Maryland Science Olympiad

Sound of Music B Exam

2023 - Johns Hopkins Science Olympiad Invitation

Date/Time: 11 February 2023
Place: [Building and Room Number], Johns Hopkins University (Homewood)
Team ID: _____

Instructions:

- You have **30 minutes** to complete this exam. It has 16 pages, including this cover (un-numbered), 12 pages with problems with instructions, and 3 blank extra pages. <u>Do not turn this page until instructed to do so.</u>

- There are 22 problems and 33 questions. We suggest that you start with the problems you find easiest. <u>If you are stuck, move on to a different problem!</u>

- Use a pencil or dark blue/black pen. You are permitted to use one three-ring binder and two stand-alone calculators of any type.

- Do your work on these sheets. If you use a blank extra page, carefully note the page number of the extra page on the question and start your work on the extra page with the question number (*e.g.*, "Question 34"). Re-staple the exam if you decide to take it apart.

- <u>Show your work.</u> Ambiguous or otherwise unreadable answers will be marked incorrect. Provide only one answer to each question. Correct number of significant figures is not necessary unless required. Ties will be broken by specific questions marked as tiebreakers.

- All electronic devices capable of external communication (*e.g.*, laptops, phones, tablets, smart watches) are prohibited. At the discretion of the Event Supervisor, you may be required to place your devices in a designated location.

- One student of each sex will be permitted to use the restroom at a time. Please raise your hand and wait for a staffer to assist you.

Honor Pledge (please read and sign below):

I agree to abide by all rules and regulations pursuant to the most recent edition of the Science Olympiad Inc.'s Rules Manual for my Division and the rules of the Maryland Science Olympiad.

Printed Name	Signature	Date

Multiple Choice Section (3 pts each, 60 pts in total.)

1. Sound CANNOT be transmitted through which medium:
    a. Air.
    b. Liquid Water.
    c. Wall.
    d. Vacuum.
    e. Ground.

2. Which of the following is NOT an instrument that can make a harmonic:

| A | B | C | D | E |

FINISH QUESTION 3 THROUGH QUESTIONS 5 WITH TABLE 1.

Note	A$_3$	B$_3$	C$_4$	D$_4$	E$_4$
f (Hz)	220.00	246.94	[*]	293.66	329.63
λ (m)	1.4545	1.2959	[**]	1.0897	0.97079

Table 1: The frequency (f) and wavelength (λ) of notes in an unknown medium.

3. Which answer is closest to the speed of sound in this unknown medium:
    a. $3.2 \times 10^2 \mathrm{m \cdot s^{-1}}$.
    b. $3.4 \times 10^2 \mathrm{m \cdot s^{-1}}$.
    c. $3.6 \times 10^2 \mathrm{m \cdot s^{-1}}$.
    d. $4.0 \times 10^2 \mathrm{m \cdot s^{-1}}$.
    e. $3.0 \times 10^8 \mathrm{m \cdot s^{-1}}$.

4. What should be filled into [*] in Table 1:
    a. 257.59
    b. 261.63.
    c. 270.30.
    d. 273.88.
    e. 277.18.

5. Assume this medium is air under standard pressure, what can we interpret about the temperature of the air:
    a. The temperature approaches the absolute zero.
    b. The temperature is slightly below 290K.
    c. The temperature is about 290K.

  d. The temperature is slightly above 290K.

  e. The temperature approaches Plank's temperature.

6. Which type of wave does sound belongs to and how are displacement and the direction of energy propagation related:

  a. Longitudinal wave, displacement parallel to the direction of energy transfer.

  b. Longitudinal wave, displacement normal to the direction of energy transfer.

  c. Transverse wave, displacement parallel to the direction of energy transfer.

  d. Transverse wave, displacement normal to the direction of energy transfer.

  e. Both longitudinal and transverse wave, displacement and the direction of energy transfer can be in arbitrary directions.

