RAYMOND PARK
RANGERS

Raymond Park Middle School Invitational

Sounds of Music 2019-20

Do not begin until you are told to do so.

This test is way too long. You probably won't finish all of it in time, and that's okay. Use your time efficiently by skipping questions you don't know, and eliminating choices on the multiple-choice section. The order of questions is multiple choice, short answer, and free response. Each multiple choice question has only one answer and we won't deduct points for incorrect answers. For most short answer questions, you won't need more than a sentence to receive full credit.

I will call you by team number to test your instrument. One of you may continue to work, but both of you can come if you like. Good luck!

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.

School: _____   Team number: _____

Student names: _____

Test score: _____ /total   Final score: _____   Rank: _____

1. Welcome to Raymond Park Middle School! If you drove here, you probably arrived on Interstate 465 or 70, where you saw tall concrete noise barriers designed to reflect sound from cars and trucks. Which of the following is used to measure how much sound is reflected in rooms?

   (A) Extinction rule
   (B) Sabine's Law
   (C) Nyquist's Theorem
   (D) Mersenne's Theorem
   (E) A-weighting

2. The fifth harmonic of a pipe open at one end and closed at the other is 1280 Hz. What is the length of the pipe?

   (A) 0.0670 m
   (B) 0.335 m
   (C) 0.402 m
   (D) 0.670 m
   (E) 2.56   m

3. What is the first overtone of a closed pipe with fundamental frequency f?

   (A) f
   (B) $2f$
   (C) $3f$
   (D) $4f$

4. The 7th, 3rd, and 1st harmonics play in a closed pipe, but no other harmonics are present. How many points exist in the pipe where the pressure at the point is always constant?

   (A) 0 points
   (B) 1 point
   (C) 2 points
   (D) 11 points
   (E) 14 points

5. Which of the following statements is true of intensity for sound waves?

   (A) It fluctuates sinusoidally over time
   (B) Lower intensities indicate a greater sound decay per distance
   (C) It is negatively correlated with loudness
   (D) It is a dimensionless quantity measuring how long a sound lasts
   (E) It is a measure of the power transmitted per area

6. A tube has fundamental frequency f in a room of atmospheric air of molar mass of approximately 28.98 g/mol. The air is pumped out and helium gas is pumped in at a constant temperature. When the room is filled entirely with helium, the new fundamental frequency of the tube is most closely

   (A) $1.000f$
   (B) $1.091f$
   (C) $2.692f$
   (D) $2.936f$
   (E) $3.102f$
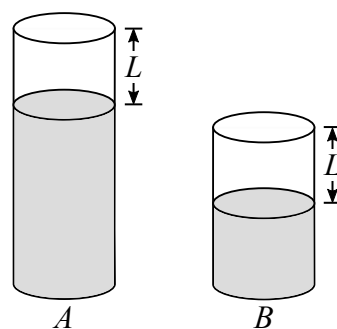
7. Cylindrical glasses A and B are filled with water to heights shown above. If tapped, the frequency of which glass will be higher?

   (A) A
   (B) B
   (C) Both glasses will have equal frequencies
   (D) Additional information is needed to rank the frequencies of the glasses
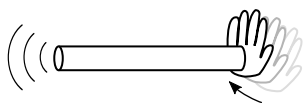
8. A person whacks an open PVC pipe with the flat palm of her hand, as shown above. What sound will result from the air in the pipe?

(A) The fundamental frequency of an open pipe will be heard
(B) The fundamental frequency of a closed pipe will be heard
(C) Open pipe frequencies will be heard, followed by closed pipe frequencies
(D) Noise (an incoherent statistically random distribution of sound) will be heard
(E) Negligible sound will be heard

9. 2019 Hz is closest to the pitch of what note?

(A) A_6
(B) B_6
(C) C_6
(D) B_7
(E) C_7

Questions 10-12 refer to the following types of waves.

(A) Longitudinal wave
(B) Surface wave
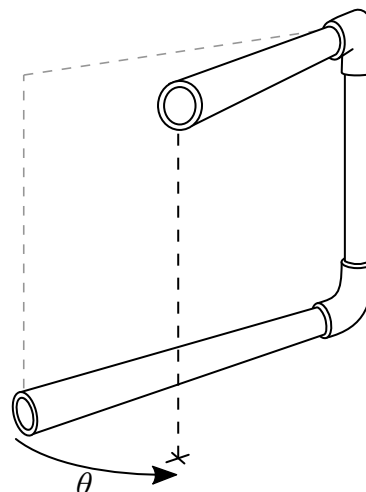(C) Transverse wave
(D) Torsional wave
(E) Flexural wave

10. Which type best describes sound in air?

11. Which type has compressions and rarefactions?

12. Which type occurs when particles rotate in a plane perpendicular to the direction of the wave?

13. What is the lowest note on a concert piano?

(A) A_0
(B) A_1
(C) A_{-1}
(D) C_0
(E) C_1

14. A PVC pipe is made with pipe connectors, letting the top segment of pipe be turned to an angle θ relative to the bottom, as illustrated above. At what value of θ is the fundamental frequency of the pipe greatest?

