THE SCIENCE OF MUSIC (HSI2013)
Mid-Term Class Test, Semester 1, 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 least appropriate example of a scientific activity?
   (a) An electronic engineer performing on a newly invented percussion instrument which can be adjusted to produce various kinds of drum sounds.
   (b) A trumpet player testing how mouthpieces of different shapes affect the sound of his trumpet.
   (c) A clarinet player investigating how clarinet bodies made of different metals affect the tone of the clarinets.
   (d) A piano technician trying out hammers of different materials to find out how they affect the loudness of the sound produced.

   Answer: (a) The trumpet player, clarinet player and piano technician are all performing essentially scientific activities. The electronic engineer is the only one performing an essentially musical activity.

2. Which of the following is the least appropriate example of a technological activity?
   (a) A bassoon player inventing a new type of bassoon which can be folded up to become more compact for travelling.
   (b) A violin maker devising a new type of violin which can be tuned electronically.
   (c) A mechanical engineer performing on a new type of pipe organ which can be operated using solar energy.
   (d) A trombone player designing a new type of trombone which has valves in addition to its slide.

   Answer: (c) The bassoon player, violin maker and trombone player are all performing essentially technological activities. The mechanical engineer is the only one performing an essentially musical activity.

3. Which of the following is the least appropriate example of an object undergoing a vibration?
   (a) A single raindrop falling from the sky into a pail of water.
   (b) A dog shaking its body from side to side rapidly to dry its dripping wet fur.
   (c) A student's head moving up and down repeatedly as he falls asleep during a boring lecture.
   (d) A little girl jumping up and down repeatedly.

   Answer: (a) The dog, student's head and little girl are each undergoing a repeated motion and hence undergoing a vibration. Only the single raindrop is not undergoing a repeated movement and is therefore not undergoing a vibration.

4. Two bamboo poles carrying clothes to be dried are both swaying repeatedly from left to right during a strong wind. The shorter pole undergoes 6 complete cycles in the same time period during which the longer pole undergoes 5 complete cycles. What is the time period during which the longer pole would undergo 7 complete cycles if the shorter pole undergoes 4 complete cycles in 3 seconds?

(a) $\frac{21}{4}$ seconds.
(b) $\frac{9}{2}$ seconds.
(c) $\frac{27}{5}$ seconds.
(d) None of the above.

Answer: (d) The shorter pole undergoes 4 cycles in 3 seconds, and hence the time it takes to undergo one cycle is equal to $\frac{3}{4}$ seconds. The shorter pole thus undergoes 6 cycles in $\frac{3}{4}$ seconds times 6 cycles i.e. $\frac{9}{2}$ seconds. Since the longer pole undergoes 5 cycles in the same time period, the duration of each of the longer pole's cycles is given by $\frac{9}{2}$ seconds divided by 5 i.e. $\frac{9}{10}$ seconds. Therefore the pole would undergo 7 cycles in a duration equal to $\frac{9}{10}$ seconds times 7 i.e. $\frac{63}{10}$ seconds.

5. A dining table is designed by a furniture designer. From the furniture designer's plans for the table, a furniture maker builds the actual table. A businessman sees the dining table in a furniture showroom and buys it for his family at home. A piano sonata is composed by a composer, and the sonata is performed by a famous pianist for an appreciative audience during a concert at the Victoria Concert Hall. Which of the following has the same relationship to the composer as the furniture maker has to the furniture designer?

(a) The musical score of the sonata.
(b) The pianist.
(c) The Victoria Concert Hall.
(d) The audience.

Answer: (b). The furniture maker follows the plans of the furniture designer and builds the dining table bought by the businessman. The pianist reads the musical score of the sonata composed by the composer and performs the sonata for the audience. The pianist thus has the same relationship to the composer as the furniture maker has to the furniture designer.

6. A school choir is practising in the school music room for a National Day concert. They start by singing the National Day song "Home". A choir member who is late for the practice then enters the music room. If counterpoint is to be produced by the choir and the choir member who is late as they sing together, which of the following songs should the choir member not sing as she enters the classroom?

