Massachusetts Institute of Technology:

Science Olympiad Invitational 2k19

Sound of Music Exam

Total Points: 120
Total Questions: 34

Answer the questions in the spaces provided on the question sheets. Write your team number on every page. We are not responsible for pages that are lost or misplaced with no team number on them. You will be called up for instrument testing during this exam.

Names _____

School name: _____

Team Number: _____

1. (1 point) Which of the following analogies to electrical power is most representative of the sources of sound for reed instruments and the flute?

    A. Reed: DC power, Flute: AC power

    B. Reed: AC power, Flute: DC power

    C. Both DC power

    D. Both AC power

    Most woodwind instruments can be roughly generalized into tubes in which standing waves will travel through. The differences in this fundamental construction for instruments causes most of the differences in sound and timbre for woodwinds.

2. (3 points) Consider a perfectly cylindrical clarinet and a perfectly cylindrical flute, whose lengths are .5 meters long (that's a long flute, but we are using this for simplicity's sake). What is the maximum possible wavelength of a standing wave in each of these instruments?

3. (4 points) Explain how a wind player creates a standing wave of sound within a flute and a clarinet (using this crude analogy). What is the main cause of the discrepancy in the above part?

4. (2 points) How do sound waves in a conical instrument such as a saxophone differ from those in a pipe-like instrument?

5. (4 points) How does the timbre and sound quality of a saxophone vary if the player blows faster air (high pressure) as opposed to slower air (low pressure)?

Pythagorean Tuning was a popular type of tuning used in the middle ages. However, this type of tuning has some drawbacks for modern music which led to alternatives being developed.

6. (6 points) Pythagorean Tuning is developed around the idea of the perfect fifth. What ratio(s) do you need to use to be able to generate all the relative frequencies of the notes in the standard harmonic series? How does using this form of tuning favor making certain tones more in tune with each other, and how does this give rise to wolf intervals? (Tie Breaker 6)

7. Calculate the following frequency ratios of the ratios in Pythagorean tuning: (1pt each)

    (a) (1 point) Major Second: _____

    (b) (1 point) Perfect Fourth: _____

    (c) (1 point) Major Seventh: _____

    (d) (1 point) Tritone: _____

8. The Cochlea is a spiral organ that transforms mechanical vibrations into electro-chemical signals to nerves to the brain that it perceives as sound. Label the following diagram with the parts of the cochlea: (1pt each)
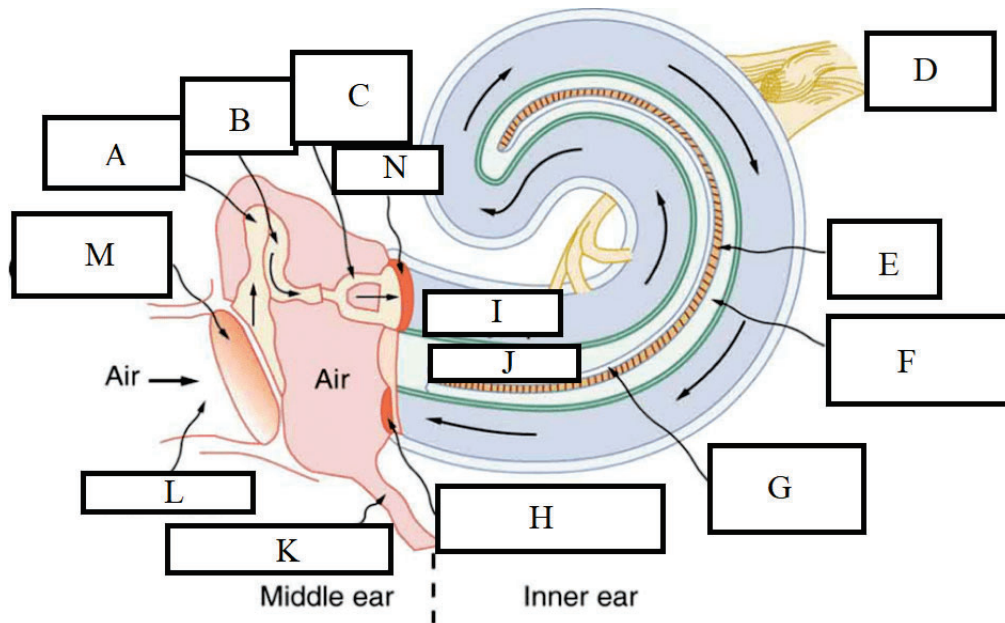
(a) (1 point) _____

(b) (1 point) _____

(c) (1 point) _____

(d) (1 point) _____

(e) (1 point) _____

(f) (1 point) _____

(g) (1 point) _____

(h) (1 point) _____

(i) (1 point) _____

(j) (1 point) _____

(k) (1 point) _____

(l) (1 point) _____

(m) (1 point) _____

9. (1 point) The ear can hear a much larger range of sounds than the dynamic range of the inner hair cells inside the inner ear. What allows the ear to do this?

10. (1 point) What physical characteristic of the ear allows the phenomena described in the above problem?

Who says music can only be made with pieces of wood and metal vibrating? What if we wanted living flesh to also make music? Before you get morbid, I'm talking about our vocal cords!

