Sounds of Music • 2020 December 5

Do not begin until you are told to do so.

This test uses these conventions unless implied or stated otherwise:

- All frequencies are greater than 20 Hz.
- Sound sources are points emitting continuously in windless 20°C air at sea level.
- All strings and pipes are of very small, nonzero radius.
- An octave consists of twelve equally distant half steps referenced to A_4 = 440 Hz.

This test was written so that you'll be able to read every question, but not answer every question. Don't feel bad to make an educated guess even when you're not sure of your answer.

To begin, you should save a copy by clicking "File → Make a Copy" on Google Drive, or by clicking "Save a copy to OneDrive" on OneDrive. This creates an editable version of this test, which you and your partner should work on together. When you are done, you should submit or upload the test to the Google Form.

Some questions will be graded by a computer, while other sections will be graded by a human. You should follow the instructions in each section on how to format your responses so that the computer can successfully grade them. Good luck!

School: _____ Team number: _____

Student names: _____

Test score: _____ Final score: _____ Rank: _____

NCSO Invitational

Multiple choice

Each multiple-choice question has exactly one answer, and there is no additional penalty for choosing the wrong answer. Write only the letter of your answer choice in the box to the right of each question. Either lowercase or uppercase letters will be accepted, but you should *not* include parentheses, calculations, explanations, or any other text in the box.

1. Two pure tones play with frequencies of 212 Hz and 216 Hz. The tones create beats of what frequency?

   (A) 2 Hz
   (B) 4 Hz
   (C) 214 Hz
   (D) 428 Hz
   (E) 11448 Hz

2. Which of the following gives pressure amplitude in terms of SI base units?

   (A) mm Hg
   (B) $N \cdot m^2$
   (C) $kg \cdot m / s^2$
   (D) $kg / (m \cdot s^2)$
   (E) kg / m^2

3. An intensity of 10^{-12} W/m^2 corresponds to what intensity level, in decibels?

   (A) 0 dB
   (B) 12 dB
   (C) 60 dB
   (D) 120 dB
   (E) 144 dB

4. In a standing wave on a string, a region of zero displacement is known as

   (A) Crest
   (B) Trough
   (C) Colgate
   (D) Displacement antinode
   (E) Displacement node

5. Which of the following techniques is most commonly used by scientists to determine the frequency of a sound?

   (A) Zero-width points
   (B) Envelope detection
   (C) Fourier transform
   (D) Autocorrelation
   (E) Wave cycle counting

6. When a musician holds down one string on an ukulele and plucks it, a different string begins playing too. This best exemplifies

(A) Empathetic strings
(B) Resonance
(C) Decoupling
(D) Diffraction
(E) Attraction

7. Which of the following is a complete major scale in fixed *do* solfège, in any order?

I. *do ti la sol fa mi re do*
II. *do re mi fa sol la ti do*
III. *do ti mi sol fa re mi do*

(A) I only
(B) II only
(C) III only
(D) I and II
(E) I, II, and III

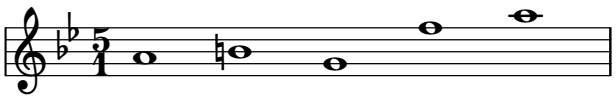
8. Which of these intervals has a size of 350 cents?

(A) Semitone
(B) Perfect fifth
(C) Augmented sixth
(D) Minor seventh
(E) None of these

9. What scale is formed by transposing each note of a C major scale downwards by three half steps?

(A) A minor
(B) C minor
(C) A major
(D) E♭ major
(E) G major

10. Which of the following notes is an F?



(A) (B) (C) (D) (E)

11. A measure has exactly four quarter notes. Which of the following is a valid time signature for this measure?

I. $\frac{2}{2}$

II. $\frac{4}{4}$

III. $\frac{3}{4}$

(A) II only
(B) I and II
(C) II and III
(D) I, II, and III
(E) None of these

12. Which of these instruments has definite pitch?

(A) Snare drum
(B) Cymbal
(C) Sleigh bell
(D) Viola
(E) Bongo

13. Normally, a guitar acts as a chordophone. However, some guitarists knock their free hand on the soundboard of their guitar like a drum to keep rhythm. When this occurs, the guitar simultaneously acts as what other type of instrument?

(A) Membranophone
(B) Idiophone
(C) Mellophone
(D) Aerophone
(E) Electrophone

14. All of the following instruments are aerophones EXCEPT

(A) Bassoon
(B) Synthesizer
(C) Tuba
(D) Cornet
(E) Didgeridoo

Short answer questions

Questions with an answer box to the *right* of the question will be graded automatically. Include only your answer and units, if any. Exponents, slashes, and dots are allowed for units, but do *not* include parentheses or non-SI units anywhere in your response. You may express numbers as a single decimal number, or you may use scientific notation using the format "$A \times 10^B$" (copy and paste it from here, and change A and B as desired). Do *not* use "e" for scientific notation. Questions with an answer box *below* the question will be graded by a real human being (yay!). You don't have to show your work to receive full credit on any question.

