THE SCIENCE OF MUSIC (HSI2013)
Mid-Term Class Test, Semester 1, 2025/26

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) A trumpet player performing on a newly invented trumpet which can electronically produce various other brass instrument sounds.

   (b) A trombone player studying how different shapes of the trombone tube cross-section affect the trombone's loudness and sound quality.

   (c) A clarinet player investigating how the material of the mouthpiece of a clarinet affects the sound of the clarinet.

   (d) A metallurgist playing on flutes made of different metals including rare earths to find how their sound quality varies with each metal.

   Answer: (a) The trombone player, clarinet player and metallurgist are all performing essentially scientific activities. The trumpet player 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 trumpet player inventing a new type of trumpet which can be lengthened to produce a sound more like a trombone.

   (b) A tuba player devising a new type of adjustable tuba which can change the tone colour of the tuba.

   (c) A pianist inventing a new type of portable electronic piano which can produce many types of instrumental sounds.

   (d) An engineer performing on a new type of viola whose string tension can be increased to also produce violin sounds.

   Answer: (d) The trumpet player, tuba player and pianist are all performing essentially technological activities. The 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 glacier sliding to a stop in a valley high up in the mountains.

   (b) An apple tree swaying repeatedly from side to side during a storm.

   (c) A woman's head shaking from left to right repeatedly as she argues with a friend during a conversation.

   (d) A little boy shaking his leg repeatedly up and down while watching a TV programme.

   Answer: (a) The apple tree, woman's head and little boy's leg are each undergoing a repeated motion and hence undergoing a vibration. Only the glacier is undergoing a single movement and is therefore not undergoing a vibration.

4. During a strong wind, two bamboo poles next to each other are swaying repeatedly from left to right. The shorter pole undergoes 5 complete cycles in the same time period during which the longer pole undergoes 4 complete cycles. If the longer pole undergoes 3 complete cycles in 4 seconds, calculate the time period during which the shorter pole would undergo 9 complete cycles.

   (a) $\frac{16}{15}$ seconds.
   (b) $\frac{16}{5}$ seconds.
   (c) $\frac{48}{7}$ seconds.
   (d) None of the above.

   Answer: (d) Since the longer pole undergoes 3 cycles in 4 seconds, the time it takes to undergo one cycle is given by $\frac{4}{3}$ seconds. Therefore the longer pole undergoes 4 cycles in $\frac{4}{3}$ seconds times 4 cycles i.e. $\frac{16}{3}$ seconds. Since the shorter pole undergoes 5 cycles in the same time period, the duration of each of the shorter pole's cycles is given by $\frac{16}{3}$ seconds divided by 5 i.e. $\frac{16}{15}$ seconds. The shorter pole would thus undergo 9 cycles in a duration given by $\frac{16}{15}$ seconds times 9 i.e. $\frac{48}{5}$ seconds.

5. An architect designs a house, and from the architect's plans, a contractor builds the actual house. A businessman sees the house for sale and buys it for his family to live in. A composer composes an overture, and from the musical score of the overture, an orchestra performs the overture for an audience during a symphony concert at the Victoria Concert Hall. Which of the following has the same relationship to the composer as the contractor has to the architect?

   (a) The Victoria Concert Hall.
   (b) The overture.
   (c) The orchestra.
   (d) The audience.

   Answer: (c). The contractor follows the plans of the architect and builds the house which is bought by the businessman for his family. The orchestra reads the musical score of the overture composed by the composer and performs the overture for the audience. The orchestra thus has the same relationship to the composer as the contractor has to the architect.

6. A junior college choir starts its choir practice in the college music studio by singing the National Day song "The Road Ahead". A choir member who is late for the practice then enters the music studio. Of the following songs, which one should the choir member not sing as he enters the music studio, if counterpoint is to be produced by the choir and the choir member who is late as they sing together?

   (a) "Home".
   (b) "We Are Singapore".
   (c) "Count On Me Singapore".
   (d) "The Road Ahead".