(A) $0°$
(B) $90°$
(C) $135°$
(D) $180°$
(E) θ has a negligible impact on the fundamental frequency

15. A wave that does not disperse in a dispersive medium is called a

(A) Bending wave
(B) Breaking wave
(C) Shoal
(D) Soliton
(E) Seiche

16. All of the following instruments have harmonic overtones EXCEPT

(A) bassoon
(B) guitar
(C) harp
(D) timpani
(E) mandolin

Questions 17-18 refer to the information provided below.

Identical point sources of sound are placed at distinct points A and B. Both sources are synchronized to emit sound of the same wavelength, phase, and amplitude at any moment.

_____ 17. The sound sources begin to play a sinusoidal tone of constant frequency f. Which of the following must be true at the midpoint of A and B?

(A) The pressure varies as a sine wave
(B) The pressure varies as a triangle wave
(C) The intensity varies as a sine wave
(D) The intensity varies as a triangle wave
(E) The tones interfere completely destructively

_____ 18. Now suppose that at time t in seconds, the frequency played by both speakers is $f(t) = nt^2 + m$, where $n = \sqrt[3]{2} \text{ s}^{-3}$ and $m = 110 \text{ s}^{-1}$. Which of the following must be true at the midpoint of A and B?

(A) The tempo at $t = 10$ s will be more than twice its value at $t = 0$
(B) The tempo at $t = 10$ s will be less than half its value at $t = 0$
(C) The pitch rises by a major third every second
(D) The pitch rises by a perfect fourth every second
(E) The rate of increase of pitch is decreasing between $t = 99$ s and $t = 100$ s

_____ 19. A person first hears a sinusoidal tone of 130 Hz, then one of 140 Hz, then both tones at the same time. What frequency will be heard when both are played at the same time?

(A) 10 Hz
(B) 130 Hz
(C) 135 Hz
(D) 140 Hz
(E) 1820 Hz

_____ 20. The image above was captured with a technique that renders sound visible as dark lines, shown emanating from an airplane. What may be inferred about the plane?

(A) It moves slightly under the speed of sound
(B) Its speed is supersonic, but less than twice the speed of sound
(C) Its speed is supersonic, but more than twice the speed of sound
(D) Its speed is hypersonic
(E) Its acceleration is in the same direction as its velocity

_____ 21. If the bell of a trumpet is sliced off without changing how the trumpeter plays, which of the following must increase?

I. intensity of each note
II. pitch of each fingering

(A) I only
(B) II only
(C) Both I and II
(D) None of these

_____ 22. All of the following are pronounced with vibrating vocal folds EXCEPT

(A) [a]
(B) [l]
(C) [v]
(D) [m]
(E) [k]

Questions 23-25 refer to the information provided below.

In 12-tone equal temperament, twelve perfect fifths have the same interval of pitch as seven octaves. However, in Pythagorean tuning, twelve perfect fifths are slightly sharper than seven octaves. As a result, one fifth must be tuned slightly flatter than the other eleven.

____ 23. In Pythagorean temperament, seven octaves and twelve perfect fifths are best described as

(A) non-Schenkerian
(B) Schenkerian
(C) enharmonically nonequivalent
(D) enharmonically equivalent
(E) generated by 7-limit tuning

____ 24. What is the ratio between two notes in Pythagorean tuning separated by twelve perfect fifths?

(A) $\left(\dfrac{3}{2}\right)^{12}$

(B) 128

(C) $\left(\dfrac{9}{8}\right)^{6(7)}\left(\dfrac{256}{243}\right)^{2(7)}$

(D) $\left(\dfrac{9}{8}\right)^{7(7)}$

(E) $\left(\dfrac{9}{8}\right)^{3(12)}\left(\dfrac{256}{243}\right)^{12}$

____ 25. Unlike sensorineural hearing loss, conductive hearing loss involves impairment of

(A) the inner ear
(B) the inner or middle ear
(C) the middle ear
(D) the outer ear
(E) the middle or outer ear

