PRINCETON SCIENCE OLYMPIAD

2019 DIVISION C

SOUNDS OF MUSIC

TEST

Instructions: You will have about 40 minutes to complete this test. Expect the remaining 10 minutes to be used to conduct the practical portion of the event. Note that you may be called away from the written test at any point throughout the 50 minute testing window to complete the practical portion of the event.

For each question, clearly mark or write the best answer you are able to provide. Partial credit is awarded where applicable, and no points are rewarded (or deducted) for illegible or blank answers. Please use metric units and fundamental constants for answers when possible.

There are 33 questions across three sections in the written exam: matching, multiple choice, and short answer. Point values are labeled in parentheses after each question. For example, "...? **(2)**" implies that the question is worth 2 points.

Team Number: _____

Team Name: _____

Participant Names: _____

_____

Point Total:

/100

Section 1: Matching

1. Classify each instrument by the acoustic family to which it belongs. **(7)**

a. Violin: ____
b. Timpani: ____
c. Slide whistle: ____
d. Cello: ____
e. Guitar: ____
f. Accordion: ____
g. Piano: ____
h. Glockenspiel: ____
i. Eigenharp: ____
j. Claves: ____
k. Boobam: ____
l. Sitar: ____
m. Countertenor: ____
n. Theremin: ____

A. Idiophones

B. Membranophones

C. Chordophones

D. Aerophones

E. Electrophones

Section 2: Multiple Choice

2. ____
   Which audio representation format scales frequencies by their perceptual distance from a fixed tone? **(1)**
   a. Waveform
   b. Spectrogram
   c. Mel-Spectrogram
   d. Constant-Q Transform
   e. None of the Above

3. ____
   Under which audio representation format are the relative distances between harmonics constant along the axis or axes? **(1)**
   a. Waveform
   b. Spectrogram
   c. Mel-Spectrogram
   d. Constant-Q Transform
   e. None of the Above

4. ____
   If a trumpeter wants to lower his instruments pitch by a whole step, which piston valve should he or she depress? **(1)**
   a. The first valve
   b. The second valve
   c. The third valve
   d. The fourth valve
   e. The fifth valve

5. ____
   A keyboard is tuned using standard five-prime-limit tuning with a middle C fixed to 261.6 Hz. Using **thirds**, what is the frequency of E above this C? **(2)**
   a. 320.8 Hz
   b. 324.3 Hz
   c. 327.0 Hz
   d. 329.6 Hz
   e. 331.1 Hz

6. ____
   A keyboard is tuned using standard five-prime-limit tuning with a middle C fixed to 261.6 Hz. Using **fifths**, what is the frequency of E above this C? **(2)**
   a. 320.8 Hz
   b. 324.3 Hz
   c. 327.0 Hz
   d. 329.6 Hz
   e. 331.1 Hz

7. ____
   A keyboard is tuned using standard five-prime-limit tuning with a fixed middle C. What sort of tuning temperament is obtained? **(1)**
   a. Equal Temperament
   b. Pythagorean Tuning
   c. Just intonation
   d. Meantone Temperament
   e. Well Temperament

8. ____
   Which tuning temperament do most Western tuned-instruments use? **(1)**
   a. Equal Temperament
   b. Pythagorean Tuning
   c. Just intonation
   d. Meantone Temperament
   e. Well Temperament

9. ____
   Which tuning temperament is generally preferred by a capella groups? **(1)**
   a. Equal Temperament
   b. Pythagorean Tuning
   c. Just intonation
   d. Meantone Temperament
   e. Well Temperament

10. ____

What is the lowest number of equal divisions of the octave that produces a better perfect fifth than 12-tone equal temperament? **(1)**

a. 24-EDO
b. 27-EDO
c. 29-TET
d. 41-TET
e. 53-TET

11. ____

You strike a perfect, uniform bar. What factor relates the **second** mode of vibration to the first mode of vibration? That is, find f_2 / f_1 . **(2)**

a. 0.19
b. 0.36
c. 1.66
d. 2.76
e. 5.40

12. ____

You strike a perfect, uniform bar. What factor relates the **third** mode of vibration to the first mode of vibration? That is, find f_3 / f_1 . **(2)**

a. 0.19
b. 0.36
c. 1.66
d. 2.76
e. 5.40

13. ____

The telephone bandwidth is from 300 to 3,300 Hz. How many full octaves fit within this bandwidth? **(1)**

