PRACTICE FINAL

PHYS 1240

Sound and Music

Summer 2019

Name: Solutions

Start Time: 11:00 AM

End Time: 12:35 PM

Total Allotted Time: 1 hour and 35 minutes

Permitted Materials: one $8\frac{1}{2}$"×11" sheet of paper with anything written on both sides, calculator without internet access, pencils, erasers

*Instructions: Write your name on the front page of the exam, but DO NOT open the exam booklet until told to do so. When told to begin, you may open the exam and begin working until time is called. Answer **all** questions in the space provided in the test booklet, and show all your work.*

This exam has four (4) parts, each worth 25% of the total exam grade.

Useful Information

SI Prefixes:

milli (m)	0.001	10^{-3}
centi (c)	0.01	10^{-2}
deci (d)	0.1	10^{-1}
kilo (k)	1,000	10^{3}
mega (M)	1,000,000	10^{6}

Conversion factors:

1 m $\approx$ 3.28 ft

1 hr = 60 min = 3600 s

1 atm $\equiv$ 101,325 N/m^2 $\approx$ 14.7 psi

1 Pa $\equiv$ 1 N/m^2

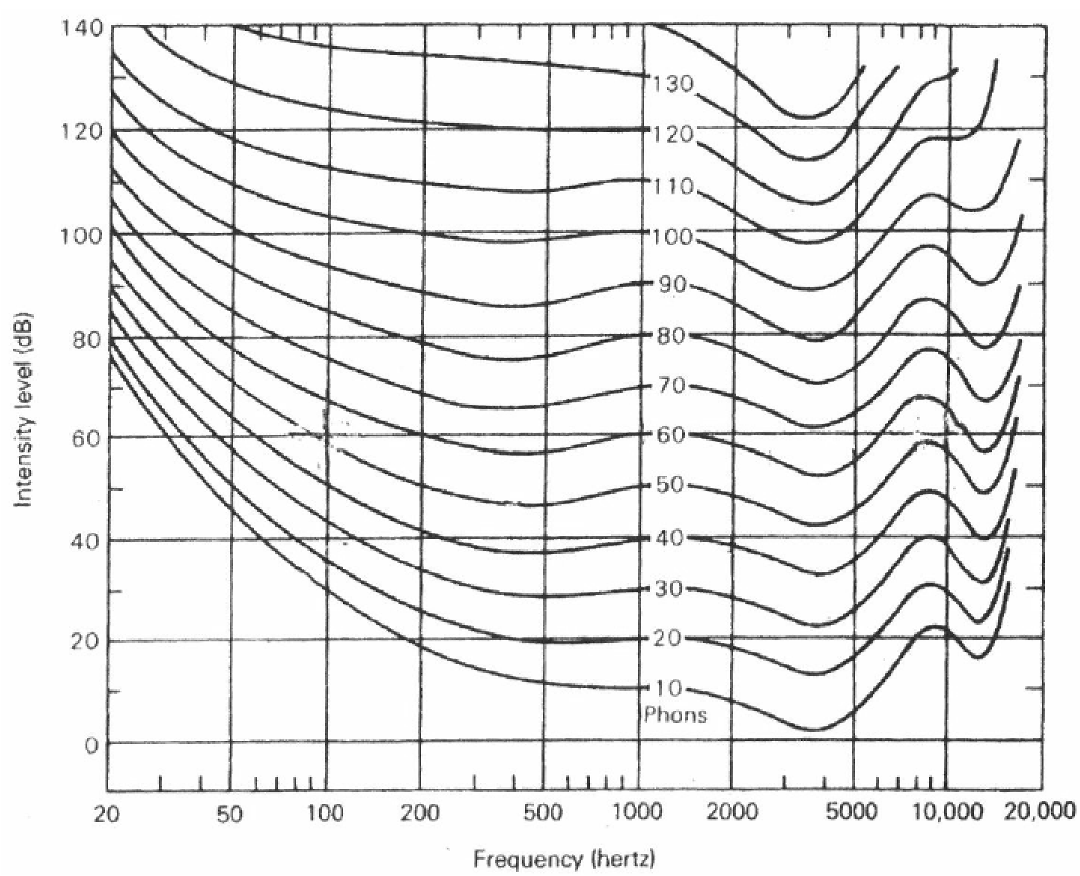
1 Hz $\equiv$ 1 s^{-1}

Formulas:

