THE SCIENCE OF MUSIC (HSI2013)
Mid-Term Class Test, Semester 2, 2024/25

This is an open book test. The test is one hour long.

Give your answers to ALL 25 questions on the computer-readable sheet provided, using a soft (2B) pencil to shade the appropriate choice for each question.

1. Which of the following is the most appropriate example of a scientific activity?
   (a) A percussion player performing on a newly invented set of cymbals which can electronically produce various other percussion sounds.
   (b) A tuba player trying to find out how different shapes of tubas affect their loudness and sound quality.
   (c) An oboe player practising on an oboe whose body can be adjusted to have different curvatures instead of the normal conical shape.
   (d) A chemist performing on a flute made of a new metal alloy which includes rare earths.

   Answer: (b) The percussion player, oboe player and chemist are all performing essentially musical activities. The tuba player is the only one performing an essentially scientific activity.

2. Which of the following is the most appropriate example of a technological activity?
   (a) A trumpet player inventing a new type of trumpet which can be lengthened to produce a sound more like a trombone.
   (b) A French horn player playing on a new type of adjustable French horn which can change the tone colour of the French horn.
   (c) An organist performing on a new type of portable electronic organ which can produce many types of sounds.
   (d) A bassoon player performing on a new type of bassoon which can be lengthened to also produce double bassoon sounds.

   Answer: (a) The French horn player, organist and bassoon player are all performing essentially musical activities. The trumpet player is the only one performing an essentially technological activity.

3. Which of the following is the most appropriate example of an object undergoing a vibration?
   (a) A block of ice cream sliding to a stop on a dinner table.
   (b) A cat jumping down from a wall and then lying down.
   (c) A girl's head nodding up and down just once as she agrees with a classmate during a discussion.
   (d) A little baby shaking his rattle repeatedly from left to right.

   Answer: (d) The block of ice, cat and girl's head are each undergoing a single motion and hence not undergoing a vibration. Only the baby's rattle is undergoing a repeated movement and is therefore undergoing a vibration.

4. A guava tree and a tembusu tree next to each other are both swaying repeatedly from side to side during a thunderstorm. The guava tree undergoes 4 complete cycles in the same time period during which the tembusu tree undergoes 3 complete cycles. Calculate the time period during which the guava tree would undergo 10 complete cycles if the tembusu tree undergoes 5 complete cycles in 7 seconds.

(a) $\frac{21}{10}$ seconds.

(b) $\frac{21}{5}$ seconds.

(c) $\frac{21}{2}$ seconds.

(d) None of the above.

Answer: (c) The tembusu tree undergoes 5 cycles in 7 seconds so the time it takes to undergo one cycle is equal to $\frac{7}{5}$ seconds. The tembusu tree thus undergoes 3 cycles in $\frac{7}{5}$ seconds times 3 cycles i.e. $\frac{21}{5}$ seconds. The guava tree undergoes 4 cycles in the same time period, so the duration of each of the guava tree's cycles is equal to $\frac{21}{5}$ seconds divided by 4 i.e. $\frac{21}{20}$ seconds. The guava tree would undergo 10 cycles in a duration given by $\frac{21}{20}$ seconds times 10 i.e. $\frac{21}{2}$ seconds.

5. A graphic designer designs a flower vase, and from the design, a ceramicist makes the actual flower vase. A housewife sees the flower vase in a ceramics showroom and buys it for her family to enjoy at home. A songwriter composes a song, and from the musical score, a pop singer performs the song which is enjoyed by an enthusiastic audience during a pop concert at the Esplanade Concert Hall. Of the following, which one has the same relationship to the songwriter as the housewife's family has to the graphic designer?

   (a) The song.

   (b) The pop singer.

   (c) The audience.

   (d) The Esplanade Concert Hall.

   Answer: (c). The ceramicist follows the design of the graphic designer and makes the flower vase which is bought by the housewife for her family to enjoy. The pop singer reads the musical score of the song composed by the songwriter and performs the song for the audience to enjoy. The audience thus has the same relationship to the songwriter as the family has to the graphic designer.

