Sounds of Music C

BirdSO

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Directions:

- You will have about 50 minutes.
- A graphing calculator, a binder (digital or physical), writing utensils, and your brain are permitted.
- Assume conditions are 1 atm and 20°C unless otherwise specified; that is, that the speed of sound is 343 m/s. Also, assume that reverberations are negligible unless otherwise specified.
- For calculations, use a reasonable number of significant figures. Often, the precision will be specified.
- You may use any third-party application, such as Discord or Zoom, to communicate with your partners. Voice/video call is permitted.
- Unless otherwise specified, do NOT include units on short answer calculations.

Contents

Constants

Please use the following constants in the questions that call for calculations unless otherwise noted:

$$v = 343 \frac{m}{s}$$

$$R = 8.31 \frac{J}{\text{mol} \cdot \text{K}}$$

$$g = 10 \frac{m}{s^2}$$

$$\text{A4} = 440 \text{ Hz}$$

1 First Principles

1. (8 points) Myth has a string that has a density of $8.0\frac{kg}{m^3}$, a radius of $0.50mm$ and a length of $0.50m$. What tension does he need to apply to the string so that it plays with a fundamental frequency of 900 Hz?

   A. 1.3N B. 1.6N C. 2.3N D. 5.1N E. 5.4N

2. (6 points) Myth gets another string and plays it at its fundamental frequency. He notices that at a certain time, the equation $y = 0.050\sin(7.854x + 0.21)$ describes the vertical displacement at every point on the string. How long is his string? (3 sig figs)

3. (6 points) Samantha has a tube that she is planning on using to build a clarinet. If it has a diameter of 4.00cm and a length of 43.0cm, what is the fundamental frequency plays? Consider end corrections.

   A. 194 Hz B. 199 Hz C. 189 Hz D. 398 Hz E. 378 Hz F. 388 Hz

4. (9 points) Samantha visits Myth and plays her clarinet at 300 Hz. Myth notices that his string (with a fundamental frequency of 900 Hz) has started vibrating while she plays even though his string has a different fundamental frequency! Explain why this is happening with as much detail as possible. Would this happen if Myth's string had a fundamental frequency of 600 Hz?

5. (5 points) Myth likes flutes more than clarinets, so he asks Samantha to open the closed end of her clarinet. What is the fundamental frequency of her instrument now? Take end corrections into account.

   A. 194 Hz B. 199 Hz C. 189 Hz D. 398 Hz E. 378 Hz F. 388 Hz

6. (11 points) Jimmy is once again on the run from police. After stealing the secret plans for government spy drones, he races away on his car at a speed of 33 m/s. He can hear police sirens at a frequency of 3300 Hz, but he knows that Birdland's police sirens are supposed to have a frequency of 3000 Hz. How fast are the police cars traveling towards him? Assume Jimmy and the police are both traveling at constant speeds.

7. (17 points) Jimmy realizes that he isn't going to get away on his car, so he steals a supersonic jet. While at a competition, Mira notices him flying above at an altitude 500 km. If Mira hears a supersonic boom 0.56s later, how fast is Jimmy flying the jet? Assume Jimmy is flying at a constant speed. (Assume Mira's height is negligible.) Use 3 sig figs.

8. (7 points) After a long day of doing SciOly, Mira goes to listen to his favorite songs. Unfortunately, his speakers are broken and can only play music at 125 dB when he stands 1.00m away. He knows that noise above 120. dB can cause damage to ears. How far should he stand from his speaker so his ears stay safe?

   A. 1.04 m B. 1.02 m C. 2.16 m D. 1.78 m E. 5.00 m F. 2.24 m

9. (5 points) Mira ties 2 different strings together. The first has a linear mass density of 10. g/cm while the second has a linear mass density of 20. g/cm. He ties the loose end of the second rope to a pole and grabs the loose end of the first string. He starts shaking it up and down at a frequency of 20. Hz (his wrist is very fast). What will be the frequency the second string vibrates at?