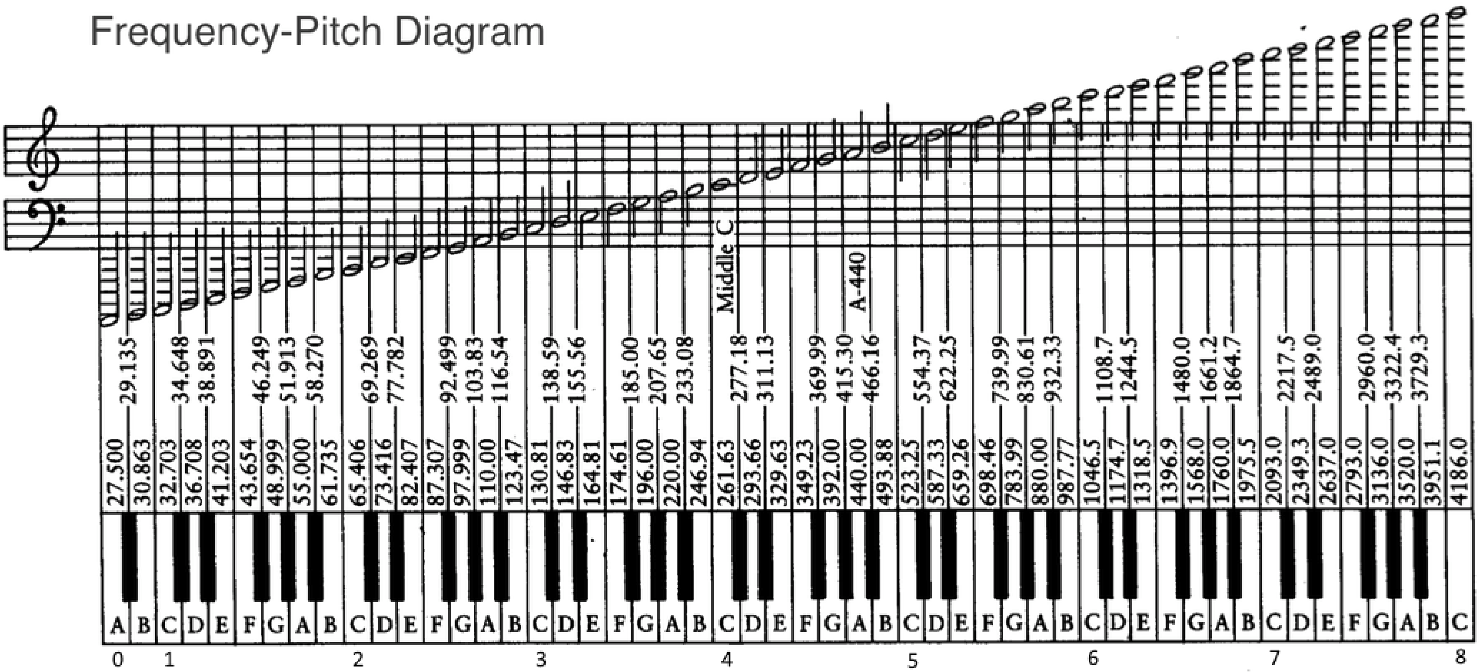
$$v = \lambda f \qquad v[\mathrm{m/s}] = 331 + 0.6\, T[^\circ\mathrm{C}]$$

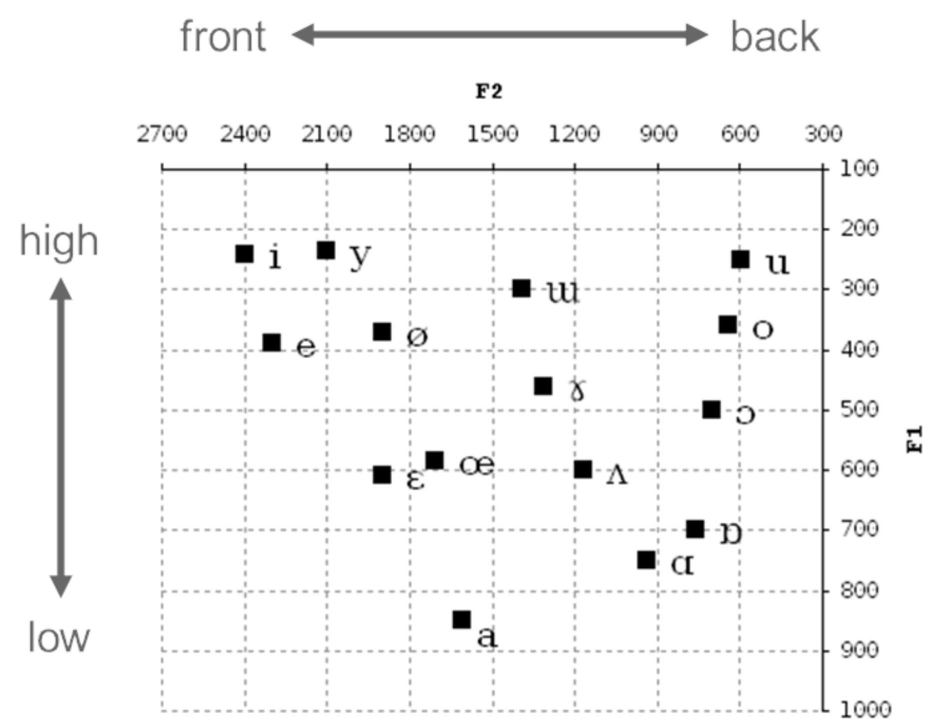
$$f_n^{\text{open-open}} = n\frac{v}{2L} \qquad f_n^{\text{closed-open}} = n\frac{v}{4L}$$