6. A college choir starts its choir practice in the college music room by singing the National Day song "We Will Get There". A choir member who is late for the practice then enters the music room. Which of the following songs should the choir member sing as he enters the music room, if counterpoint is not to be produced by the choir and the choir member who is late as they sing together?

   (a) "Home".

   (b) "We Will Get There".

   (c) "Where I Belong".

   (d) "Stand Up For Singapore".

   Answer: (b) Counterpoint is produced only when two or more different melodies are sung simultaneously. Therefore the choir member who is late should sing the same song which is being sung by the rest of the choir, i.e. he should sing "We Will Get There".

7. The very first item of a school concert is the school's brass band which reads 94 dB on a sound level meter which you as a member of the audience are holding. The second item of the concert is a flute solo whose sound power reaching you is 1,000 times less powerful than the sound from the brass band. What would the sound level meter reading due to the flute solo be? (Assume that the sound level meter readings are due only to the brass band and the flute solo.)

(a) 84 dB.
(b) 74 dB.
(c) 54 dB.
(d) None of the above.

Answer: (d) The sound level meter reading should decrease by 10 dB when the sound power decreases by 10 times, so a decrease of 1,000 times i.e. 10 times 10 times 10 times would therefore result in a decrease in the sound level meter reading of 10 dB plus 10 dB plus 10 dB i.e. 30 dB. Therefore the sound level meter reading due to the flute solo would be 94 dB minus 30 dB i.e. 64 dB.

8. During a symphony orchestra concert, a tuba player plays a note with a frequency of 55 Hz. A piccolo player then plays a note with a frequency of 2,090 Hz. Which of the following best describes the interval between the note played by the tuba player and the note played by the piccolo player?

(a) Greater than 3 complete octaves but less than 4 complete octaves.
(b) Greater than 4 complete octaves but less than 5 complete octaves.
(c) Greater than 5 complete octave but less than 6 complete octaves.
(d) Greater than 6 complete octaves but less than 7 complete octaves.

Answer: (c) Since an octave is an interval with a ratio of $\frac{2}{1}$ i.e. 2, if we go up from a musical note by the interval of an octave, the frequency of the musical note should be multiplied by 2. If we start with the tuba player's note of 55 Hz, successive multiplying by 2 six times will give us the following frequencies: 55 Hz, 110 Hz, 220 Hz, 440 Hz, 880, 1,760 Hz and 3,520 Hz. Therefore the interval from 55 Hz to 2,090 Hz is greater than 5 complete octaves but less than 6 complete octaves.

9. The A4 string of an upright piano is tuned to a frequency of 439 Hz, and all its strings are tuned relative to each other as is normal for a piano. If one particular note on this upright piano has a frequency of approximately 620.8 Hz, which of the following notes is most likely to be the note with this frequency? (Take the ratio of an Equal-tempered semitone to be equal to 1.05946 for your calculations.)

(a) D5
(b) Dsharp5.
(c) E5
(d) F5.

Answer: (b) Since the frequency of the A4 string of the upright piano is 439 Hz, if we go up from this note by six Equal-tempered semitones, we have to multiply 439 Hz by the ratio of an Equal-tempered semitone i.e. 1.05946 six times. We will thus obtain a frequency of approximately 620.83 Hz. Therefore the note with a frequency of 620.8 Hz is the note which is six semitones above A4 i.e. Dsharp5/Eflat5.

10. The musical score of a melody for solo clarinet begins with a time signature of 24/8. One particular bar of this melody begins with three quavers and ends with two dotted crotchets and six semiquavers. Of the following combinations of notes, which one would fit exactly into the middle of this bar in agreement with the time signature?

(a) 4 dotted quavers, 2 quavers and 7 semiquavers.

(b) 2 minims and 6 semiquavers.
(c) 2 dotted crotchets, a minim and 5 semiquavers.
(d) 3 crotchets, 2 dotted quavers and 6 semiquavers.

Answer: (d) Since the time signature is 24/8, each bar of the melody has to contain the duration equivalent of 24 quavers or 48 semiquavers. The beginning of the bar has three quavers equivalent to 6 semiquavers, and the end of the bar has 2 dotted crotchets equivalent to 12 semiquavers and 6 semiquavers, so the bar already has the duration equivalent of 24 semiquavers. The middle of the bar thus needs to be filled with the duration equivalent of 24 semiquavers. 3 crotchets are equivalent to 12 semiquavers and with 2 dotted quavers (6 semiquavers) and 6 semiquavers make up a total of 24 semiquavers.