   Answer: (d) Since counterpoint is produced only when two or more different melodies are sung simultaneously, the choir member who is late should not sing the same song which is being sung by the rest of the choir, i.e. he should not sing "The Road Ahead".

7. The siren of a police car passing right in front of you registers a reading of 94 dB on a sound level meter which you are carrying. When the police car stops at a traffic light some distance away, the siren registers a reading of 74 dB on your sound level meter. How much less powerful is the sound from the siren reaching you when the police car is at the traffic light compared to when the police car was in front of you? (Assume that the sound level meter readings are due only to the police car's siren.)

   (a) 10 times.
   (b) 100 times.
   (c) 1,000 times.
   (d) None of the above.

   Answer: (b) The decrease in the sound level meter reading from 94 dB to 74 dB is a decrease of 94 dB minus 74 dB i.e. 20 dB. Since a decrease in the sound level of 10 dB is due to a decrease in the sound power by 10 times, a decrease in the sound level meter reading of 20 dB or 10 dB plus 10 dB is due to a decrease in the sound power of 10 times 10 times i.e. a decrease of 100 times.

8. A trumpet player performing in a jazz concert plays a note with a frequency of 512 Hz. A double bass player then plays a note with a frequency of 62 Hz. Which of the following best describes the interval between the note played by the trumpet player and the note played by the double bass 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: (c) The octave is an interval with a ratio of $\frac{2}{1}$ i.e. 2, so if we go down from a musical note by the interval of an octave, the frequency of the musical note should be divided by 2. Hence starting from the trumpet player's note of 512 Hz, successive division by 2 four times would give us the following frequencies: 512 Hz, 256 Hz, 128 Hz, 64 Hz and 32 Hz. The interval from 512 Hz to 62 Hz is greater than 3 complete octaves but less than 4 complete octaves.

9. A grand piano has its A4 string tuned to a frequency of 442 Hz, and all its strings are tuned relative to each other as is usual for a piano. A certain note on this grand piano has a frequency of approximately 147.5 Hz. Which of the following 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) F3
   (b) E3.
   (c) Dsharp3
   (d) D3.

   Answer: (d) The frequency of the A4 string of the grand piano is 442 Hz, so its A3 note has a frequency half of this i.e. 221 Hz. If we go down from this note by seven Equal-tempered semitones, we have to divide 221 Hz by the ratio of an Equal-tempered semitone i.e. 1.05946 seven times, giving us a frequency of approximately 147.503 Hz. Therefore the note with a frequency of 147.5 Hz is most likely to be the note which is seven semitones below A3 i.e. D3.

10. A melody for solo 'cello has a musical score beginning with a time signature of 28/8, and a certain bar of this melody starts with a dotted crotchet and ends with 6 quavers and 6 semiquavers. Which of the following combinations of notes would fit exactly into the middle of this bar in accordance with the time signature?

    (a) 3 dotted crotchets, a minim and 7 semiquavers.
    (b) 2 minims and 15 semiquavers.
    (c) 4 crotchets, a minim and 8 semiquavers.
    (d) 2 crotchets, a dotted minim and 7 quavers.

    Answer: (c) The time signature of 28/8 means that each bar of the melody must have the duration equivalent of 28 quavers or 56 semiquavers. Since the start of the bar has a dotted crotchet equivalent to 6 semiquavers, and the end of the bar has 6 quavers equivalent to 12 semiquavers and 6 semiquavers, the bar already has the duration equivalent of 24 semiquavers, so the middle of the bar should be filled with the duration equivalent of 32 semiquavers. 4 crotchets are equivalent to 16 semiquavers and with a minim (8 semiquavers) and 8 semiquavers make up a total of 32 semiquavers.

11. You start from the note A5 on the keyboard of a piano and go downwards by an interval of one and a quarter octaves to arrive at a second note. You then go upwards from this second note by two and one-third octaves to arrive at a third note. Going downwards from this third note by three and five-sixth octaves, you arrive at the fourth and final note. Of the following notes, which one is the correct letter name of the fourth note?