____ 26. In movable *do* solfège, the syllable *ti* refers to which scale degree?

(A) Ionian
(B) Tonic
(C) Dominant
(D) Supertonic
(E) Leading tone

____ 27. All of the following consist of a conical bore EXCEPT

(A) Bassoon
(B) Clarinet
(C) Wagner tuba
(D) Tuba
(E) Oboe

____ 28. What term refers only to a slow decrease in tempo?

(A) *rinunciarono*
(B) *langsam*
(C) *adagio*
(D) *ritardando*
(E) *lent*

____ 29. A sequence of three notes with proportion 3:2 to the normal rhythm is known as

(A) hemiola
(B) dotted note
(C) divisio
(D) triad
(E) staccato

____ 30. A broken chord where all successive notes either rise or fall in pitch most closely refers to

(A) arpeggio
(B) power chord
(C) fragmented chord
(D) swing notes
(E) horizontal sequencing

Questions 31-33 refer to the information provided below.

Annie, Briana, and Chloe stand on a train moving at a constant nonzero subsonic velocity in the direction from Annie to Briana, as shown in the figure. Briana and Chloe both stand 50.0 m away from Annie and all are colinear. Annie plays a note on a flute with constant power output, while Briana and Chloe hold measuring devices capable of measuring various physical quantities with <u>infinite</u> precision. The train has no walls or roofs. The devices automatically account for effects of wind generated by the train so that they only measure the sound of the flute.

Note: not to scale
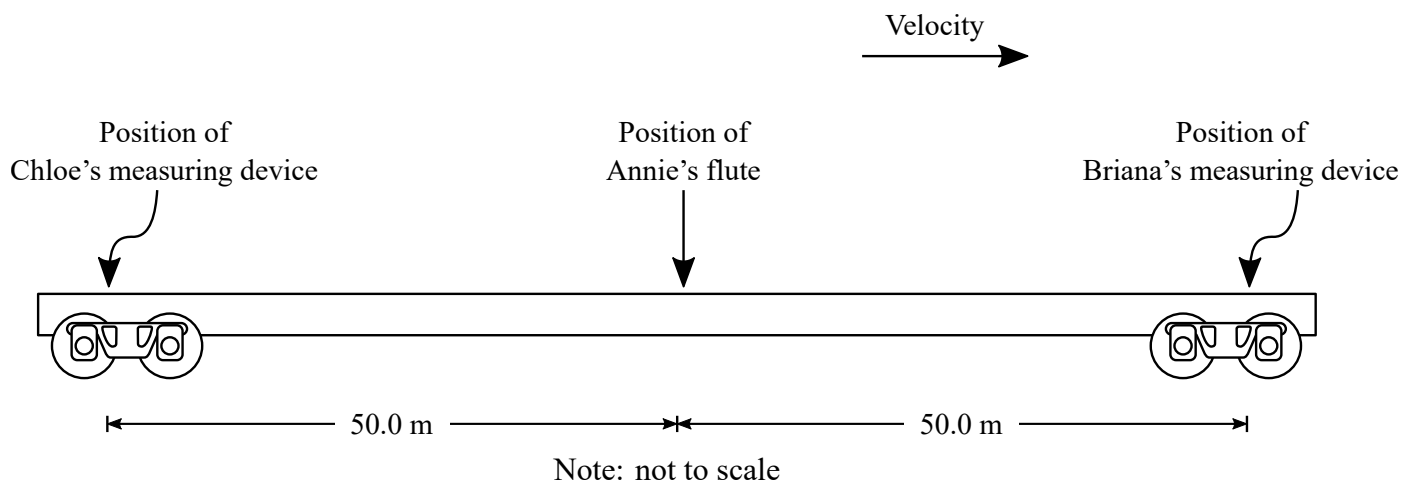
____ 31. Which device will register a higher intensity?

(A) Briana's device will register a higher intensity

(B) Chloe's device will register a higher intensity

(C) Both devices will initially register equal intensities, but Briana's measurement will increase while Chloe's measurement will decrease

(D) Both devices will initially register equal intensities, but Briana's measurement will decrease while Chloe's measurement will not change

(E) The answer cannot be determined without knowing the velocity of the train

____ 32. Which device will measure a higher wavelength?

(A) Briana's device will measure a higher wavelength

(B) Chloe's device will measure a higher wavelength

(C) Both devices will measure an identical wavelength

(D) The answer cannot be determined without knowing the velocity of the train

____ 33. Now suppose that the train had airtight ceilings and walls. Would this result in a different answer for questions 31 and 32?
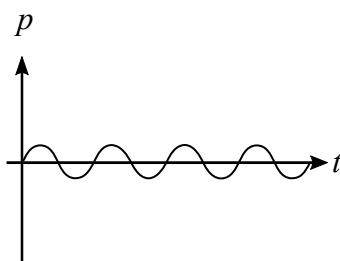
(A) Both answers would be different