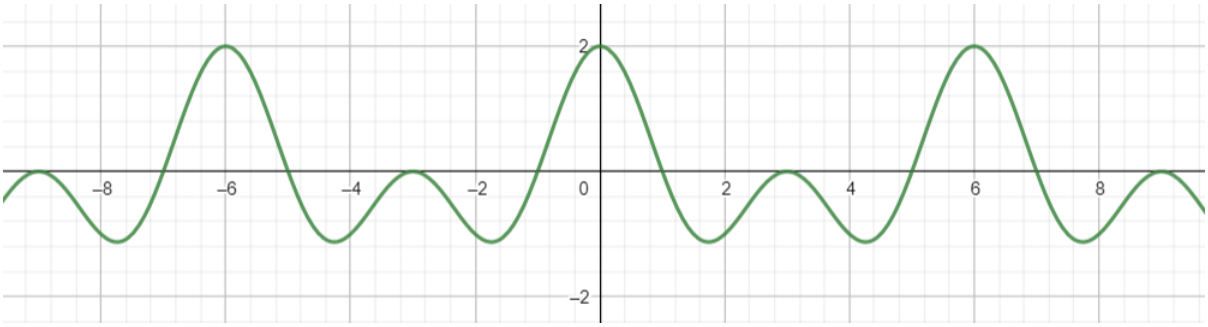
   A. 5.0Hz B. 10.Hz C. 14Hz D. 20.Hz E. 28Hz F. 40.Hz

10. (7 points) Timmy is playing around with his drone on a cold morning. He notices that the air temperature near the ground is $5.0°C$ while the air temperature higher up is $25°C$. Suddenly he hears his friend Tummy, who is standing very far away, saying hi to him. Explain why Timmy is able to clearly hear Tummy.

11. (22 points) Timmy and Tummy meet up with their speakers. It is still a little cold, so the speed of sound is 342 m/s. They stand 3.75 m apart and start playing a sound of 114 Hz. Veronica walks between the two of them. What is the closest distance to Timmy where she will hear maximum constructive interference? What is the closest she can stand to Timmy to hear complete silence? Use 3 decimal points.

12. (6 points) Assuming that it could still work as an instrument, find the length of a closed pipe that is the highest frequency a human can hear. Use 7 decimal points. Show your work.

Questions 13 to 16 refer to the graph below, which is the graph of $f(x) = \cos(a\pi x) + \cos(b\pi x)$, where a and b are constants less than 2 and $a < b$.



13. (4 points) What is the wavelength of f?
14. (6 points) The waves $\cos(a\pi x)$ and $\cos(b\pi x)$ constructively interfere when x is a multiple of k, a positive integer. Compute k.
15. (12 points) Compute a and b.
16. (9 points) The angular wavenumber of f can be written in the form π/k, where k is a positive integer. Compute k.

1.a An Exploration in Tensity

17. (7 points) Suppose you stand 3.0 m away from a point source emitting a sound with power 5.0 W. Compute the intensity of sound you hear.
18. (9 points) In a strange alternate universe, instead of emitting in spheres, sound emits in cubes. Compute the intensity of sound you would hear in this alternate universe for the above scenario.
19. (13 points) Flat-Vincent is standing on a plane in a 2-D universe, and he is confused about where he is. Is he in a 2-D world? Or is the 2-D world in him? He screams, for he does not know. His scream can be abstracted as a point source, emitting a sound with power 5.0 W. If you are standing 12 meters away from Flat-Vincent, compute the intensity, in decibels, of the sound that you hear.