11. Starting from the note G3 on the keyboard of a piano and going upwards by an interval of one and a half octaves, you arrive at a second note. You then go downwards from this second note by two and one-sixth octaves to arrive at a third note. Going upwards from this third note by one and one-quarter octaves, you arrive at the fourth and final note. Which of the following notes is the correct letter name for the fourth note?
    (a) D4.
    (b) Dsharp4.
    (c) E4.
    (d) None of the above.

    Answer: (a) Going up from the starting note G3 by one and a half octaves or 18 semitones (since an octave consists of 12 semitones), you will arrive at the second note Csharp5. Going down by two and one-sixth octaves or 26 semitones brings you to the third note B2. Finally, going up from B2 by one and one-quarter octaves or 15 semitones brings us to the fourth note D4.

12. The musical score of a melody for solo trumpet consists of a musical staff starting with a treble clef. A certain bar of this score has its first note written on the second highest space of the four spaces of the staff, its second note written on the highest line of the five lines of the staff, its third note written on the lowest space of the four spaces of the staff, and its fourth note written on the middle line of the five lines of the staff. Which of the following gives the correct names of these four notes in the correct sequence from the first note to the fourth note?
    (a) C5, F5, F4 and B4.
    (b) C5, F5, G4 and B4.
    (c) C5, E5, F4 and B4.
    (d) C5, F5, F4 and A4.

    Answer: (a) Since the treble clef shows that the second lowest line of the staff is the note G4, the note on the second highest space of the four spaces of the staff is the note C5. The note on the highest line of the five lines is the note F5, the note on the lowest space of the four spaces is the note F4 and the note on the middle line of the five lines is the note B4.

13. The A string of a violin is tuned to a frequency of 440 Hz and all its other strings are tuned relative to each other in Just fifths as is normal for a violin. The A string of a guitar is tuned to a frequency two octaves below the frequency of the violin's A string, and all the guitar's strings are tuned in Equal-tempered semitones as is normal for a guitar. Of the following, which one is closest to the ratio of the interval between the note from the open E string of the violin

and the Fsharp4 note of the guitar? Open string means that the notes are not played with a finger on the violin's fingerboard, i.e. they are played with the full length of the respective string vibrating. (Take the ratio of an Equal-tempered semitone to be equal to 1.05946 for your calculations.)

(a) 1.684.
(b) 1.784.
(c) 1.890.
(d) 2.002.

Answer (b) The frequency of the A string of the guitar which is the note A2 is equal to 440 divided by 2 twice i.e. 110 Hz. The guitar's A4 note thus has a frequency of 440 Hz, and the frequency of its Fsharp4 note is three Equal-tempered semitones below its A4 note. Its frequency is thus equal to 440 Hz divided by 1.05946 three times which gives approximately 369.9977 Hz. Since the A string of the violin has a frequency of 440 Hz, the frequency of its E string which is E5 is a Just fifth above the A string and is equal to 440 Hz multiplied by $\frac{3}{2}$ i.e 660 Hz. Therefore the ratio between this E5 note and the guitar's Fsharp4 note is approximately equal to 660 Hz divided by 369.9977 Hz i.e. approximately 1.784.

14. You start from a first note and then go up by an interval of a Just seventh to arrive at a second note. You start again from this second note and then go down by the interval of an octave and a Pythagorean sixth to arrive at a third note. Finally you go up from this third note by the interval of two octaves and a Just second to arrive at a fourth note. Of the following, which one gives the ratio of the interval between the first note and the fourth note?

(a) $\frac{45}{32}$.
(b) $\frac{20}{9}$.
(c) $\frac{5}{2}$.
(d) None of the above.