(a) "Home".
(b) "We Are Singapore".
(c) "Count On Me Singapore".
(d) "Stand Up For Singapore".

Answer: (a) Since counterpoint is produced only when two or more different melodies are sung at the same time, the choir member who is late should not sing the same song which is being sung by the rest of the choir, i.e. she should not sing "Home".

7. An ambulance rushes past you as you stand on the pavement carrying a sound level meter. The sound of the ambulance's siren causes the sound level meter to register a reading of 96 dB. When the ambulance reaches a hospital nearby, the sound from the siren is 100 times less powerful than when the ambulance rushes past you. What would the reading on the sound level meter be when the ambulance is at the hospital? (Assume that the sound level meter readings are due only to the ambulance's siren.)

(a) 86 dB.
(b) 76 db.
(c) 66 dB.
(d) None of the above.

Answer: (b) If the sound power decreases by 10 times, the sound level meter reading should decrease by 10 dB. A decrease of 100 times i.e. 10 times 10 times would thus result in a decrease in the sound level meter reading of 10 dB plus 10 dB i.e. 20 dB. Hence the sound level meter reading would be 96 dB minus 20 dB i.e. 76 dB.

8. A trumpet player plays a note with a frequency of 1,760 Hz during a jazz concert, and a double bass player then plays a note with a frequency of 82.5 Hz. Which of the following describes the interval between the note played by the double bass player and the note played by the trumpet player?

(a) Greater than 1 complete octave but less than 2 complete octaves.
(b) Greater than 2 complete octaves but less than 3 complete octaves.
(c) Greater than 3 complete octaves but less than 4 complete octaves.
(d) Greater than 4 complete octaves but less than 5 complete octaves.

Answer: (d) An octave is an interval with a ratio of $\frac{2}{1}$ i.e. 2, so if we go down by the interval of an octave this means dividing the frequency of a musical note by 2. Starting with the trumpet player's note of 1,760 Hz and dividing this frequency by 2 five times successively, the following frequencies are obtained: 1,760 Hz, 880 Hz, 440 Hz, 220 Hz, 110 and 55 Hz. The interval from 1,760 Hz to 82.5 Hz is therefore greater than 4 complete octaves but less than 5 complete octaves.

9. A grand piano has its A4 string tuned to a frequency of 441 Hz, and all its strings are tuned relative to each other as is usual for a grand piano. A particular note on this grand piano has a frequency of approximately 330.4 Hz. Of the following notes, which one 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) G4.
(b) F4.
(c) E4.
(d) None of the above.

Answer: (c) The frequency of the A4 string of the grand piano is 441 Hz, so going down from this note by five Equal-tempered semitones, we have to divide 441 Hz by the ratio of an Equal-tempered semitone i.e. 1.05946 five times. This gives us a frequency of approximately 330.38 Hz. Hence the note with the frequency of 330.4 Hz is the note which is five semitones below A4 i.e. E4.

10. A tune for solo voice has a musical score beginning with a time signature of 28/8, and a certain bar of this tune begins with a dotted crotchet and ends with 3 dotted quavers and 10 semiquavers. Which of the following combinations of notes would fit exactly into the middle of this bar in agreement with the time signature?

(a) 4 dotted quavers, 5 quavers and 8 semiquavers.
(b) 3 minims and 6 semiquavers.

(c) 2 dotted crotchets, a minim and 12 semiquavers.
(d) 2 crotchets, 4 dotted quavers and 11 semiquavers.

Answer: (d) The time signature is 28/8, so each bar of the tune should contain the duration equivalent of 28 quavers or 56 semiquavers. Since the beginning of the bar has a dotted crotchet equivalent to 6 semiquavers, and the end of the bar has 3 dotted quavers equivalent to 9 semiquavers and 10 semiquavers, the bar already has the duration equivalent of 25 semiquavers. Therefore the middle of the bar has to be filled with the duration equivalent of 31 semiquavers. 2 crotchets are equivalent to 8 semiquavers and with 4 dotted quavers (12 semiquavers) and 11 semiquavers make up a total of 31 semiquavers.

