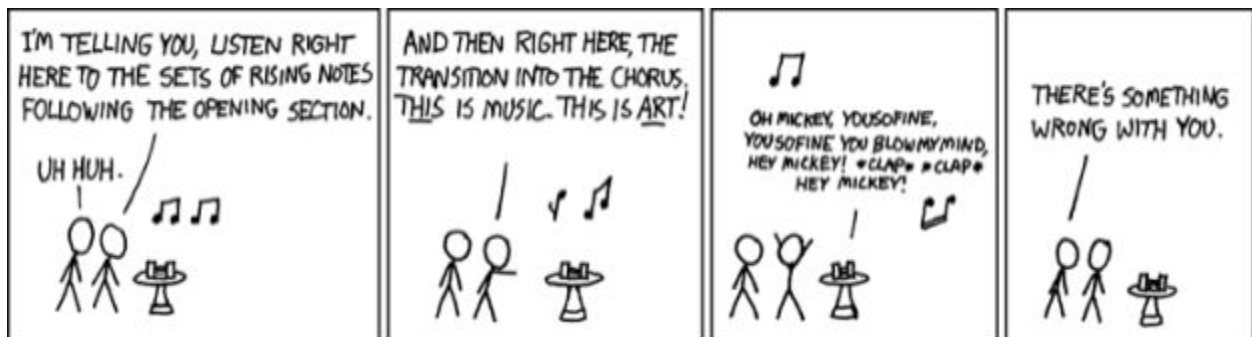




River Hill Science Olympiad Invitational 2021

# Sounds of Music



## Exam Booklet

Total Points: \_\_\_\_/120

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# Exam Instructions

- You will have **50 minutes** to complete this exam.
- You may use any resources that you have compiled prior to the start of this exam (print or online, but this test is **NOT** open-internet) and two calculators as allowed by national Science Olympiad rules.
- Please use at least **three significant figures** in your answers. More is fine, fewer is not.
- Assume the speed of sound in air is **343 m/s** unless stated otherwise.
- Assume A4 = **440. Hz** unless stated otherwise.
- Assume pitches are **equally tempered** unless stated otherwise.

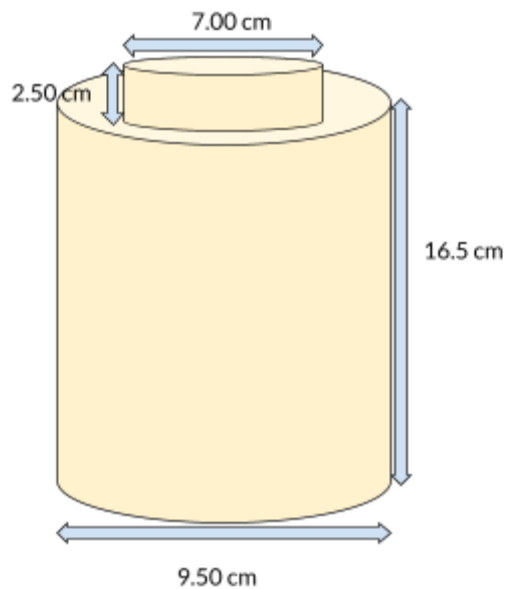
**GOOD LUCK! Hope you enjoy the test!**

The displacement of a particle on a string (in meters) over time (in seconds) is characterized by the function  $x(t) = 0.571\sin(876t)$ . Calculate:

1. (1.00 points) The frequency of the function, in Hz. (Don't write units as part of your answer.)
2. (1.00 points) The period of the function, in milliseconds. (Don't write units as part of your answer.)
3. (1.00 points) The amplitude of the function, in centimeters. (Don't write units as part of your answer.)
4. (2.00 points) The wavelength of the function, in decimeters. (Don't write units as part of your answer.)
5. (2.00 points) Which of the three most common states of matter (solid, liquid, gas) is sound slowest in? What property of matter causes sound to be slowest in this state of matter?
6. (3.00 points) You are a certain cabbage vendor in the Earth Kingdom city of Omashu, and you're absent-mindedly tending to your goods one day when you hear a shout. You turn, startled, to see a bunch of kids hurtling toward you on the package delivery system at 20.0 m/s and shouting what you perceive as a perfectly in-tune, equally tempered G4. What frequency were they actually shouting at?
7. (3.00 points) The kids pass by you, still heading at the same speed and shouting at the same frequency, and you breathe a sigh of relief, but then you see another group of kids coming down the ramp at 25.0 m/s shouting what you perceive as an in-tune, equally tempered A4. What beat frequency do you perceive between the first group of kids and the second?
8. (3.00 points) What is the actual beat frequency between the two groups of kids?
9. (2.00 points) Meet Stringy. Stringy is 1.86 meters long with a linear density of 70.0 g/m. What tension does Stringy need to have in order to vibrate at a second harmonic of 440. Hz?