Answer: (c) Since the ratio of a Just seventh is $\frac{15}{8}$, going up by a Just seventh means multiplying by $\frac{15}{8}$. The ratio of a Pythagorean sixth is $\frac{27}{16}$. Going down by an octave means dividing by 2 and then going down by a Pythagorean sixth means dividing by $\frac{27}{16}$ i.e. multiplying by $\frac{16}{27}$. The ratio of a Just second is $\frac{9}{8}$, so going up by two octaves and a Just second means multiplying by 4 and then multiplying by $\frac{9}{8}$. Therefore the ratio of the fourth note as compared to that of the first note is given by $\frac{15}{8}$ times $\frac{1}{2}$ times $\frac{16}{27}$ times 4 times $\frac{9}{8}$. This gives a ratio of $\frac{5}{2}$.

15. A string vibrates at a frequency of 960 Hz when you put your finger at a distance of 14 cm from the nearer end of the string. What is the fundamental frequency of the string if its length is 84 cm?

(a) 240 Hz.
(b) 200 Hz.
(c) 120 Hz.
(d) None of the above.

Answer: (d) Since 14 cm is one-sixth of 84 cm, the string is vibrating at its 6th harmonic. Therefore the fundamental frequency of the string is given by 960 Hz divided by 6 i.e. 160 Hz.

16. An 80 cm long string is vibrating at a frequency of 1,050 Hz with a certain number of nodes between its two ends. A second string which is 60 cm long is vibrating at a frequency of 1,800 Hz with 9 antinodes between its two ends. Calculate the number of nodes between the two ends of the first string (not counting the nodes at both ends). (Assume that the two strings are identical in all respects except length.)

    (a) 6 nodes.
    (b) 5 nodes.
    (c) 4 nodes.
    (d) None of the above.

    Answer: (a) Since the second string has 9 antinodes, it is at its 9th harmonic and its fundamental frequency is given by 1,800 Hz divided by 9 i.e. 200 Hz. Therefore the fundamental frequency of the first string is given by 200 Hz times $\frac{60}{80}$ i.e. 150 Hz. The first string is vibrating at a frequency of 1,050 Hz, and since 1,050 Hz divided by 150 Hz is equal to 7, it must be vibrating at its 7th harmonic. The first string must therefore have 7 antinodes and 6 nodes between its two ends (not counting the nodes at both ends).

17. The distance between the adjacent nodes of a vibrating string is 15 cm. If the string has a fundamental frequency of 110 Hz and is 90 cm long, calculate the wavelength in the air of the sound wave produced by the vibrating string travelling towards a listener. (Assume that the velocity of sound in air is 330 m/s.)

    (a) 50 cm.
    (b) 60 cm.
    (c) 75 cm
    (d) None of the above.

    Answer: (a) Since the length of each vibrating segment of the string is 15 cm, the number of such segments in the string is given by 90 cm divided by 15 cm i.e. 6 segments. Therefore the string has 6 antinodes and is vibrating at its 6th harmonic. Its frequency is thus given by 110 Hz multiplied by 6 i.e. 660 Hz. The wavelength of the sound wave is thus equal to 330 m/s divided by 660 Hz i.e. 0.5 m or 50 cm.

18. A violin player plays a musical note on her violin which produces a sound wave travelling towards a listener with a wavelength of exactly 0.25 metres. Of the following musical notes, which is most likely to be the note played by the violin player? (Assume that the velocity of sound in air is 330 metres per second. Assume also that the notes played by the violin are part of the Just scale and that the A4 note on the violin has a frequency of 440 Hz.)

    (a) E5.
    (b) Dsharp6.
    (c) E6.
    (d) None of the above.

    Answer: (c) If the musical note has a wavelength of 0.25 metres in air, it will have a frequency given by the speed of sound in air i.e. 330 metres per second divided by 0.25 metres i.e. 1,320 Hz. If we go up from the A4 note or 440 Hz on the violin by a Just fifth, we multiply 440 Hz by the ratio $\frac{3}{2}$ to obtain the frequency 660 Hz which is the note E5. If we go up from 660 Hz by an octave by multiplying 660 Hz times 2, we will obtain 1,320 Hz. Therefore the note an octave and a Just fifth above A4 must be E6, so the note played is the note E6.

19. A common pentatonic scale has a succession of intervals as follows: tone, tone, 3 semitones, tone, 3 semitones, making up a total of 12 semitones. Which of the following sequences of notes follows this scale correctly starting from the note D4?