$$f_n^{\text{string}} = \frac{n}{2L}\sqrt{\frac{T}{m/L}} \qquad SIL_1 - SIL_2 = 10\,\log\left(\frac{I_1}{I_2}\right)$$



Frequency-Pitch Diagram





Section 1: Matching

Match the following 7 effects to a real-life example or application of each effect. For each numbered example, write the letter choice of its corresponding effect in the space provided to the left of each question number. All effects match exactly one example.

E 1. Slip-grip motion of a bow on a string

A 2. An ambulance siren changing pitch as it passes by you

F 3. Blowing air into a flute

G 4. Blowing air into a trumpet

D 5. The "wind throb" from one open window in a moving car

C 6. Hearing a male voice through a telephone not able to reproduce frequencies less than 300 Hz

B 7. Hearing a continuously falling Shepard tone as it subtly doubles the falling frequencies

A. Doppler effect

B. Octave equivalence

C. Missing fundamental effect

D. Helmholtz resonance

E. Helmholtz motion

F. Vortex shedding

G. Bernoulli effect

Section 2: Multiple Choice

Answer the following 7 questions with the most correct choice. Write your letter choice in the space provided to the left of each question number.

B 8. You are going for a hike in the Flatirons when off in the distance you see a bolt of lightning. Being a PHYS 1240 student, you decide to figure out how far the storm is from you. First, you note that it is about 68°F outside (20°C). What is the speed of sound in the air around you?

A) 337 m/s
B) 343 m/s
C) 346 m/s
D) 349 m/s

C 9. After you see a single flash of lightning, you count 2 seconds before you hear the peal of thunder. Assuming the speed of light is instantaneous, approximately how far away from you is the bolt?

A) 1.7 km
B) 3.7 km
C) 0.7 km
D) 10 km
E) 100 km

B 10. As you keep walking, you hear the distant sound of a marching band. You look around but do not see anything. What is the best explanation for how the sound is able to reach you?

A) You're hallucinating
B) The sound is refracting at higher altitudes where the temperature, pressure, and wind conditions cause it to bend back down to you
C) The sound is travelling through the solid mountains to reach you more quickly than you can see
D) The low frequency sounds are able to travel faster
E) None of the above

D 11. You then notice an airplane flying overhead, and much to your surprise, you hear a loud boom as you see clouds forming around the plane. What happened?

A) The plane was struck by lightning
B) The plane flew through a cloud and experienced acoustic drag effects
C) The plane engaged its thrusters
D) The plane exceeded the local speed of sound
E) None of the above

D 12. Once you reach the summit, you hear a cricket chirping the same pitch as the highest note on a piano, a C_8 (around 4186 Hz). What is the time period between each successive rubbing of this cricket's wings?

A) 2.4 seconds
B) 2.4 milliseconds
C) 24 milliseconds
D) 0.24 milliseconds
E) None of the above

A 13. If a second cricket were to join in with the same intensity but at a musical interval of a perfect fourth below the first cricket, what is the frequency of the second cricket's chirps?

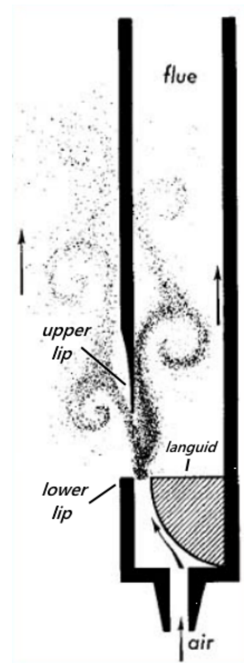
A) 3140 Hz
B) 4186 Hz
C) 2791 Hz
D) 5581 Hz
E) 3349 Hz

B 14. If each cricket alone produces a sound at 80 dB, what is the sound intensity level when both chirp together (assuming they are both the same distance from you)?