(B) Neither answer would be different

(C) Only 31 would be different

(D) Only 32 would be different

(E) Additional information is needed to determine which would be different

6

____34. Which graph below best represents the <u>absolute</u> pressure over time at a point located at a fixed distance from a sinusoidal sound source?
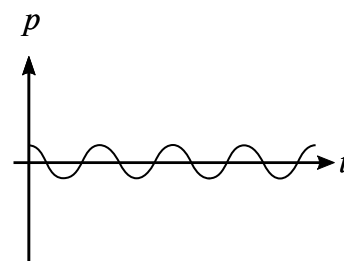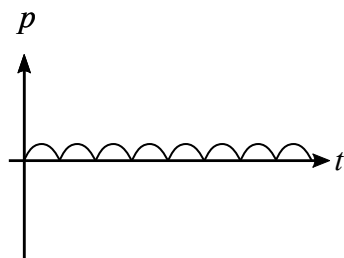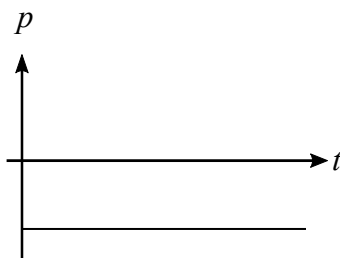
(A)

p

t

(B)

p

t

(C)

p

t

(D)

p

t

(E)

p

t
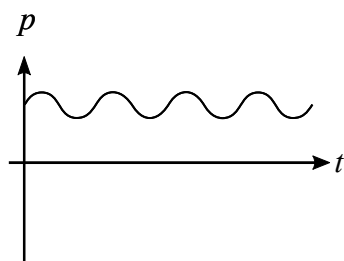
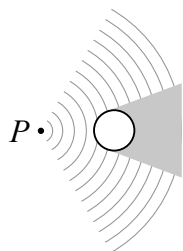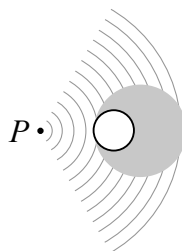____35. As with light, a *shadow* is a region that sound does not reach. Which of the following shaded regions most accurately depicts the sound shadow cast by a large cylindrical tree to the right of a loudspeaker at *P*?
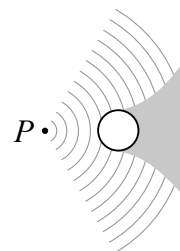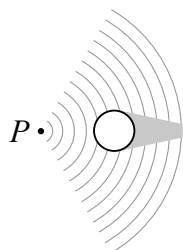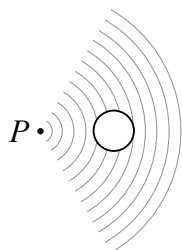
(A)

P •

(B)

P •

(C)

P •

(D)

P •

(E)

P •

A shadow is impossible
in this situation

Short answer

A response with just one word or phrase is acceptable for some of these questions; no questions need more than a sentence for you to answer for full credit. You do not need to show work for full credit except for question 48.

36. What interval is the inversion of an augmented fifth?

38. What is the total number of distinct eight-note natural minor scales?

37. What are the notes of the D major pentatonic scale?

39. Name the notes, in order, of an Fmaj^{11} chord.

40. In acoustics, what is the definition of a normal mode?

41. A thin rod has Young's modulus 7.8×10^{10} Pa, shear modulus 2.7×10^{10} Pa, and bulk modulus 1.80×10^{11} Pa. The rod has a density of 1.93×10^4 kg/m^3. What is the speed of sound in the material?

42. A PVC pipe closed at <u>both</u> ends has a length of 0.317 m. Calculate the fundamental frequency and first three overtones of the air column of the pipe. (4 points)

43. What characteristic distinguishes a zither and a lute?

44. What does the term "infrasound" mean?

45. A gas has heat capacity ratio of 1.30 and density of 1.98 kg/m^3. If the speed of sound in the gas is 2.67×10^2 m/s, what is the pressure of the gas?