    (a) B2.
    (b) C3.
    (c) Csharp3.
    (d) None of the above.

    Answer: (b) By going down from the starting note A5 by one and a quarter octaves or 15 semitones (since an octave consists of 12 semitones), you arrive at the second note Fsharp4. Going up by two and one-third octaves or 28 semitones, you arrive at the third note Asharp6. Finally, going down from Aaharp6 by three and five-sixth octaves or 46 semitones, you reach the fourth note which is C3.

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

    (a) A2, D3, Dsharp3 and A3.
    (b) A2, D3, F3 and A3.
    (c) G2, D3, E3 and A3.
    (d) A2, D3, E3 and A3.

    Answer: (d) The bass clef shows that the second highest line of the staff is the note F3. Therefore the note on the lowest space of the four spaces of the staff is the note A2, the note on the middle line of the five lines is the note D3, the note on the second highest space of the four spaces is the note E3 and the note on the highest line of the five lines is the note A3.

13. A viola has its A string 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 viola. The A string of a guitar is tuned to a frequency two octaves below the frequency of the viola's A string, and all the guitar's strings are tuned in Equal-tempered semitones as is usual for a guitar. Which of the following is closest to the ratio of the interval between the note from the open C string of the viola and the F3 note of the guitar? Open string means that the notes are not played with a finger on the viola'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) 1.264.
    (b) 1.339.
    (c) 1.419.
    (d) 1.503.

    Answer (b) The frequency of the A string of the guitar is the note A2 i.e. 110 Hz. The guitar's A3 note thus has a frequency of 220 Hz, and the frequency of its F3 note is four Equal-tempered semitones below its A3 note, i.e. 220 Hz divided by 1.05946 four times which is approximately equal to 174.6162 Hz. The A string of the viola has a frequency of 440 Hz, so the frequency of its C string which is C3 is three Just fifths below the A string and is thus given by 440 Hz divided by $\frac{3}{2}$ three times i.e 130.3704 Hz. Therefore the ratio between this C3 note and the guitar's F3 note is approximately equal to 174.6162 Hz divided by 130.3704 Hz i.e. approximately 1.339.

14. Starting from a first note, you go down by an interval of a Just sixth to arrive at a second note. From this second note you 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 a Pythagorean seventh to arrive at a fourth note. Finally you go up by an octave and a Just fourth to arrive at a fifth note. Which of the following gives the ratio of the interval between the first note and the fifth note?

    (a) $\frac{64}{15}$.
    (b) $\frac{32}{15}$.
    (c) $\frac{64}{5}$.
    (d) None of the above.

    Answer: (a) The ratio of a Just sixth is $\frac{5}{3}$, so going down by a Just sixth means dividing by $\frac{5}{3}$ or multiplying by $\frac{3}{5}$. The ratio of a Pythagorean third is $\frac{81}{64}$. Going up by two octaves means multiplying by 2 twice and then going up by a Pythagorean third means multiplying by $\frac{81}{64}$. The ratio of a Pythagorean seventh is $\frac{243}{128}$, so going down a Pythagorean seventh means multiplying by $\frac{128}{243}$. Going up by an octave means multiplying by 2 and up by a Just fourth means multiplying by $\frac{4}{3}$. The ratio of the interval between the first note and the fifth note is hence equal to $\frac{3}{5}$ times 4 times $\frac{81}{64}$ times $\frac{128}{243}$ times 2 times$\frac{4}{3}$. This gives a ratio of $\frac{64}{15}$.

15. When you put your finger at a distance of 15 cm from the nearer end of a string, it vibrates at a frequency of 1,792 Hz. If the length of the string is 105 cm, calculate the frequency of the 9th harmonic of the string.

    (a) 2,048 Hz.
    (b) 2,304 Hz.
    (c) 2,560 Hz.

(d) None of the above.