11. You start from the note D5 on the keyboard of a piano and move downwards by an interval of one and a quarter octaves to arrive at a second note. You then move upwards from this second note by five-sixths of an octave to arrive at a third note. Moving downwards from this third note by two and one-third octaves, you arrive at the fourth and final note. Of the following notes, which one is the correct letter name for the fourth note?

(a) G2.
(b) Gflat2.
(c) F2.
(d) None of the above.

Answer: (c) If you go down by one and a quarter octaves or 15 semitones (since an octave consists of 12 semitones) from the starting note D5, you will arrive at the second note B3. Moving up by five-sixths of an octave or 10 semitones brings you to the third note A4. Finally, moving down from A4 by two and one-third octaves or 28 semitones brings us to the fourth note which is F2.

12. A melody for solo oboe has a musical score consisting of a musical staff which starts with a treble clef. One particular bar of this melody has its first note written on the highest line of the five lines of the staff, its second note written on the second highest space of the four spaces of the staff, its third note written on the lowest line of the five lines of the staff, and its fourth note written on the lowest space of the four spaces of the staff. Which of the following gives the correct names of these four notes from the first note to the fourth note in the right sequence?

(a) F5, D5, E4 and F4.
(b) F5, C5, E4 and G4.
(c) F5, C5, D4 and F4.
(d) F5, C5, E4 and F4.

Answer: (d) The treble clef shows that the second lowest line of the staff is the note G4. Therefore the note on the highest line of the five lines of the staff is the note F5, the note on the second highest space is the note C5, the note on the lowest line of the five lines is the note E4 and the note on the lowest space is the note F4.

13. A 'cello's A string is tuned to a frequency of 220 Hz, and all its other strings are tuned relative to each other in Just fifths as is usual for a 'cello. A bass guitar's A string is tuned to a frequency two octaves below the frequency of the 'cello's A string, and all the bass guitar's strings are tuned in Equal-tempered semitones as is usual for a bass guitar. Which of the following is closest to the ratio of the interval between the note from the open D string of the 'cello and the F2 note of the bass guitar? Open string means that the notes are not played with

a finger on the 'cello'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) 1.497.
(b) 1.586.
(c) 1.680.
(d) 1.780.

Answer (c) The frequency of the A string of the bass guitar is 55 Hz i.e. the note is A1. The bass guitar's A2 note thus has a frequency of 110 Hz, and the frequency of its F2 note is four Equal-tempered semitones below its A2 note which is thus equal to 110 Hz divided by 1.05946 four times. This gives approximately 87.3081 Hz. The A string of the 'cello has a frequency of 220 Hz which is A3, so the frequency of its D3 string which is a Just fifth below the A string is equal to 220 Hz divided by $\frac{3}{2}$ or times $\frac{2}{3}$ i.e. approximately 146.6667 Hz which is D3. Therefore the ratio between this D3 note and the bass guitar's F2 note is approximately equal to 146.6667 Hz divided by 87.3081 Hz i.e. approximately 1.680.

14. Starting from a first note, you then go down by an interval of a Pythagorean sixth to arrive at a second note. Starting again from this second note, you then go up by the interval of two octaves and a Pythagorean third to arrive at a third note. You then go down from this third note by the interval of an octave and a Just fourth to arrive at a fourth note. Which of the following is the ratio of the interval between the first note and the fourth note?

(a) $\frac{9}{4}$.
(b) $\frac{9}{8}$.
(c) $\frac{9}{16}$.
(d) None of the above.

Answer: (b) The ratio of a Pythagorean sixth is $\frac{27}{16}$, so going down by a Pythagorean sixth means dividing by $\frac{27}{16}$ or multiplying by $\frac{16}{27}$. The Pythagorean third has a ratio of $\frac{81}{64}$, so going up by two octaves means multiplying by 4 and then going up by a Pythagorean third means multiplying by $\frac{81}{64}$. The ratio of a Just fourth is $\frac{4}{3}$, so going down by an octave and a Just fourth means multiplying by $\frac{1}{2}$ and then multiplying by $\frac{3}{4}$. Therefore the ratio of the fourth note as compared to that of the first note is given by $\frac{16}{27}$ times 2 times 2 times $\frac{81}{64}$ times $\frac{1}{2}$ times $\frac{3}{4}$. This gives a ratio of $\frac{9}{8}$.