A) 80 dB
B) 83 dB
C) 86 dB
D) 90 dB
E) 160 dB

Section 3: Instrument

Answer the following 6 short answer questions. If the question requires a sketch, be sure to label all relevant parts and axes, if necessary.



15. The diagram to the right shows the mechanism behind sound production in the flue pipe of an organ. To what category of instruments does the organ belong (e.g. idiophone, membranophone, etc.)?

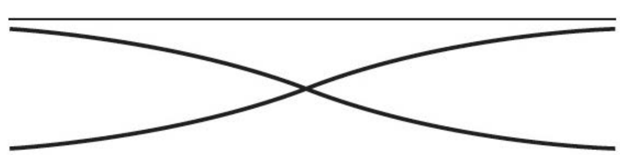
    Aerophone

16. In the diagram to the right, what physical mechanism is shown producing sound? Explain in a sentence or two how the sound is produced, assuming we already have an air stream entering the foot of the pipe.

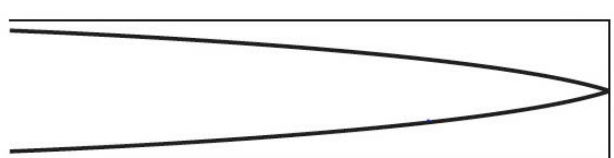
    Producing "edge tones" (vortex shedding) - when the air stream reaches the upper lip, it splits and forms vortices that repeat in a periodic fashion we hear as a tone.

17. Draw the standing waves of the fundamental mode for the organ's flue pipe, plotting the air velocity as a function of the distance along the pipe. Then, draw the standing waves of the fundamental mode for the same pipe when a stopper is placed at the top of the flue to prevent any air from escaping out that end.

    Flue pipe:



    Flue pipe with stopper:

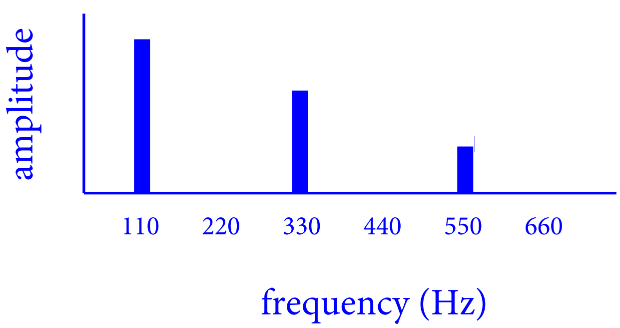


18. If you begin with the pipe in the diagram on the previous page and then add a stopper to the top, how does the pitch change (by what musical interval does it increase/decrease)? What would happen if you push the stopper at the top farther down into the pipe?

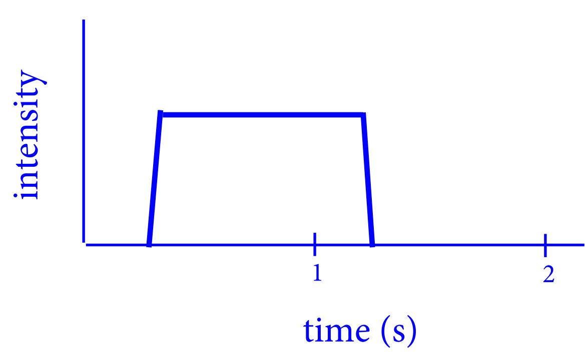
Adding a stopper causes the frequency to decrease by a factor of 2, corresponding to the pitch dropping down an octave.

Pushing the stopper farther down decreases the length and therefore increases the pitch.

19. Make a plot of the spectrum of a note produced by an organ flue pipe with a stopper placed at the top. Plot the amplitude on the y-axis and the frequency on the x-axis, and assume the fundamental frequency is 110 Hz. Clearly indicate which frequencies are present and which are not.