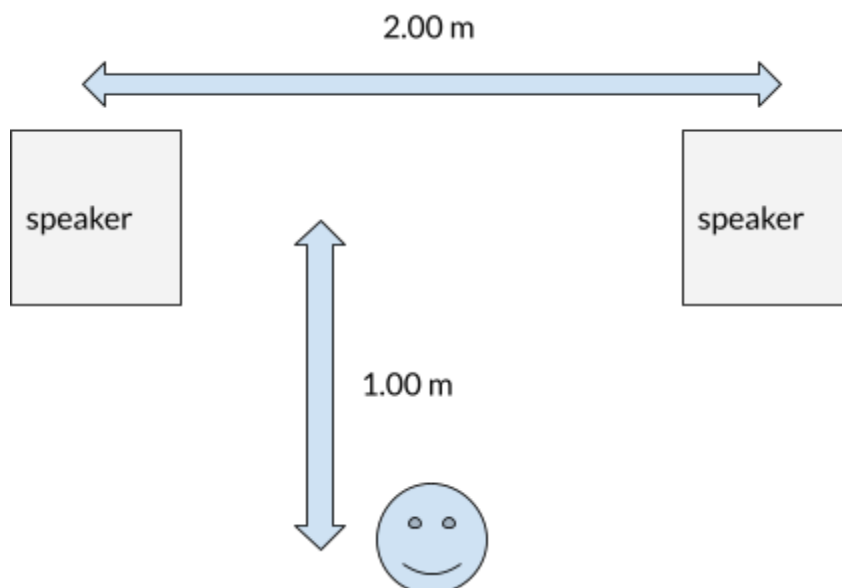
Patrick Star finally gets fed up with everyone telling him mayonnaise isn't an instrument, and he sets out to prove Bikini Bottom wrong. He presents his neighbors with an empty mayonnaise jar whose dimensions are displayed in the artist's rendering below. (That's a neck on top, not a cap.)

(Additional author's note: I admit that the dimensions of this jar are not very conducive to actually producing sound, but it's Patrick, what did you expect?)



10. (3.00 points) Patrick blows across the opening of the jar's neck. Assuming that Patrick knows nothing about end correction, what frequency can he expect to hear?
11. (3.00 points) Squidward, Bikini Bottom's resident acoustics expert, informs Patrick that end correction does, in fact, apply to the mayonnaise jar. Patrick looks at him blankly, says "Oh", and redoes his math. Now what frequency does Patrick expect to hear from the mayonnaise jar if he blows across the top?
12. (1.00 points) After embarrassing himself in front of the populace of Bikini Bottom with his jar antics, Patrick eventually realizes that his "instrument" isn't actually very good at making sound. Had it worked though, the mayonnaise jar would exemplify what specific acoustical device?
13. (2.00 points) A standing wave has a fundamental frequency of 622 Hz. What is the wavelength of the 3rd overtone of this wave?

Two speakers are positioned 2.00 meters apart. You are standing equidistant from the speakers, 1.00 meters in front of both. The artfully rendered diagram below illustrates this configuration.