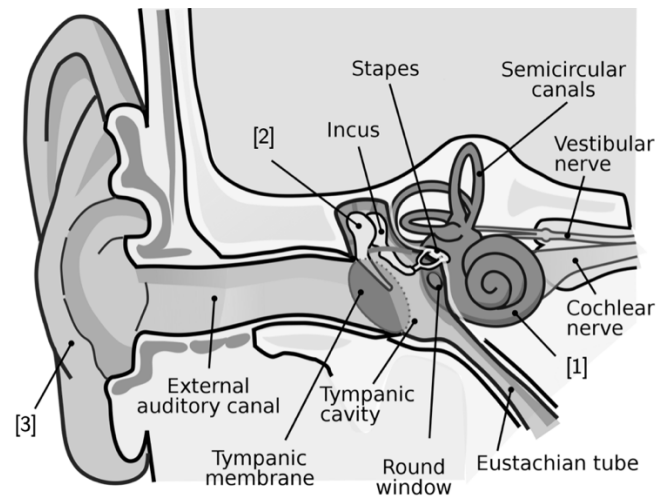FINISH QUESTION 7 AND QUESTIONS 8 WITH FIGURE 1.

Figure 1: Anatomy of the Human Ear.

7. In Figure 1, what are the names of label [1], [2], and [3]:

Label	[1]	[2]	[3]
a.	Circular canals	Malleus	Cras
b.	Circular canals	Malleus	Auricle
c.	Circular canals	Outcus	Cras
d.	Cochlea	Outcus	Auricle
e.	Cochlea	Malleus	Auricle

8. Cerumen, also known as earwax, often appears at:

  a. Structure [3].

  b. External auditory canal.

  c. Tympanic cavity.

  d. Structure [1].

  e. Eustachian tube.

9. Suppose wave A and B are of the same type with directions indicated in Figure 2. Out of the 4 given diagrams of pulses, which ones can be an intermediate diagram that follows the principle of superposition:
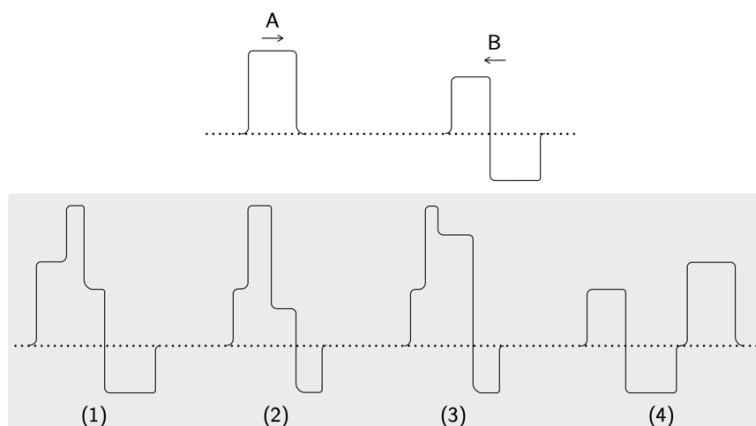

Figure 2: Movements of 2 Waves and Intermediate Diagrams.

    a. (1) (2) (3).
    b. (1) (2) (4).
    c. (1) (3) (4).
    d. (2) (3) (4).
    e. (1) (2) (3) (4).

10. Which of the following units are used to measure noise:
    a. Hertz.
    b. Decibel.
    c. Volt.
    d. Roentgen.
    e. Lumen.

11. Which of the following is not an approach to reduce the impact of noise in life:
    a. Plug earplugs into ears.
    b. Build noise barriers on the sides of highways.
    c. Install mufflers on vehicles.
    d. Decrease the amount of carbon dioxide in air.
    e. Plant trees around to absorb noise.

12. Which of the following conditions is not necessary to form a standing wave:
    a. Two waves have the same speed.
    b. Two waves have the same direction.
    c. Two waves have the same amplitude.
    d. Two waves have the same wavelength.
    e. Two waves are of the same type.
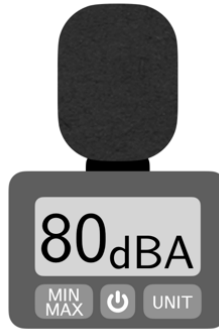
FINISH QUESTION 12 THROUGH QUESTIONS 14 WITH FIGURE 3.