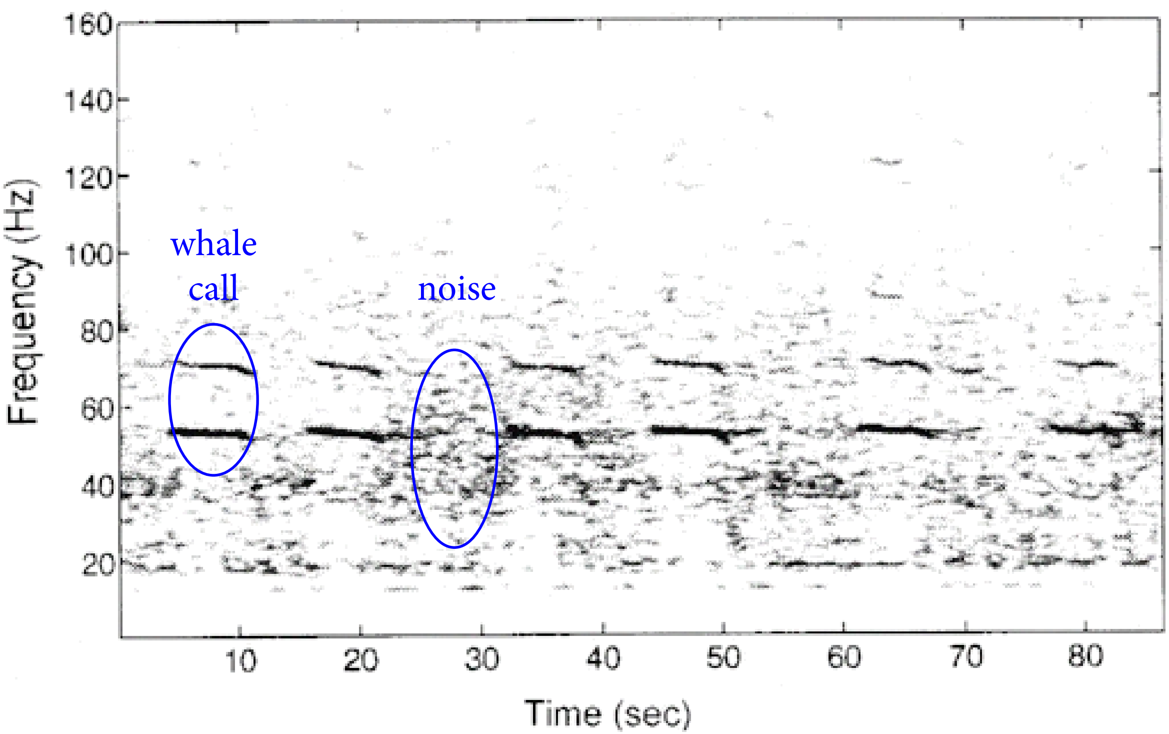


20. Make a plot of the sound envelope for a single note played by the organ, assuming a key is pressed down for 1 second and then released. Label your axes.



Section 4: Spectrogram

Answer the following 5 short answer questions related to the spectrogram below.



The spectrogram shown above is a hydrophone recording from 2/3/1993 of the so-called "52-Hz whale," a whale that wanders the northeast Pacific between Alaska and Washington and is named for its unusually high calls at a frequency of 52 Hz (other whales with similar migratory patterns vocalize at frequencies between 10 and 30 Hz).

21. The hydrophone used to record this whale picks up more sounds than just the whale's call. On the spectrogram above, circle a portion showing the whale's call (where you can hear a tone), and circle a portion showing only ocean noise (where you can't pick out a tone).

22. What is the approximate duration of one call (i.e. continuous vocalization) from this whale?

    About 6.5 seconds

23. Each whale call consists of more frequencies than just the 52-Hz sound. What other frequency is present? If these were members of a harmonic series, what would be the fundamental frequency?

    The other frequency is at about 70 Hz.
    The difference between these two frequencies (GCF) is about 17 or 18 Hz, which will be the fundamental frequency. Then 52 Hz is the third harmonic and 70 Hz is the fourth.

24. Researchers speculate that the 52-Hz whale may be a blue whale or fin whale with some sort of deformity (though not detrimental to its survival). Assume the whale produces its calls through an open-open tube as air circulates within its body, and assume the body temperature of the whale is 38°C. What is the approximate length of the whale's vocal tract? Use the fundamental frequency you found in the previous question.

First, find the speed of sound:
v = 331 + (0.6 x 38) = 353.8 m/s

Then, find the length with the open-open tube frequency formula:

$$L = \frac{v}{2 f_1} = \frac{353.8 \text{ m/s}}{2 \text{ (17 Hz)}} = 10.4 \text{ m}$$

25. In the decades since this 1993 recording, the 52-Hz whale's calls have deepened slightly to around 49 Hz. What could this suggest about how the whale's size has changed in this time?

If the frequency is decreasing, then the whale's size must be increasing (which makes sense if it is growing larger as it ages and matures).

——— *End of Examination* ———