   (a) D4, E4, Fsharp4, A4, B4, and D5.
   (b) D4, E4, F4, A4, B4, and D5.
   (c) D4, E4, Fsharp4, Asharp4, B4, and D5.
   (d) D4, E4, Fsharp4, A4, C5, and D5.

   Answer: (a) The correct succession of intervals i.e. tone, tone, 3 semitones, tone and 3 semitones is given by the sequence of notes D4, E4, Fsharp4, A4, B4, and D5.

20. A newly invented musical instrument produces a musical note which has a spectrum showing that all its harmonics are present, odd and even, up to its 18th harmonic. The spectrum of a square wave shows its fundamental frequency and all its harmonics up to its 19th harmonic. The 6th line from the left in the spectrum of the square wave has a frequency equal to the frequency of the 9th line from the left in the spectrum of the musical instrument's note. If the square wave's note has a fundamental frequency of 180 Hz, what is the frequency of the 13th line from the left in the spectrum of the musical instrument's note? (Assume that the frequencies in each spectrum increase from left to right.)

   (a) 1,340 Hz.
   (b) 1,560 Hz.
   (c) 2,420 Hz.
   (d) None of the above.

   Answer: (d) Since the 6th line from the left in the spectrum of the square wave is its 11th harmonic, its frequency must be equal to 180 Hz times 11 i.e. 1,980 Hz. As the 9th line from the left in the spectrum of the musical note is its 9th harmonic, its fundamental frequency is given by 1,980 Hz divided by 9 i.e. 220 Hz. The 13th line from the left in the spectrum of the musical note is its 13th harmonic, which means that the frequency of this 13th line is equal to 220 Hz times 13 i.e. 2,860 Hz.

21. A newly discovered string instrument has a spectrum which shows all its harmonics (even and odd) present up to its 20th harmonic. The spectrum of a closed pipe vibrating at its fundamental frequency shows all its harmonics up to the 19th harmonic, and the frequency of the 7th line from the left in the spectrum of the string instrument's note is the same as the frequency of the 6th line from the left in the spectrum of the note from the closed pipe. What is the frequency of the 15th line from the left in the spectrum of the string instrument's note if the fundamental frequency of the closed pipe is 210 Hz? (Assume that the frequencies in each spectrum increase from left to right.)

   (a) 2,700 Hz.
   (b) 3,675 Hz.
   (c) 4,950 Hz.
   (d) None of the above.

   Answer: (c) The closed pipe has a fundamental frequency of 210 Hz, so the frequency of the 6th line in its spectrum which is its 11th harmonic is equal to 210 Hz times 11 i.e. 2,310 Hz. Since the 7th line from the left in the spectrum of the string instrument's note is its 7th harmonic, the fundamental frequency of the note is given by 2,310 Hz divided by 7 i.e. 330

Hz. The 15th line from the left in the spectrum of the string instrument's note is its 15th harmonic, so its frequency is equal to 330 Hz times 15 i.e. 4,950 Hz.

22. A string labelled X and an open pipe have the same fundamental frequency. A second string labelled Y has a length 70% that of X. When Y vibrates with three nodes (not counting the nodes at both ends), the wavelength of the sound wave it generates in the air is exactly 0.75 metres. What would be the frequency produced by the open pipe when it vibrates with 3 antinodes (not counting the antinodes at both ends)? (Assume that X and Y are similar strings and the velocity of sound in air is 330 m/s.)

    (a) 629 Hz.
    (b) 308 Hz.
    (c) 231 Hz
    (d) None of the above.

    Answer: (b) The frequency of the sound wave produced by Y will be 330 m/s divided by 0.75 m i.e. 440 Hz. Y vibrates with three nodes or is at its fourth harmonic. The fundamental frequency of Y is therefore 440 Hz divided by 4 or 110 Hz. The fundamental frequency of X will be 110 multiplied by 0.7/1 i.e. 77 Hz. When the open pipe vibrates with 3 antinodes or 4 nodes, it will be at its 4th harmonic which is therefore given by 4 times 77 Hz or 308 Hz.