15. When your finger is placed at a distance of 9 cm from the nearer end of a string, the string vibrates at a frequency of 1,200 Hz. Calculate the fundamental frequency of the string if its length is 72 cm.

(a) 100 Hz.
(b) 150 Hz.
(c) 300 Hz.
(d) None of the above.

Answer: (b) The string is 72 cm long so it must be vibrating at its 8th harmonic since 9 cm is one-eighth of 72 cm. The fundamental frequency of the string is thus equal to 1,200 Hz divided by 8 i.e. 150 Hz.

16. A string which is vibrating at a frequency of 960 Hz with a certain number of nodes between its two ends is 100 cm long. A second string which is 80 cm long is vibrating at a frequency of 2,800 Hz with 7 antinodes between its two ends. What is 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) 2 nodes.
    (b) 3 nodes.
    (c) 4 nodes.
    (d) None of the above.

    Answer: (a) The second string has 7 antinodes so it is at its 7th harmonic. Therefore its fundamental frequency is equal to 2,800 Hz divided by 7 i.e. 400 Hz, and hence the fundamental frequency of the first string is equal to 400 Hz times $\frac{80}{100}$ i.e. 320 Hz. The first string is vibrating at a frequency of 960 Hz, and since 960 Hz divided by 320 Hz is equal to 3, it must be vibrating at its 3rd harmonic. Therefore the first string must have 3 antinodes and 2 nodes between its two ends (not counting the nodes at both ends).

17. A string which is vibrating at a frequency of 1,320 Hz with 5 nodes between its two ends (not counting the nodes at both ends) is labelled P. A second string labelled Q is 10% longer than P and is sliced into 5 pieces of equal length, and 4 of these 5 pieces are joined up to make a third string labelled R. When R vibrates with 7 nodes between its two ends (not counting the nodes at both ends), what would be its frequency of vibration? (Assume that the strings are identical in all respects except length.)

    (a) 1,500 Hz.
    (b) 1,800 Hz.
    (c) 2,000 Hz.
    (d) None of the above.

    Answer: (c) The string P has 5 nodes so it has 6 antinodes and is hence vibrating at its 6th harmonic. Its fundamental frequency is thus given by 1,320 Hz divided by 6 i.e. 220 Hz. The string Q is 10% longer than P, so its fundamental frequency is given by 220 Hz times $\frac{1}{1.1}$ i.e. 200 Hz. Since the string R has a length which is four-fifths that of the length of Q, its fundamental frequency is given by 200 Hz times $\frac{5}{4}$ i.e. 250 Hz. When R vibrates with 7 nodes or 8 antinodes, it will be at its 8th harmonic and its frequency of vibration will be given by 250 Hz times 8 i.e. 2,000 Hz.

18. A string is vibrating such that the distance between its adjacent nodes is 12 cm. What is the wavelength of the note in the air produced by the vibrating string travelling towards a listener, if the string has a fundamental frequency of 55 Hz and is 96 cm long? (Assume that the velocity of sound in air is 330 m/s.)

    (a) 50 cm.
    (b) 65 cm.
    (c) 75 cm
    (d) None of the above.

    Answer: (c) The length of each vibrating segment of the string is 12 cm, so the number of such segments in the string is equal to 96 cm divided by 12 cm i.e. 8 segments. The string thus has 8 antinodes and is vibrating at its 8th harmonic with a frequency given by 55 Hz multiplied by 8 i.e. 440 Hz. Therefore the wavelength is given by 330 m/s divided by 440 Hz i.e. 0.75 m or 75 cm.

19. A musical note which produces a sound wave travelling towards a listener with a wavelength of exactly 0.4 metres is played by a 'cello player. Which of the following musical notes is most likely to be the note played by the 'cello player? (Assume that the velocity of sound is 330 metres per second. Assume also that the notes played by the 'cello are part of the Just scale and that the A3 note on the 'cello has a frequency of 220 Hz.)