It is well known that the derivative of the volume of a sphere, $\frac{4\pi r^3}{3}$, with respect to r, is equal to the surface area of the sphere, $4\pi r^2$. However, this principle also applies in n-spheres of any $n \in \mathbb{Z}_{>1}$. It turns out that the volume of a ball radius r in n-dimensional space is:

$$V_n(r) = \frac{\pi^{n/2}}{\Gamma\left(\frac{n}{2}+1\right)} r^n,$$

where $\Gamma(z) = (z-1)!$ if z is a positive integer.
Also, if z is a positive integer,

$$\Gamma\left(z+\frac{1}{2}\right) = \left(z-\frac{1}{2}\right)\cdot\left(z-\frac{3}{2}\right)\cdots\frac{1}{2}\cdot\pi^{1/2} = \frac{1\cdot 3\cdot 5\cdots(2z-1)}{2^z}\sqrt{\pi} = \frac{\prod_{i=1}^{z}(2i-1)}{2^z}\sqrt{\pi}.$$

20. (21 points) $\mathfrak{Hyper}$-Vincent stands in a hyperspace in a 5-D universe, and he is confused about where he is. Is he in a 5-D world? Or is the 5-D world in him? He screams, for he does not know. His scream can be abstracted as a point source, emitting a sound with power 8.5 W. If you are standing 0.6 meters away from $\mathfrak{Hyper}$-Vincent, compute the intensity, in decibels, of the sound that you hear.
21. (23 points) Like everyone else, you abhor $\mathfrak{Hyper}$-Vincent; thus, you would like to get as far away from this lazy son of a bird as you can. Using the threshold of human hearing, determine that shortest distance that you have to walk away from $\mathfrak{Hyper}$-Vincent in order to not listen to him scream.

2 Acoustic Architecture

22. (9 points) Ariel's room has dimensions 5.0m x 10.0m x 3.0m. She plays a sound of 120 dB in it. After 0.31 seconds, she notices that it has an intensity of 60 dB. What is the absorption coefficient of her room in Sabins?

23. (11 points) Ariel has large, high-quality speakers that she uses to play music in her room. Unfortunately, whenever she is listening to music, she notices that she only seems to hears a few bass frequencies louder and ring longer than others no matter what she plays! What is the cause of this, and what can she do to fix it?

24. (7 points) Ms. Breeze visits a new concert hall where all the surfaces reflect sound nearly perfectly. The designer explains that this means no sound energy will be lost to absorption, so the audience will be able to hear the music more. Is this a good idea? Why or why not?

25. (14 points) One day, Ms. Breeze (who is careful to avoid loud sounds so she does not develop hearing loss) wins a front seat row to an orchestra. Afterwards, she meets with her friend Jennifer (who has healthy ears as well), who sat in the back row. (It is a big concert hall.) Jennifer complains that the flutes and clarinets completely overpowered the low brass, but Ms. Breeze thought that the balance was fine. If the woodwinds and low brass were roughly the same distance from Jennifer, why did Jennifer hear the woodwinds more? What is a design choice that could be made to remedy this?

26. (7 points) Jiayou is going to watch a large parade with a marching band travel through the streets of UC Birdkeley to celebrate the end of the school year. However, since the crowds are so large, he is stuck behind a large building and cannot even see the band. (The crowd is perfectly silent, for some reason.) He can hear the low brass pretty clearly, but not the flutes. What is mainly responsible for this?

    A. refraction B. diffraction C. reflection D. Doppler effect E. None of the above

27. (9 points) Why do recording spaces have foam on the walls? How does this improve the quality of the recordings produced?

28. (12 points) Explain why people on podcasts often have microphones right against their faces with a pop filter.

3 Bioacoustics (including a bit on birds!)

29. (4 points) The length of the mouth to the vocal cord is roughly 17.0 centimeters. Assuming it forms a perfect cylinder with a closed end, what is the fundamental frequency of the vocal tract?

30. (10 points) Is a cylindrical air column a good representation for how humans make sound? Why or why not? (Hint: The range of human speaking usually is around 150-300 Hz)

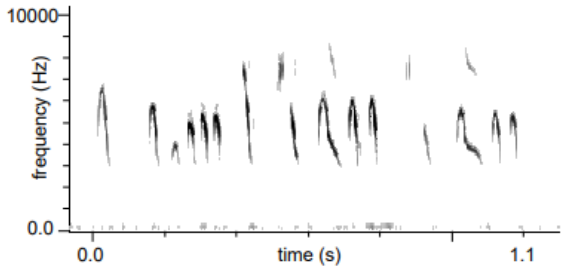
31. (12 points) Many birds are capable of mimicking human voices. However, there are certain human sounds they are unable to make. Give 3 examples and explain why birds cannot make these sounds. Hint: Birds have a rigid beak while humans don't!