a. 2 Octaves
b. 3 Octaves
c. 4 Octaves
d. 11 Octaves
e. 1000 Octaves

14. ____

The A string on a violin is 346 mm long, from bridge to nut. Using the standard American tuning of A = 440 Hz, what is the speed of sound across the string? **(1)**

a. 1.44 m/s
b. 134 m/s
c. 296 m/s
d. 304 m/s
e. 440 m/s

15. ____

The A string on a violin is 346 mm long, from bridge to nut. A violinist wishes to play the D a perfect fourth above the open A string, which requires shortening the playing region of the string. Using equal temperament and the standard American tuning of A = 440 Hz, how far away from the nut of the violin (in mm) should the violinist place his or her fingers? **(1)**

a. 308.2 mm
b. 290.9 mm
c. 274.6 mm
d. 259.2 mm
e. 244.6 mm

16. ____

Which of the following is **NOT** an example of resonance? **(1)**

a. You strike a Tibetan singing bowl and it vibrates in several of its modes.
b. You run a wet finger around the rim of a crystal goblet and it vibrates in its main mode.
c. You strike a tuning fork and it ultimately vibrates only in its main mode.
d. You bow a violin string and it vibrates at its natural frequency.
e. All of the above

17. ____

What is the approximate speed of sound on a really cold day of -18 °C? **(1)**

a. 300.4 m/s
b. 308.3 m/s
c. 311.9 m/s
d. 315.7 m/s
e. 320.9 m/s

18. ____

What is the approximate speed of sound on a really hot day of 40 °C? **(1)**

a. 340.4 m/s
b. 348.3 m/s
c. 351.9 m/s
d. 355.4 m/s
e. 360.9 m/s

19. ____

You hear two tones with a beat rate of 5.0 Hz. One of the tone has a frequency of 440.0 Hz. What is a possible frequency for the other tone? **(1)**

a. 88.0 Hz
b. 416.4
c. 435.0 Hz
d. 758.8 Hz
e. 2,200.0 Hz

20. ____

You want to make a bass instrument from PVC pipe. The pipe should produce the musical note C2 with a frequency of 65.4 Hz an end is slapped. You have PVC pipe with an inside diameter of 3.81 cm. How long should you cut the pipe?? **(2)**

a. 130.34 cm
b. 131.5 cm
c. 260.68 cm
d. 263.0 cm
e. 397.81 cm

21. ____

What is the period of a wave with components at 200 and 601 Hz? **(1)**

a. 1/301s
b. 1/200s
c. 1/110s
d. 1/60s
e. 1s

22. ____

What is the period of a wave with components at 220, 330, 550, and 660 Hz? **(1)**

a. 1/301s
b. 1/200s
c. 1/110s
d. 1/60s
e. 1s

23. ____

A sound level meter at the back of the hall measures 103 dB during a rock concert. What is the intensity of sound there? **(1)**

a. 0.002 W/m^2
b. 0.02 W/m^2
c. 0.2 W/m^2
d. 0.5 W/m^2
e. 5 W/m^2

24. ____

The intensity of a thirty member violin section is 30 times greater than that of a solo violin. What is the dB difference between the two? **(1)**

a. 1.48 dB
b. 2.96 dB
c. 4.7 dB
d. 14.8 dB
e. 29.6 dB

25. ____

When struck, timpani do not sound a fundamental frequency. After striking a drum, you measure the spectral frequencies of the sound and find peaks at 0.83, 1.03, and 1.230 kHz. What is the frequency of the fundamental that is best suggested by your measurement ? **(2)**

a. 200 Hz
b. 206 Hz
c. 210 Hz
d. 415 Hz
e. 630 Hz

Section 3: Short Response

26. Suppose you are camping on the shore of a lake which is not too wide, maybe a kilometer across or so. During the day you can see campers on the other side of the lake, but you cannot hear them. At night, however, you can not only see the campers on the other side of the lake but you can also hear their conversations as they sit around their camp fire.
    a. Draw a graph that linearly approximates how height correlates with air temperature across a lake during the **day**. To facilitate grading, please use height as your y-axis. **(1)**

    b. Draw a graph that linearly approximates how height correlates with air temperature across a lake, and yet near a fire, at **twilight**. To facilitate grading, please use height as your y-axis. **(1)**

    c. Use what you know about refraction and the speed of sound to explain the behavior you witnessed while camping. In particular, name this phenomenon if possible, and be sure to note how sound bends under temperature conditions touched on in (a) and (b). **(4)**

27. The clarinet has a register key to aid in playing the second mode of vibration of air in the column. Why would you expect the register key to be at a position that is 1/3 of the way from the mouthpiece to the bell of the instrument? **(8)**