Answer: (b) The string must be vibrating at its 7th harmonic, since 15 cm is one-seventh of 105 cm, and hence the fundamental frequency of the string is equal to 1,792 Hz divided by 7 i.e. 256 Hz. The ninth harmonic of 256 Hz will be equal to 256 Hz times 9 i.e. 2,304 Hz.

16. A string labelled A is 100 cm long and vibrates at a frequency of 1,050 Hz with m number of nodes between its two ends (not counting the nodes at both ends). A second string labelled B is 70 cm long and vibrates at a frequency of 2,400 Hz with 8 antinodes between its two ends. String A is then shortened by 25% and vibrates at 1,400 Hz with n number of nodes between its two ends (not counting the nodes at both ends). Find the ratio m:n. (Assume that strings A and B are identical in all respects except length.)

    (a) 2:3.
    (b) 3:4.
    (c) 4:5.
    (d) None of the above.

    Answer: (d) String B has 8 antinodes so it is at its 8th harmonic. Its fundamental frequency is thus equal to 2,400 Hz divided by 8 i.e. 300 Hz. The fundamental frequency of string A is therefore given by 300 Hz times $\frac{70}{100}$ i.e. 210 Hz. Since 1,050 Hz divided by 210 Hz is equal to 5, string A is vibrating at its 5th harmonic and has 5 antinodes or 4 nodes between its two ends. String A is shortened by 25% or is 75 cm, and its fundamental frequency will be equal to 210 Hz times $\frac{100}{75}$ i.e. 280 Hz. Since 1,400 Hz divided by 280 Hz is equal to 5, the shortened string A is vibrating at its 5th harmonic and has 5 antinodes or 4 nodes between its two ends. Therefore the ratio m:n is 4:4 or 1:1.

17. The distance between the adjacent nodes of a vibrating string which has a fundamental frequency of 125 Hz is 20 cm. If the string is 120 cm long, what is 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) 20 cm.
    (b) 22 cm.
    (c) 44 cm
    (d) None of the above.

    Answer: (c) The length of each vibrating segment of the string is 20 cm so the number of such segments in the string is equal to 120 cm divided by 20 cm i.e. 6 segments. The string thus has 6 antinodes and is vibrating at its 6th harmonic, which means that its frequency is equal to 125 Hz multiplied by 6 i.e. 750 Hz. Therefore the wavelength of the sound wave is given by 330 m/s divided by 750 Hz i.e. 0.44 m or 44 cm.

18. A musical note played by a 'cello player produces a sound wave travelling towards a listener which has a wavelength of exactly 1.25 metres. Which of the following musical notes is most likely to be the note played by the 'cello player? (Assume that the velocity of sound in air is 330 m/s. Assume also that the notes played by the 'cello are part of the Just scale and that the A string on the 'cello is tuned to a frequency of 220 Hz.)

    (a) B3.
    (b) Csharp4.
    (c) D4.

(d) None of the above.

Answer: (d) The 'cello's musical note has a wavelength of 1.25 m in air, so its frequency is equal to the speed of sound in air i.e. 330 m/s divided by 1.25 m i.e. 264 Hz. The 'cello's A4 note is one octave above its A3 note on its A string, and is thus equal to 220 Hz multiplied by 2 i.e. 440 Hz. Going down from the A4 note by a Just sixth, we divide 440 Hz by the ratio $\frac{5}{3}$ to obtain the frequency 264 Hz. The note with a frequency of 264 Hz which is a Just sixth below A4 must be C4, so the note played is the note C4.

19. A Balinese pentatonic scale has 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 starting from the note E3?

(a) E3, F3, G3, C4, Csharp4 and E4.

(b) E3, F3, Gsharp3, B3, C4 and E4.

(c) E3, F3, G3, B3, C4 and E4.

(d) E3, Fsharp3, G3, B3, C4 and E4.

Answer: (c) The correct succession of intervals starting from E3 i.e. semitone, tone, 2 tones, semitone and 2 tones, is given by the sequence of notes E3, F3, G3, B3, C4 and E4.