46. Assuming a major key, write each note from the excerpt in the blank below it following movable *do* solfège. (8 points)


47. (Serious tiebreaker) The notation where pitch is denoted by a letter name then a number (usually in a subscript) is sometimes called *scientific pitch notation*. In this notation, C_4 is middle C. What are some reasons for the origin of scientific pitch notation? (1 point, 4 tiebreaker points)

48. (Silly tiebreaker) What if there were no air? Describe the effect on the SciOly industry. Show all work. (0 points, 2 tiebreaker points)[Note 1]

---

[1] please don't spend too much time on this question lol it's not worth any points unless for some highly unlikely reason we *reallyyyyy* need to break ties and the other tiebreakers listed in the rules manual don't work hooray (but in the unlikely chance we actually grade this question to break a tie, a scientific answer is preferred)

Free response questions
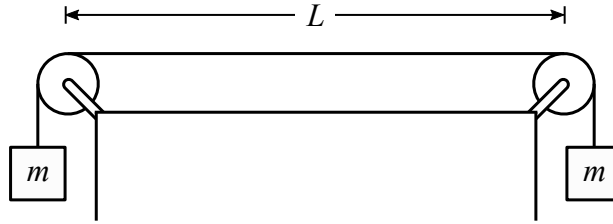
49. A length of uniform string with linear mass density μ is suspended between two pulleys with negligible friction. The total length of the string is less than $2L$, but only a length L is suspended between the pulleys. A mass m is attached at each end of the string, with $2\mu L \ll m$. Express all algebraic answers in terms of the given quantities and fundamental constants.

   (a) Determine an expression for the fundamental frequency of the string. (1 point)

   (b) Another mass m is attached to each end of string so that the mass at each end is now $2m$. Determine the new fundamental frequency of the string. (1 point)
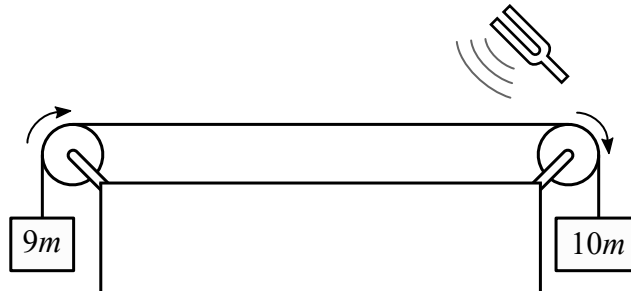
   (c) The masses on each end are now $9m$ and $10m$, causing the string to accelerate from rest. Does there exist a tuning fork capable of driving resonance on the string when it first begins to accelerate? (2 points)

   _____ Yes   _____ No

   Justify your answer.

9

50. A loudspeaker is attached to the outside of a helicopter. At sea level, the loudspeaker acts as a point source of sound and can play an MP3 file consisting of a single triangular waveform of a single five-second tone.

   (a) The helicopter ascends to an altitude of 2000 meters, where it maintains a stationary position. Assuming that altitude has negligible impact on the electronics of the loudspeaker, an observer directly outside the helicopter would find that which of the following quantities changes in the playback sound of the MP3 file as a result of altitude? Select all that apply. (5 points)

   _____ Frequency   _____ Wavelength   _____ Pressure amplitude

   _____ Ratio of RMS pressure to pressure amplitude   _____ Intensity at a distance of one meter

   Justify ONE of your responses. You may select either a quantity you believe will not change, or a quantity you believe will change.

   (b) The loudspeaker is dropped from the helicopter while continuing to play the tone. It eventually falls at its terminal velocity. According to an observer standing on the ground, is the frequency lower, higher, or equal to the frequency played when the loudspeaker was at rest? (2 points)

   _____ Lower   _____ Equal   _____ Higher

   Justify your response.

Time (s)
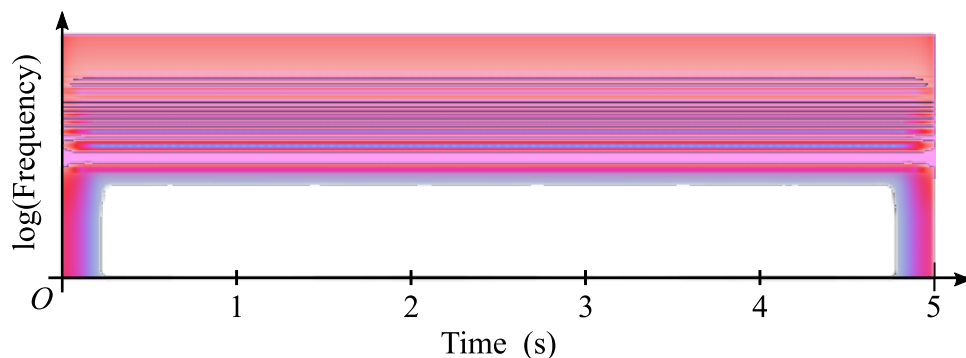
   (c) The MP3 file is recovered after the loudspeaker hits the ground. A computer program generates a spectrogram of the MP3 file, shown above. Explain why the spectrogram has blurs near the sides. Address the fact that the MP3 file contains only a single tone. (2 points)