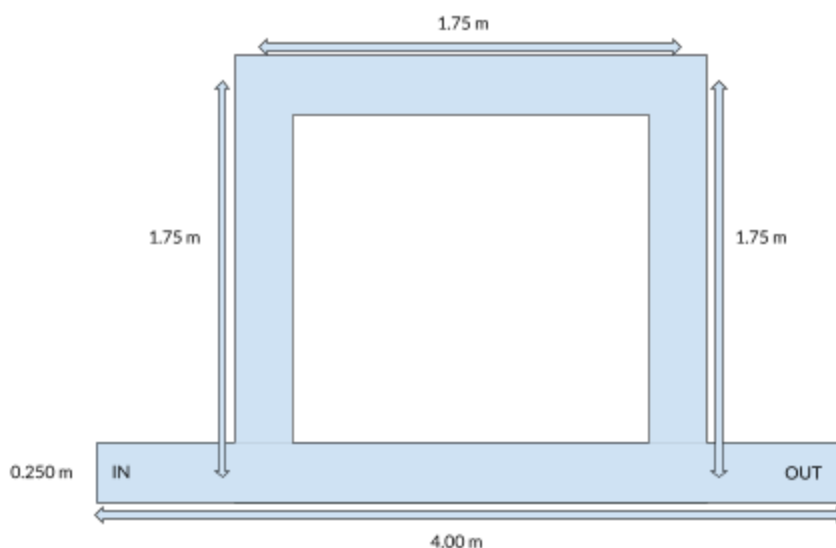


14. (3.00 points) The speaker on the left emits a tone whose wavelength is equal to the distance between you and the speaker. Some time  $t$  later, the speaker on the right emits the same tone at the same amplitude. What is the minimum value of  $t$  such that you hear nothing when the second speaker starts playing?
15. (2.00 points) What is the name of the phenomenon at work here? What is a real-world use of this phenomenon?
16. (2.00 points) Remember Stringy? Well, Stringy has a son, named Stringson. (Wow, I'm so original with names!) Stringson is 3.00 meters long, with a speed of sound of 600. m/s. If Stringson vibrates with a frequency of 300. Hz, what is an equation  $D(t)$  that represents the displacement over time of a particle on Stringson located 1.00 meters from one of Stringson's ends?

Saketh lights a firecracker to celebrate the very first RHSOI, but forgets to get away from it in time. He's 1.00 meters away from the firecracker when it detonates with a sound intensity of 160. dB, and poor Saketh has to be taken to the hospital for potential ear damage.

17. (4.00 points) (Tiebreaker 3) Where Jeff is standing, the firecracker has a sound intensity of 100. dB, and from Victoria's location it has an intensity of 60.0 dB. If Victoria, Jeff, Saketh, and the firecracker are all along a straight line, how far apart are Victoria and Jeff?
18. (3.00 points) Express the sound intensity of the firecracker at Saketh's location in terms of the threshold of hearing  $I = 1.00 \text{ kg/s}^3$ .
19. (6.00 points) (Tiebreaker 1) The local hospital is busy treating JOVID-21 patients and has no space for Saketh, so he's taken by helicopter to another location. The helicopter happens to fly at 343 m/s. Given that the adiabatic heat index for the speed of sound  $\gamma$  is 1.4, the ideal gas constant  $R$  is 8.31 J/mol, the molecular mass of air  $M$  is 0.0290 kg/mol, and the temperature in degrees Celsius varies linearly with altitude in meters by  $T(a) = 308 - 0.00200a$ , what is the highest altitude the helicopter can fly at in order to avoid exceeding the speed of sound?

Here's an extremely professional drawing of a pipe setup. The pipes are cylindrical with a constant diameter of 0.250 meters. Note the arrows. (The light-blue rectangular sections are all connected to each other.)



20. (2.00 points) A tone is played through the pipe at the location marked "IN". What is the lowest frequency that the tone can be in order for the waves to still remain in phase at the location marked out?

21. (2.00 points) What is the highest wavelength that the tone can be in order for the waves to be completely out of phase with each other at the location marked "OUT"?
22. (4.00 points) A certain solid has density  $\rho = 2720 \text{ kg/m}^3$ , bulk modulus  $B = 67.2 \text{ GPa}$  and shear modulus  $G = 45.0 \text{ GPa}$ . Calculate its speed of sound given that it is homogeneous and isotropic.
23. (2.00 points) Why can't decibels be used as a unit of loudness?
24. (2.00 points) This is a table relating phons and sones, which are both units of loudness. Calculate a function  $s(p)$  that returns the loudness of a sound in sones when given its loudness in phons.

Phons	Sones
100	64
90	32
80	16
70	8
60	4
50	2
40	1

25. (3.00 points) I'm trying to analyze some audio. I decided to use a spectrogram, but then I discovered a mel-spectrogram, and now I'm confused. What's the difference between a mel-spectrogram and a regular one?

For questions 26-40, you'll be analyzing score 1 (located at [this URL](#)).

26. (2.00 points) What time signature is this piece in? What is the name of the meter of this piece?
27. (1.00 points) What's the Italian term for the type of repeated rhythm played by the string section at the beginning of the piece?
28. (2.00 points) Both of the harps alternate between two notes for the first few measures of the piece. State the names of these two notes (e.g. C4 and D4) as well as the interval between them.
29. (1.00 points) You'll notice at the bottom of the first page that the strings are instructed to play *col legno*. What does this style marking mean?

Let's look at the first and third notes played by the Bassoon 2 part. (Ties are considered to be one note.)

30. (1.00 points) What is the interval between these two notes?
31. (1.00 points) What is the width of the interval between these notes (in cents) in equal temperament?