20. The spectrum of a musical note produced by an ancient musical instrument shows that only its odd harmonics are present, up to its 23rd harmonic. The spectrum of a square wave shows its fundamental frequency and all its harmonics up to its 19th harmonic. The 5th line from the left in the spectrum of the musical instrument's note has a frequency equal to that of the 4th line from the left in the spectrum of the square wave. If the square wave has a fundamental frequency of 180 Hz, calculate the frequency of the 11th 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) 2,772 Hz.

(b) 2,940 Hz.

(c) 3,220 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 equal to 180 Hz times 7 i.e. 1,260 Hz. The 5th line from the left in the spectrum of the ancient instrument's musical note is its 9th harmonic, so its fundamental frequency is equal to 1,260 Hz divided by 9 i.e. 140 Hz. The 11th line from the left in the spectrum of the ancient instrument's musical note is its 21st harmonic, so the frequency of this 21st line is equal to 140 Hz times 21 i.e. 2,940 Hz.

21. The spectrum of a newly invented instrument shows all its harmonics (even and odd) present up to its 18th harmonic. A closed pipe vibrating at its fundamental frequency has a spectrum showing all its harmonics up to the 19th harmonic. The frequency of the 8th line from the left in the spectrum of the closed pipe's note is the same as the frequency of the 9th line from the left in the spectrum of the new instrument's note. If the fundamental frequency of the closed pipe is 180 Hz, calculate the frequency of the 13th line from the left in the spectrum of the new instrument's note. (Assume that the frequencies in each spectrum increase from left to right.)

(a) 2,080 Hz.

(b) 2,700 Hz.

(c) 3,900 Hz.

(d) None of the above.

Answer: (c) Since the closed pipe has a fundamental frequency of 180 Hz, the frequency of the 8th line in its spectrum which is its 15th harmonic is given by 180 Hz times 15 i.e. 2,700 Hz. The 9th line from the left in the spectrum of the new instrument's note is its 9th harmonic, so the fundamental frequency of the note is equal to 2,700 Hz divided by 9 i.e. 300 Hz. Since the 13th line from the left in the spectrum of the new instrument's note is its 13th harmonic, its frequency is given by 300 Hz times 13 i.e. 3,900 Hz.

22. An open pipe and a string labelled P have the same fundamental frequency. A string labelled Q has a length 80% that of P. When Q vibrates with five nodes (not counting the nodes at both ends), the wavelength of the sound wave it generates in the air is exactly 0.55 metres. Calculate the frequency produced by the open pipe when it vibrates with 4 antinodes (not counting the antinodes at both ends). (Assume that P and Q are similar strings and the velocity of sound in air is 330 m/s.)

    (a) 400 Hz.

    (b) 500 Hz.

    (c) 625 Hz

    (d) None of the above.

    Answer: (a) The sound wave produced by Q will have a frequency given by 330 m/s divided by 0.55 m i.e. 600 Hz. Since Q is vibrating with five nodes it is at its sixth harmonic, and its fundamental frequency is equal to 600 Hz divided by 6 i.e. 100 Hz. Therefore the fundamental frequency of P is equal to 100 multiplied by 0.8/1 i.e. 80 Hz. Since the open pipe is vibrating with 4 antinodes or 5 nodes, it will be at its 5th harmonic which is equal to 5 times 80 Hz i.e. 400 Hz.

23. An open pipe D vibrating with 6 nodes has the same frequency as that of a closed pipe E which is also vibrating with 6 nodes (not counting the node at one end). E is then cut into ten short open pipes and one short closed pipe all of equal lengths, and five of these short open pipes are joined up with the short closed pipe to make a closed pipe labelled F. F is then cut into one open pipe F1 and one closed pipe F2 of the same lengths. If the fundamental frequency of D is 260 Hz, calculate the frequency of F1 when it vibrates with 3 antinodes between its two ends (not counting the antinodes at both ends).

    (a) 1,760 Hz.