    (a) G5.
    (b) Gsharp5.
    (c) A5.
    (d) None of the above.

    Answer: (b) A musical note which has a wavelength of 0.4 metres in air will have a frequency equal to the speed of sound in air i.e. 330 metres per second divided by 0.4 metres i.e. 825 Hz. Going up from the A3 note or 220 Hz on the 'cello by an octave brings us to the note A4 which has a frequency of 440 Hz. If we go up from 440 Hz by a Just seventh by multiplying 440 Hz by $\frac{15}{8}$, we will obtain 825 Hz. The note a Just seventh above A4 must be Gsharp5, so the note played is the note Gsharp5.

20. One particular pentatonic scale has five notes with a succession of intervals as follows: semitone, tone, 2 tones, semitone, 2 tones, making up a total of 12 semitones. Which of the following sequences of notes follows this scale correctly?

    (a) G4, Gsharp4, Asharp4, C5, Dsharp5, and G5.
    (b) G4, Gsharp4, B4, D5, Dsharp5, and G5.
    (c) G4, Gsharp4, Asharp4, D5, Dsharp5, and G5.
    (d) G4, A4, Asharp4, D5, Dsharp5, and G5.

    Answer: (c) The correct succession of intervals i.e. semitone, tone, 2 tones, semitone, 2 tones is given by the sequence of notes G4, Gsharp4, Asharp4, D5, Dsharp5, and G5.

21. A square wave has a spectrum showing its fundamental frequency and all its harmonics up to its 19th harmonic. A newly discovered musical instrument produces a musical note which has a spectrum showing all its harmonics are present, odd and even, up to its 20th harmonic. The frequency of the 4th line from the left in the spectrum of the square wave is equal to the frequency of the 4th line from the left in the spectrum of the musical instrument's note. If the square wave's note has a fundamental frequency of 140 Hz, calculate the frequency of the 9th line from the left in the spectrum of the musical note. (Assume that the frequencies in each spectrum increase from left to right.)

    (a) 1,260 Hz.
    (b) 2,205 Hz.
    (c) 2,380 Hz.
    (d) None of the above.

    Answer: (b) The 4th line from the left in the spectrum of the square wave is its 7th harmonic, so its frequency is 140 Hz times 7 i.e. 980 Hz. The 4th line from the left in the spectrum of the musical note is its 4th harmonic, so its fundamental frequency is equal to 980 Hz divided by 4 i.e. 245 Hz. Since the 9th line from the left in the spectrum of the musical note is its 9th harmonic, the frequency of this 9th line is given by 245 Hz times 9 i.e. 2,205 Hz.

22. A note produced by an ancient string instrument has a spectrum which shows all its harmonics (even and odd) present up to its 18th harmonic, and the spectrum of a closed pipe vibrating at its fundamental frequency shows all its harmonics up to the 19th harmonic. The frequency of the 6th line from the left in the spectrum of the string instrument's note is the same as the frequency of the 8th line from the left in the spectrum of the note from the closed pipe. If the fundamental frequency of the closed pipe is 120 Hz, calculate the frequency of the 12th line from the left in the spectrum of the string instrument's note. (Assume that the frequencies in each spectrum increase from left to right.)

    (a) 1,920 Hz.
    (b) 2,400 Hz.
    (c) 3,600 Hz.
    (d) None of the above.

    Answer: (c) Since the closed pipe has a fundamental frequency of 120 Hz, the frequency of the 8th line in its spectrum which is its 15th harmonic is equal to 120 Hz times 15 i.e. 1,800 Hz. The 6th line from the left in the spectrum of the string instrument's note is its 6th harmonic, so the fundamental frequency of the note is equal to 1,800 Hz divided by 6 i.e. 300 Hz. The 12th line from the left in the spectrum of the string instrument's note must be its 12th harmonic, so its frequency is given by 300 Hz times 12 i.e. 3,600 Hz.