15. A pipe closed at one end and open at the other has a length of 1.75 m. What is its fundamental frequency?

16. An open pipe has a length of 0.820 m. What is the frequency of its 6th harmonic?

17. An open pipe plays its 10th harmonic at 3431 Hz. What is the length of the pipe?

18. A closed pipe of length 1.40 m plays a single frequency of 551 Hz. What harmonic is the pipe playing? Include the number only in your response.

19. A wave has a period of 1.02×10^{-3} s. What is its frequency?

20. The speed of a wave on a string is 704 m/s. What frequency would produce a wavelength of 0.766 m?

21. A transverse sine wave of frequency 559 Hz passes an observer at rest. At time $t = 0$ s, the observer is at a crest, with a displacement amplitude of 1.2 m. What is the displacement of the wave at $t = 120.0$ s? If the answer cannot be determined, write a single letter X in the answer box.

22. Waves move at 364 m/s on a cello string. A 0.500 m segment of the string has a mass of 5.00×10^{-4} kg. The string must be under how much tension?

23. Identify the letter names of two notes that could be separated by an interval of a perfect fourth.

24. How do tuning pegs change the frequency of a string instrument?

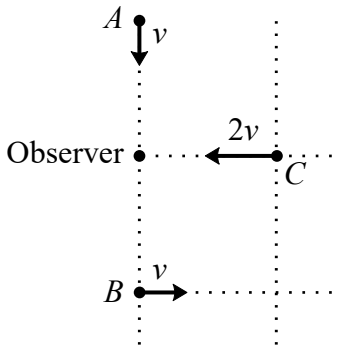
Questions 25-26

The year is 2020, and our local friendly space aliens have decided to invade the Earth. However, these aliens are no ordinary aliens: these aliens are actually rock and roll fans, so they attempt to abduct Earth's granite and bread.

25. As a precaution, the aliens decide to self-quarantine on their home planet for 14 days before they invade. Being fans of rock and roll, the aliens keep time in terms of half rests, rather than Earth days. At a tempo of ♩ = 144 in common time, how many half rests are in 14 days? Assume each day is exactly 24 hours. Enter only the number in the response box.

26. The aliens clicked on the wrong hyperspace meeting link, and they wind up unmuting their microphones to announce "take us to your leader" to the wrong planet. Therefore, they must fly as quickly to their target as possible, or else it will no longer be 2020. Identify ONE Italian tempo name that indicates a piece should be played quickly.

Questions 27-28 refer to the figure and description below.



Three cars *A*, *B*, and *C* move with subsonic velocities on a grid of perpendicular streets, as shown in the figure. An observer stands at an intersection as shown, and is equally distant from all cars. All cars are attached with identical sound sources playing a single tone.

27. Rank the frequencies f_A, f_B, and f_C received by the observer from lowest to highest. If the observer receives any frequencies as equal, state that explicitly. If any frequency's ranking cannot be determined, write "cannot be determined." Justify your ranking. (3 points)

28. Suppose that the observer was given a sound source identical to the sound sources on the cars. The sound from the observer reaches cars *A*, *B*, and *C* at the exact moment depicted in the figure, and the sound reflects back towards the observer with frequencies $f_{A\,\text{new}}$, $f_{B\,\text{new}}$, and $f_{C\,\text{new}}$ respectively. Answer each of the following questions.

    - Is the value of $f_{A\,\text{new}}$ higher than, lower than, or equal to f_A?
    - Is the value of $f_{B\,\text{new}}$ higher than, lower than, or equal to f_B?
    - Is the value of $f_{C\,\text{new}}$ higher than, lower than, or equal to f_C?

    Unlike the previous question, you do not need to justify your answer. (3 points)

Questions 29-31 refer to the information provided.

The speed of sound in water is 1480 m/s. A sound of 512 Hz is played in air just above the ocean.

29. What is the wavelength of the sound when it enters the ocean?

30. What is the frequency of the sound when it enters the ocean?

31. If a scuba diver heard the sound, the sound would have a frequency closest to what note, including note number?

32. (Silly tiebreaker) Here are punchlines to two jokes. For each punchline, write a corresponding question related to music or physics that sets up the joke.

    - To get to the other slide!
    - One of them plays with drumsticks, and the other plays with fish sticks.

    Don't spend too much time on these questions, because your responses won't affect your score unless we need to break a tie. (0 normal points, 1 tiebreaker point)

You're finished! It's time to submit your test at the link below. Note that you won't be penalized for submitting late by one or two minutes. Virtual formats are new for everybody, and we don't want to make it more stressful than necessary. Each *team* should submit only one test, but if you and your partner accidentally both submit, then we'll only grade the most recent test submitted before your 30-minute time limit runs out.

Open this link to submit your test.