    (b) 2,640 Hz.

    (c) 3,520 Hz.

    (d) None of the above.

    Answer: (c) Since the open pipe D has 6 nodes, it must be at its 6th harmonic and its frequency is equal to 260 Hz times 6 i.e. 1,560 Hz. E also has 6 nodes so it is at its 13th harmonic. Therefore its fundamental frequency is equal to 1,560 Hz divided by 13 i.e. 120 Hz. Since F is sixth-elevenths the length of E, its fundamental frequency is given by 120 Hz times 11/6 i.e. 220 Hz. F2 is half the length of F and its fundamental frequency is given by 220 Hz times 2 i.e. 440 Hz. F1's fundamental frequency is doubled that of F2 or 440 times 2 i.e. 880 Hz. When F1 vibrates with 3 antinodes or 4 nodes, it will be its 4th harmonic and its frequency will be equal to 880 Hz times 4 i.e. 3,520 Hz.

24. A closed pipe labelled X is sliced into 7 short open pipes and one short closed pipe all of equal lengths. Five of these short open pipes are joined up to make an open pipe labelled Y. If Y vibrates at a fundamental frequency of 240 Hz, calculate the wavelength of the sound wave in air produced by X when it vibrates with 3 nodes. (Assume that the velocity of sound in air is 330 m/s.)

    (a) 57.3 cm.
    (b) 62.9 cm.
    (c) 88.0 cm.
    (d) None of the above.

    Answer: (b)The fundamental frequency of a closed pipe the same size as Y is given by 240 Hz divided by 2 i.e. 120 Hz. The closed pipe X thus has a fundamental frequency equal to 120 Hz multiplied by 5/8 i.e. 75 Hz. When X vibrates with 3 nodes, it is at its 7th harmonic and its frequency is equal to 75 Hz times 7 i.e. 525 Hz. The wavelength of this sound wave in air is thus 330 m/s divided by 525 Hz i.e. 62.9 cm.

25. Arrange the following harmonics in order of increasing frequency:
    (i) The fifth harmonic frequency of an open pipe A of length d cm.
    (ii) The twelfth harmonic frequency of an open pipe B of length $\frac{7d}{3}$ cm.
    (iii) The seventh harmonic frequency of a closed pipe C of length $\frac{3d}{5}$ cm.
    (iv) The third harmonic frequency of a closed pipe D of length $\frac{2d}{7}$ cm.

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

    Answer: (a) If we let f Hz be the fundamental frequency of the open pipe A of length d cm, the fifth harmonic frequency of A is equal to $5f$ Hz. The open pipe B of length $\frac{7d}{3}$ cm has a fundamental frequency equal to f Hz times $\frac{3d}{7d}$ i.e. $\frac{3f}{7}$ Hz. The twelfth harmonic frequency of B is therefore given by $\frac{3f}{7}$ Hz times 12 i.e. $\frac{36f}{7}$ Hz. An open pipe whose length is $\frac{3d}{5}$ cm will have a fundamental frequency equal to f Hz times $\frac{5d}{3d}$ i.e. $\frac{5f}{3}$ Hz, and thus the closed pipe C which has the same length of $\frac{3d}{5}$ cm will have a fundamental frequency half of $\frac{5f}{3}$ Hz i.e. $\frac{5f}{6}$ Hz. The seventh harmonic frequency of C is thus given by $\frac{5f}{6}$ Hz times 7 i.e. $\frac{35f}{6}$ Hz. The closed pipe D of length $\frac{2d}{7}$ cm has a fundamental frequency equal to $\frac{5f}{6}$ Hz times $\frac{3d}{5}$ divided by $\frac{2d}{7}$ i.e. $\frac{7f}{4}$ Hz. Therefore the frequency of the third harmonic of D is equal to $\frac{7f}{4}$ Hz times 3 i.e. $\frac{21f}{4}$ Hz. Hence the harmonics in order of increasing frequency are (i), (ii), (iv) and (iii).

END OF TEST PAPER