28.

a. Draw the standing wave corresponding to the sixth mode of string vibration. **(5)**

b. Excluding the string's fixed ends, how many nodes are there? **(1)**

29. You are given a string of length 70 cm. The speed of sound on the string is measured to be 154 m/s.
    a. What is the frequency of the first (or fundamental) mode of vibration? Please show your work. **(2)**

    b. What is another name for this vibrational mode/frequency? **(1)**

    c. What is the frequency of the third harmonic? **(1)**

30. The frequency of a spring and mass system if a function of the spring stiffness to mass ratio.
    a. What happens to the frequency if you change the system by doubling the stiffness and doubling the mass (both at once)? **(1)**

    b. What happens to the frequency if you only double the mass? **(1)**

    c. Find the natural frequency of a spring and mass system where the spring has a stiffness of 100 N/m and the mass is 0.25 kg. Please show your work. **(3)**

31. Let's construct a pan flute that plays the tones of a major scale starting on middle C and ending an octave higher.
    a. Since the pitches are fixed once tuned, what tuning system makes the most sense for our pan flute? **(1)**

    b. We shall choose the fundamental frequency for middle C to be 261.6 Hz. If "i" denotes the ith pipe of our pan flute (where i = 0 denotes the middle C pipe), what is the equation that relates the frequency of each pipe to its number? **(1)**

    c. The diameter of our pipe is 10mm. What is the end-correction length we will need to add, in millimeters? **(2)**

    d. Compute the lengths of the eight tubes we need to cut, again in millimeters **(4)**:

0:	4:
1:	5:
2:	6:
3:	7:

32. A slide whistle is made from a cylindrical tube that is closed at one end by a stopper. The stopper can be retracted to make the tube longer. When the stopper is fully retracted, the inside length is 287 mm. The rod that retracts the stopper has a total travel distance of 232 mm.
    a. Show that the lower and upper frequencies are about 300 and 1,560 Hz, respectively. **(3)**

    b. The manufacturer claims that the range of the whistle is more than two octaves. Do you agree? Support your answer with work. **(3)**

33. Suppose we have a tuning fork with a main mode having a frequency of 256 Hz and with a first clang mode having a frequency of 1,997 Hz. Suppose further that we observe the fork when the amplitude of the main mode is 1 mm and the amplitude of the first clang mode is one-third of that.
    a. Draw the waveform of the main mode over a duration of 1/128s. Assume a sine wave with no phase. **(2)**

    b. Draw the waveform of the first clang mode over a duration of 1/128s. Again, assume a sine wave with no phase. **(2)**

    c. Now super impose these two waveforms to model the vibrations of the tuning fork. Assume both are sine waves with no phase. **(2)**

    d. What is the wave formula that describes this motion as a functions of time? **(2)**

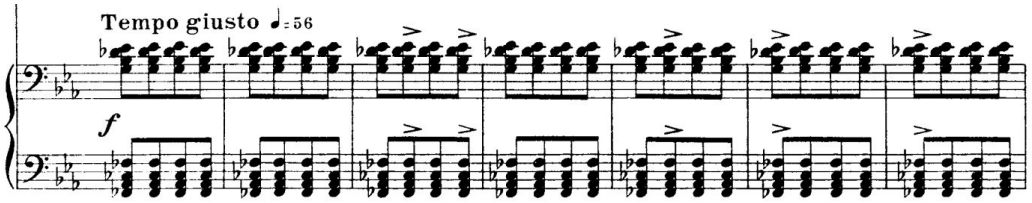
    e. Why don't the clang modes interfere much with the use of a tuning fork? Be precise in your explanation. **(2)**

34. Let's have some fun with scales!

a. To begin, give the note names of the first sixteen partials of the harmonic series, starting on C_1. For this exercise, "round" each partial to the nearest note on a traditional keyboard. **(4)**

b. The eighth through 14th partials of the harmonic series closely resemble the acoustic scale, which is one of the fundamental macro-harmonic collections of Jazz and 20th-century classical music (Debussy, Stravinsky, etc.). What is another name of the fifth mode of the acoustic scale? **(3)**

c. The following is an excerpt from a piano reduction of the "The Dance of the Adolescents" from Igor Stravinsky's Rite of Spring:



What is the name for the seven-note collection (i.e. chord) that Stravinsky is using here? **(3)**

d. For a point of **extra credit**, in what major work from the classical repertoire was the first appearance of this chord-type? (**+1)**