Figure 3: Digital Sound Level Decibel Meter

13. The device in Figure 3 indicates that the sound level for human ear is:
    a. 8B.
    b. 10B.
    c. 40B.
    d. 60B.
    e. 80B.

14. Which of the following statement for the given noise level in Figure 3 is correct:
    a. This noise level causes pain for human ears and is intolerable.
    b. This noise level impairs the hearing of human.
    c. This noise level is still on a healthy level.
    d. This noise level allows easy communication between people.
    e. This noise level can barely be heard by human ears.

15. What is approximately the sound pressure for the environment given the reference pressure is 1atm in Figure 3:
    a. 2cPa.
    b. 2dPa.
    c. 2Pa.
    d. 2daPa.
    e. 2hPa

16. When a moving sound source generating sound waves at a consistent frequency and amplitude is moving towards you, which of the following should you not anticipate:
    a. The amplitude of the sound increases.
    b. The frequency of the sound increases.
    c. The wavelength of the sound increases.
    d. The speed of the sound remains constant.
    e. The type of the sound wave remains the same.

17. During resonance, another object will have a motion, which of the following is a correct explanation in terms of the conservation of energy:

    a. The energy is no longer conserved as the other object belongs to another closed system.

    b. The energy is no longer conserved as the Earth is exerting extra forces on the other objects.

    c. The energy is conserved considering the damping effect to lose energy.

    d. The energy is conserved as motion of the other object has energy from the gluons that binds the nucleons.

    e. The energy is conserved between the kinetic and potential energy.

18. Which of the following does not exist in the 12-tone chromatic scale:

    a. A♯

    b. B♯

    c. C♯

    d. D♯

    e. G♯

19. Which of the following correctly interpret refraction when it comes to sound waves:

    a. Refraction applies to sound waves because it is a type of waves.

    b. Refraction does not apply to sound waves because they are transverse.

    c. Refraction does not apply to sound waves because sound waves cannot be dispersed in more medias.

    d. Refraction does not apply to sound waves because the refractive indices for sound waves are greater than 1.

    e. Refraction does not apply to sound waves because sound waves does not contain any energy propagated.

20. Different animals are able to hear sounds of different frequencies, what are the frequencies of sound that can be heard by most human beings:

    a. $10\text{s}^{-1} \sim 1{,}000\text{s}^{-1}$

    b. $10\text{s}^{-1} \sim 10{,}000\text{s}^{-1}$

    c. $20\text{s}^{-1} \sim 20{,}000\text{s}^{-1}$

    d. $20\text{s}^{-1} \sim 50{,}000\text{s}^{-1}$

    e. $50\text{s}^{-1} \sim 50{,}000\text{s}^{-1}$

This is the end of the Multiple-Choice part of the exam.

The Free Response Questions starts from the next page.

Free-Response Problem 1: Creating your own harmonics (30 pts)

In this problem, you will be analyzing an experiment where you are creating your own harmonics with a glass and water (as of Figure 4). Throughout the experiment, the speed of sound in air is measured to be $(340.0 \pm 0.5)\text{m} \cdot \text{s}^{-1}$.
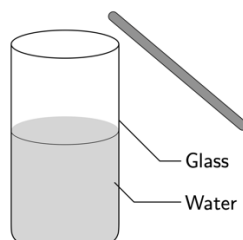

Figure 4: Experimental Setup

Part (a): Before the experiment.

21. (4 pts) If another person is standing $(68.0 \pm 0.5)\text{m} \cdot \text{s}^{-1}$ away from the glass and water, how much time is expected for the other person to hear the sound? (REMINDER: KEEP THE RIGHT SIGNIFICANT FIGURES AND UNCERTAINTY FOR YOUR ANSWER.)

