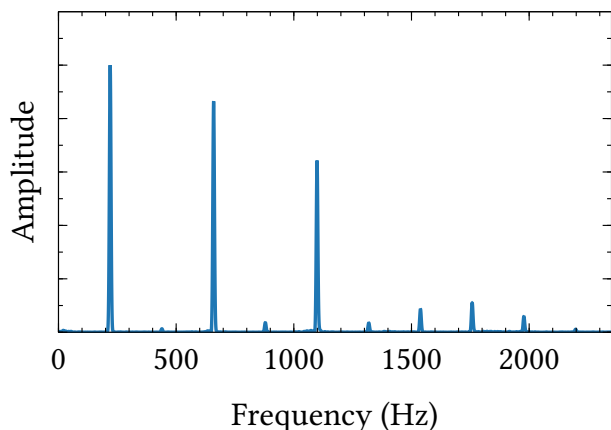
**11.2** The speed of sound is 343 m/s at 20°C but it increases with temperature by 0.61 m/s for every one degree Celsius.

- On a warm day the temperature is 25°C. What will the speed of sound be?
- A particular flute plays A4 at a perfect 440 Hz at 20°C. What will the frequency be when the temperature is 25°C?
- Is this sharp or flat, and by how many musical cents?
- To compensate for this problem, the flute has a joint in the middle that can be pulled out or pushed in to lengthen or shorten the instrument. Would one have to lengthen or shorten the flute to get it to play A4 at 440 Hz on a 25°C day?
- If the flute is 60 cm long before adjusting its length, by how much would you have to change the length to get it to play in tune?

**11.3** The excess air pressure  $p = P - P_0$  produced by the pump of a pipe organ is 900 pascals.

- What is the velocity of the air jets in the flue pipes?
- The length of the sounding portion of a certain principal pipe is 87.5 cm. What note does it play?
- At what distance from the mouth of the air jet should the labium be placed?

**11.4** These two plots show the frequency spectrum of the same note played on a soprano saxophone and on a soprano clarinet:



- Both instruments are playing the same note. Approximately what note is it?
- Which instrument is which? Explain what the giveaway features are that allow you tell.
- Briefly explain the scientific reason for the difference.
- Both instruments are about the same length, but one can play lower notes than the other. Which one can play lower, and why?
- Which instrument will have the brighter tone? Explain how you can tell.

**11.5** With no valves depressed, the lowest normal note on a trumpet is B $\flat$ 3, the B $\flat$  below middle C.

- If you use the valves, what is the lowest note you can get?
- The trombone is an octave lower. What is the lowest normal note you can get in the first slide position?
- And what is it in seventh position?
- The tuba is an octave lower still, but the tuba can play the fundamental of the harmonic series, whereas the trumpet and trombone normally do not. What is the lowest note on a tuba?
- What is the frequency of this note in hertz?
- Would this be audible to a human being?

**11.6** Recall that one does not normally play the first mode on a trombone. In normal use the lowest mode one plays is the second mode. On a standard (tenor) trombone, with the slide all the way in (first position), this mode produces the note B $\flat$ 2.

- What are the next four “open notes” above this that one can play without moving the slide from first position? Give the full note names including the octave number (e.g., C3).
- With the slide in first position, the length of the trombone pipe is 2.75 meters. To produce the note A2, one moves the slide out to “second position”. How much longer would the pipe have to get to produce this note?
- Hence, how far would one have to move the slide out?
- How much would you have to move the slide out to reach 7th position, which is 6 half-steps down from first position?