11. Please match the following sections of the body with its function in producing sound. (1pt each)

Lungs and diaphragm   Vocal folds   Vocal tract

   (a) (1 point) ———————————— Modulate airflow and produce vibration source

   (b) (1 point) ———————————— Provide air and pressure

   (c) (1 point) ———————————— Modify source to create specific sounds

12. (3 points) What are the three major mechanisms involved in producing sound (Edit: in the voice. I apologize that I was not clear enough on the original test)? (Tie Breaker 2)

13. (3 points) What are the false vocal cords, and what is their function in speech? (Tie Breaker 3)

14. (2 points) What voice quality is associated with the glottis having a very short open phase? _____

15. (2 points) Continuing from the previous question, which harmonics in the voice become weak and strong, respectively?

16. (1 point) How does the soft palate change the sound quality of your singing?

Straightforward Piano Questions, because the piano just might be important. Like, just a little bit:

17. (1 point) What material covers the hammers on a grand piano? _____

18. (2 points) How do pianos create relatively low pitches without being impractically long?

19. (2 points) Why do we generally use longer strings on the bass notes, while we compensate on the upper register by having multiple strings? (Tie Breaker 1)

20. Name these intervals: (Note: Functionally, these are the only correct answers, even if other intervals sound the same. A C to a C# sounds the same as C to a Db, but they function differently in theory.)

    (a) (1 point) C4 to Bb4 _____

    (b) (1 point) F1 to G#1 _____

    (c) (1 point) G#4 to B4 _____

    (d) (1 point) Cb6 to A6 _____

    (e) (1 point) D4 to Ab4 _____

    (f) (1 point) Bb4 to E4 _____

    (g) (1 point) C7 to D#8 _____

    (h) (1 point) Gb4 to Fb5 _____

    (i) (1 point) Fb3 to C4 _____

    (j) (1 point) Ab5 to B5 _____

21. (6 points) Name the circle of fifths in order starting from C, going from least sharps to least flats:

22. (1 point) How many semitones are in a diminished fifth interval? _____

23. Match the term with the equivalent physical meaning:

Period   Wavenumber   Amplitude
Frequency   Wavelength   Phase
Angular Frequency   Velocity

   (a) (1 point) _____ Rate of change of the phase of the waveform

   (b) (1 point) _____ Inverse of frequency

   (c) (1 point) _____ Number of times an event occurs per measurement

   (d) (1 point) _____ Angular frequency divided by wave number

   (e) (1 point) _____ Maximum height of the waveform

   (f) (1 point) _____ The location of a waveform at a certain point in time

   (g) (1 point) _____ In units of cycles per unit distance

   (h) (1 point) _____ Spatial period of a wave

24. (2 points) What kinds of materials are best at absorbing sound and why? (Tie Breaker 4)

25. (1 point) If you wanted to someone to hear you on the other side of a brick wall, would you use a high or low frequency voice to shout at them? (Tie Breaker 5)

26. (1 point) What is the purpose of the foam used in sound proof rooms?

27. (1 point) If an everyday material absorbs the energy from sound, what does most of the energy transfer as?

28. (2 points) Since the lungs expel enough air to open the vocal folds, how do the vocal cords ever counteract this force to close?

29. (1 point) To sing a higher pitch, how do the vocal cords change?

30. (1 point) How do the vocal folds cause an intensity change (ie., louder or softer) (Edit: There was a typo on the exam, I'm so sorry)?

31. (7 points) Due to the theory of superposition, anytime we pluck the string of guitar, we can expect it to form a wave form that is the sum of a bunch of sinusoidal waves. However, there is a set of sinusoidal waves whose contribution to the sum will always be zero. Consider a string that is plucked at a position x along a string of length L, where $0 < x < L$ and the string behaves in a linear fashion. Let the resulting waveform on the string be given by $y(x) = \sum\limits_{n=0}^{\infty} a_n sin(2\pi nx/L), a_n \in \mathbb{R}, n \in \mathbb{Z}$. Derive all n such that $a_n = 0$.

32. (10 points) A source of sound travels perpendicularly towards a flat wall at velocity v emitting sound at frequency f. We have two stationary receivers away from the source, one between the wall and the source and one behind the source so that there is a straight line with receiver 1, the source, receiver 2, and the wall in that order. Let the velocity of sound be v_s and $v << v_s$ and assume that the wall perfectly reflects the sound waves. Which receiver will perceive a beats phenomena and what frequency will it be? Assume that the source never passes the second receiver.

33. (5 points) Consider a diatomic ideal gas at $300^{o}C$ that has a molar mass of 16 g/mol. What is the speed of sound through it?

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34. There exists a source of sound with frequency f. The sonic power of the source is P. The velocity of sound in medium is v_s. The density of the medium is ρ. Consider a point d meters away from the source.

   (a) (3 points) Find the pressure oscillation amplitude p.

   (b) (3 points) Find the oscillation amplitude of the particles in the medium, knowing the pressure amplitude p.

End of Examination (I'm so sorry)

Question	Points	Score
1	1	
2	3	
3	4	
4	2	
5	4	
Total:	14	

Question	Points	Score
6	6	
7	4	
8	13	
9	1	
10	1	
Total:	25	

Question	Points	Score
11	3	
12	3	
13	3	
14	2	
15	2	
16	1	
Total:	14	

Question	Points	Score
17	1	
18	2	
19	2	
20	10	
21	6	
22	1	
23	8	
24	2	
25	1	
26	1	
27	1	
28	2	
29	1	
30	1	
Total:	39	

Question	Points	Score
31	7	
32	10	
33	5	
34	6	
Total:	28	