22. (4 pts) The standing wave for the first harmonics is given to you with a dot being a node and a cross being an antinode in Figure 5. Complete the third and fifth harmonics on the same figure.
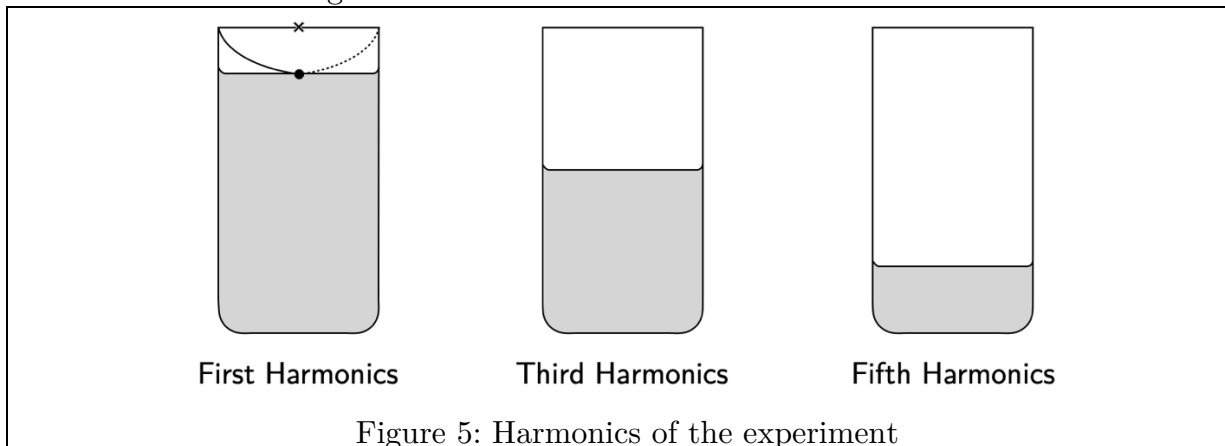

First Harmonics   Third Harmonics   Fifth Harmonics

Figure 5: Harmonics of the experiment

23. (3 pts) Explain why harmonics can be formed in this setup.

Part (b): Get your hands on.

24. (4 pts) By measurement, the height of water from the bottom of glass of the first, third, and fifth harmonics are respectively $14.0\text{cm} \pm 0.1\text{cm}$, $8.0\text{cm} \pm 0.1\text{cm}$, and $2.0\text{cm} \pm 0.1\text{cm}$. What is the height of the glass? (REMINDER: KEEP THE RIGHT SIGNIFICANT FIGURES AND UNCERTAINTY FOR YOUR ANSWER.)

25. (4 pts) Calculate the frequency of this standing wave. (REMINDER: ROUND YOUR ANSWER TO 3 DECIMAL PLACES AND THE UNCERTAINTY IS NOT REQUIRED.)

26. (2 pts) Write down a relationship between the wavelength (λ) and the height of the air section in glass (h) for the nth harmonic.

Part (c): Reflect our experiment.

27. (3 pts) During this experiment, only odd harmonics are investigated. Will there be even harmonics? If yes, calculate the height of the air (h) for the 8th harmonics. If no, explain why it wouldn't exist.

Yes ☐   No ☐ (Check the box.)

28. (4 pts) In order to create a device that can produce at least 10 harmonics, what is the minimum height of the glass?

29. (2 pts + Tie Breaker) What is one other instrument that uses the same techniques with this glass and water method? (Write down more for Tie Breaker points.)

30. (0 pts + Tie Breaker) How can this experiment be improved for more accuracy and precision? (This question will only be graded for Tie Breaker.)

Free-Response Problem 2: ANC Headsets (10 pts)

In this problem, you will be analyzing the techniques of ANC (Active Noise Cancellation) Headsets. Active Noise Cancellation Headsets reduce the background noise by using a speaker for noise-cancelling.

31. (4 pts) Passive Noise Cancellation uses ear cups to seal out the noise. How is Passive Noise Cancellation different with Active Noise Cancellation in terms of the propagation of energy?

32. (3 pts) If there is a noise with constant wavelength 20mm at a distance of 10m from the Tympanic membrane, what should be the wavelength (in SI units) and distance between the active noise cancellation headset and the Tympanic membrane?

33. (3 pts) What are some health and safety concerns with Active Noise Cancellation Headsets?

This is the end of the Free Response part of the exam.

If you need extra writing space, please use the pages after.

EXTRA PAGE

On the original page, write "continued on Page 13" and on this page, write "Question #X," where X is the question number you are continuing.

EXTRA PAGE

On the original page, write "continued on Page 14" and on this page, write "Question #X," where X is the question number you are continuing.

EXTRA PAGE