23. An open pipe K is vibrating with 6 nodes and a closed pipe L is vibrating with 4 nodes between both their two ends (not counting the node at one end for L). The frequency of K is the same as that of L. L is then cut into ten short open pipes and one short closed pipe all of equal lengths. Five of these short open pipes are joined up with the short closed pipe to make a closed pipe labelled M. If the fundamental frequency of K is 180 Hz, what is the frequency of M when it vibrates with 8 nodes between its two ends (not counting the node at one end)?

    (a) 3,740 Hz.
    (b) 3,300 Hz.
    (c) 1,760 Hz.
    (d) None of the above.

    Answer: (a) Since K has 6 nodes, it is at its 6th harmonic and its frequency is hence given by 180 Hz times 6 i.e. 1,080 Hz. L has 4 nodes so it is at its 9th harmonic, and its fundamental frequency is equal to 1,080 Hz divided by 9 i.e. 120 Hz. Since M is six-eleventh of the length of L, its fundamental frequency is given by 120 Hz times $\frac{11}{6}$ i.e. 220 Hz. When M vibrates with 8 nodes, it will be at its 17th harmonic, so its frequency will be equal to 220 Hz times 17 i.e. 3,740 Hz.

24. An open pipe labelled P is sliced into 5 short open pipes all of the equal lengths and 3 of these short open pipes are joined up and one end closed up to make a closed pipe labelled Q. Q then vibrates at its fundamental frequency and produces a sound wave travelling towards a listener with a wavelength of exactly 1.5 m. Calculate the fundamental frequency of P. (Assume that the velocity of sound in air is 330 m/s.)

    (a) 440 Hz.
    (b) 220 Hz.
    (c) 132 Hz.
    (d) None of the above.

Answer: (d) The fundamental frequency produced by Q is 330 m/s divided by 1.5 m i.e. 220 Hz. An open pipe the same length as Q will have a fundamental frequency double this value i.e. 440 Hz. P would therefore have a fundamental frequency given by 440 Hz multiplied by $\frac{3}{5}$ i.e. 264 Hz.

25. Arrange the following harmonics in order of decreasing frequency:
(i) The sixth harmonic frequency of an open pipe E of length d cm.
(ii) The eighth harmonic frequency of an open pipe F of length $\frac{7d}{5}$ cm.
(iii) The fifth harmonic frequency of a closed pipe G of length $\frac{3d}{7}$ cm.
(iv) The seventh harmonic frequency of a closed pipe H of length $\frac{5d}{9}$ cm.

(a) (i), (iv), (ii), (iii).

(b) (iii), (ii), (iv), (i).

(c) (iv), (i), (iii), (ii).

(d) None of the above.

Answer: (c) Let f Hz be the fundamental frequency of the open pipe E of length d cm. Hence the sixth harmonic frequency of E is equal to $6f$ Hz. The open pipe F of length $\frac{7d}{5}$ cm has a fundamental frequency equal to f Hz times $\frac{5d}{7d}$ i.e. $\frac{5f}{7}$ Hz. The eighth harmonic frequency of F is thus equal to $\frac{5f}{7}$ Hz times 8 i.e. $\frac{40f}{7}$ Hz. An open pipe with a length of $\frac{3d}{7}$ cm will have a fundamental frequency equal to f Hz times $\frac{7d}{3d}$ i.e. $\frac{7f}{3}$ Hz, so the closed pipe G which has the same length of $\frac{3d}{7}$ cm will have a fundamental frequency half of $\frac{7f}{3}$ Hz i.e. $\frac{7f}{6}$ Hz. Therefore the fifth harmonic frequency of G is given by $\frac{7f}{6}$ Hz times 5 i.e. $\frac{35f}{6}$ Hz. The closed pipe H of length $\frac{5d}{9}$ cm has a fundamental frequency equal to $\frac{7f}{6}$ Hz times $\frac{3d}{7}$ divided by $\frac{5d}{9}$ i.e. $\frac{9f}{10}$ Hz. Therefore the frequency of the seventh harmonic of H is equal to $\frac{9f}{10}$ Hz times 7 i.e. $\frac{63f}{10}$ Hz. Hence the harmonics in order of decreasing frequency are (iv), (i), (iii) and (ii).

END OF TEST PAPER