23. A closed pipe P is vibrating with 5 nodes (not counting the node at one end) with the same frequency as that of an open pipe Q which is also vibrating with 5 nodes. P is then cut into six short open pipes and one short closed pipe all of equal lengths, and four of these short open pipes are joined up with the short closed pipe to make a closed pipe labelled R. If the fundamental frequency of Q is 110 Hz, calculate the frequency of R when it vibrates with 7 nodes between its two ends (not counting the node at one end).

    (a) 1,078 Hz.
    (b) 1,050 Hz.
    (c) 910 Hz.
    (d) None of the above.

    Answer: (b) The open pipe Q has 5 nodes, so it is at its 5th harmonic and its frequency is equal to 110 Hz times 5 i.e. 550 Hz. P also has 5 nodes so it is at its 11th harmonic, and its fundamental frequency is given by 550 Hz divided by 11 i.e. 50 Hz. R is five-sevenths of the length of P so its fundamental frequency is equal to 50 Hz times $\frac{7}{5}$ i.e. 70 Hz. When R vibrates with 7 nodes, it will be at its 15th harmonic and its frequency will be given by 70 Hz times 15 i.e. 1,050 Hz.

24. A closed pipe labelled K is sliced into 4 short open pipes and one short closed pipe all of equal lengths. 3 of these short open pipes are joined up to make an open pipe labelled L. When L vibrates at its fundamental frequency, it produces a sound wave travelling towards a listener with a wavelength of exactly 1.1 m. What is the fundamental frequency of K? (Assume that the velocity of sound in air is 330 m/s.)

    (a) 500 Hz.
    (b) 250 Hz.
    (c) 90 Hz.
    (d) None of the above.

Answer: (c) The fundamental frequency produced by L is 330 m/s divided by 1.1 m i.e. 300 Hz. An open pipe the same length as K will have a fundamental frequency given by 300 Hz multiplied by $\frac{3}{5}$ i.e. 180 Hz. The closed pipe K will thus have a frequency half of 180 Hz i.e. 90 Hz

25. Arrange the following harmonics in order of increasing frequency:
(i) The fourth harmonic frequency of an open pipe S of length p cm.
(ii) The eighth harmonic frequency of an open pipe T of length $\frac{5p}{2}$ cm.
(iii) The seventh harmonic frequency of a closed pipe U of length $\frac{4p}{5}$ cm.
(iv) The fifth harmonic frequency of a closed pipe V of length $\frac{7p}{10}$ cm.

(a) (iii), (ii), (iv) and (i).
(b) (ii), (iv), (i) and (iii).
(c) (i), (iv), (iii) and (ii).
(d) None of the above.

Answer: (b) Let f Hz be the fundamental frequency of the open pipe S of length p cm. Hence the fourth harmonic frequency of S is equal to $4f$ Hz. The open pipe T of length $\frac{5p}{2}$ cm has a fundamental frequency given by f Hz times $\frac{2p}{5p}$ i.e. $\frac{2f}{5}$ Hz. The eighth harmonic frequency of T is hence equal to $\frac{2f}{5}$ Hz times 8 i.e. $\frac{16f}{5}$ Hz. An open pipe with a length of $\frac{4p}{5}$ cm will have a fundamental frequency equal to f Hz times $\frac{5p}{4p}$ i.e. $\frac{5f}{4}$ Hz, and thus the closed pipe U which has the same length of $\frac{4p}{5}$ cm will have a fundamental frequency half of $\frac{5f}{4}$ Hz i.e. $\frac{5f}{8}$ Hz. Therefore the seventh harmonic frequency of U is equal to $\frac{5f}{8}$ Hz times 7 i.e. $\frac{35f}{8}$ Hz. The closed pipe V of length $\frac{7p}{10}$ cm has a fundamental frequency equal to $\frac{5f}{8}$ Hz times $\frac{4p}{5}$ divided by $\frac{7p}{10}$ i.e. $\frac{5f}{7}$ Hz. Therefore the frequency of the fifth harmonic of V is equal to $\frac{5f}{7}$ Hz times 5 i.e. $\frac{25f}{7}$ Hz. Hence the harmonics in order of increasing frequency are (ii), (iv), (i) and (iii).

END OF TEST PAPER