32. (2.00 points) What is the width of the interval in Pythagorean tuning, if the first note played by the bassoon is the tonic?
33. (2.00 points) Given that the tempo is quarter note = 160. beats per minute, how long (in seconds) does it take Horn 6 in F to play their first three notes? (Again, ties count as one note.)
34. (2.00 points) Four types of instruments (according to the Hornbostel-Sachs system) are represented on the second page. Name each of them as well as how many of the parts listed on the page fall into each category.
35. (2.00 points) There are three lines intersecting the stems of the tam-tam's notes throughout the second page. What musical effect does this represent? What does it mean to change the number of intersecting lines?
36. (2.00 points) In measure 14, the words *con sordino* are written above the 1st Trumpet in C part. What does *con sordino* mean? What is another instrument that can be played *con sordino*?
37. (2.00 points) What clef is marked for the Tenor Trombone 1 part in measure 18? What note (in concert pitch) is written in the last two beats of that measure?
38. (1.00 points) At measure 25, the piece modulates into a new key, spearheaded by a horn melody. What key is this, in concert pitch?
39. (3.00 points) The score concludes with the woodwinds and upper brass sustaining a chord over a low brass/strings ostinato. What slash chord (in concert pitch) represents the conclusion of the score? (A slash chord is written in the format  $C^7/D$ , where  $C^7$  is the upper chord and D is the bass note.)
40. (2.00 points) (Tiebreaker 4) Name that tune! What piece have you been looking at this whole time? (P.S. you get half credit for simply writing anything here...)

Time for score number 2! This piece is a two-piano arrangement of a song. You can find it [here](#).

41. (1.00 points) The first measure is marked as 4/4 time signature, but that's a bit misleading... What's the measure's actual time signature? (Format your answer similar to "4/4" without the quotes.)
42. (2.00 points) The last beat of the first measure is eight 32nd notes running up a scale. What mode (e.g. C ionian) is this run in?
43. (2.00 points) Measures 2-4 in the first piano part are played by a melodica in the actual song. What Hornbostel-Sachs category does a melodica fall under? How does it produce sound and change between notes?
44. (1.00 points) What Italian term describes the small eighth note with a slash through it in measure 7 of the 2nd piano part? (Don't worry too much about spelling.)
45. (2.00 points) Measures 14 and 16 include octave intervals in the piano 1 part. Are the intervals likely tuned to be 1200 cents apart, wider, or narrower? Why?
46. (1.00 points) What two-word phrase describes the new key signature (starting from measure 22) in relation to the previous one?

47. (2.00 points) (Tiebreaker 5) What song is this? (Like the last one, you get half credit for writing anything here...)

You have your melodica-player friend handle the first piano part while you play the second part on an actual piano.

48. (3.00 points) You're playing outside as night falls and it gets colder. How does the intonation of each instrument change due to the temperature (sharper/flatter/unaffected) and why?
49. (4.00 points) (Tiebreaker 2) Your friend holds out the G<sub>4</sub> in the last measure while approaching you from behind at 2.75 m/s, and you play a G<sub>4</sub> at the same time. However, this leads to some weird-sounding beats. It's harder to tune a piano than it is to tune a melodica, so you ask them to play the last note with slightly different intonation so that someone standing in front of both of you hears the same (in-tune) frequency from both instruments. Should they play sharper or flatter, and by how many cents?

This is a Yamaha YCL-CSVR B♭ soprano clarinet.



50. (3.00 points) Identify the six components of the instrument pointed out on the diagram. (The arrows are not pointing to keys or holes.)
51. (1.00 points) "Crossing the break" is a comparatively difficult task for a beginning clarinetist. While they may know the fingerings for higher notes, they struggle to actually get the notes out and often end up making painful squeaking noises. What concept in acoustics causes this difficulty?
52. (2.00 points) I tried learning flute a few years ago. (Spoiler alert: I was known for having absolutely horrible tone.) I was trying to get the hang of high notes, but whenever I tried playing G<sub>6</sub> I would end up playing the D below. What was causing that to happen? (Hint: the lowest G on a standard flute is G<sub>4</sub>.)
53. (2.00 points) Trumpets and cornets are relatively interchangeable instruments. What is the main difference between the two, and how does it affect the tonal characteristics of the two instruments?
54. (5.00 points) (Tiebreaker 2) It's quite disappointing that due to the limitations of virtual Science Olympiad, you can't share your Sounds of Music devices with everyone. Write about a device you would have brought to the competition had it been in-person. What Hornbostel-Sachs category is it? How do you



operate it? How does it make sound? What advantages do your specific design have over other devices? What disadvantages might it have?