32. (9 points) What is a vowel? Refer to how a vowel sound is produced compared to a consonant.

33. (8 points) Distinguish between a voiced consonant and unvoiced consonant.

34. (11 points) How is it possible that a solo singer can be heard over an entire orchestra?

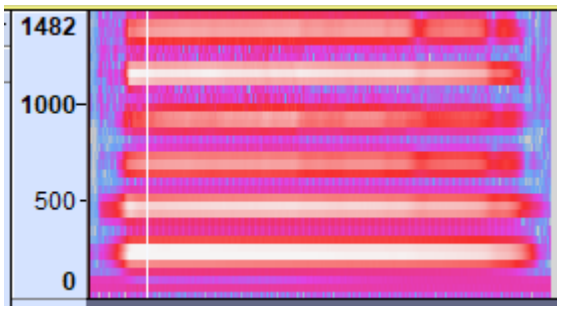
35. (13 points) Bird songs are typically structured into syllables and phrases. A syllable is typically a short block of sound that is repeated throughout a song. Shown below is a graph over time of a bird song.



Explain why each syllable appears to span a wide range of frequencies.

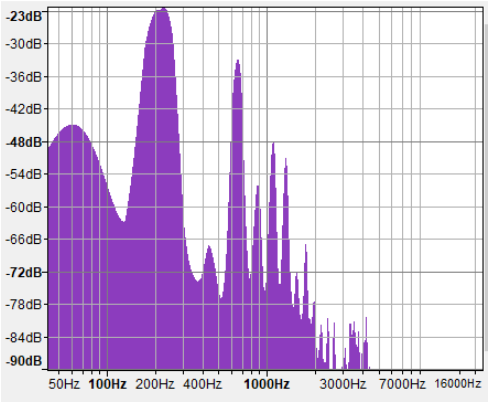
4 Digital Sound Engineering

Questions 36 to 38 refer to the image below, which is a spectrogram of a note Klebb played:



36. (6 points) Approximately what frequency is being played here? Any answer within about 5% will be accepted.
37. (7 points) Klebb is a woodwind player, and he plays both clarinet and saxophone. Which instrument did he play in this recording? How do you know?
38. (14 points) Klebb runs a high-pass filter on the note with maximum frequency 300 Hz and a 48 dB drop-off per octave. When he plays the note back, he still hears the original note! What phenomenon is this, and why does it occur?

Klebb now plays another note. The spectrum analysis is shown below:



39. (7 points) Is Klebb playing on his clarinet or saxophone? How do you know?
40. (6 points) What note is Klebb playing here?

4.a Colorful Sounds

41. (8 points) You might know that pink noise decreases logarithmically, meaning that bands that are proportionately wide have equal power. The intervals 20 Hz to 50 Hz and 900 Hz to x Hz have equal power. What is x?
42. (9 points) By how many decibels does the power of pink noise decrease over the frequency interval from 30 Hz to 71 Hz?
43. (18 points) Klebb, being a clarinetist, decides to play "Rhapsody in Blue," but he accidentally plays "Rhapsody in Blue Noise" instead. "Rhapsody in Blue" famously has a glissando from F3 to Bb5 in the opening solo. By how many decibels does the power density of the blue noise change over that interval? Be sure to note if this is an increase or decrease.
44. (11 points) Grey noise's spectrum follows an equal loudness curve. Which of the following would be closest to the shape of the spectrum of grey noise?

    A. Line with positive slope B. Horizontal line C. Absolute value function D. Parabola

5 Instruments

45. (9 points) 2 birds, a chickadee and a goldfinch, are watching a trumpet player practice from the window. The chickadee says that the bell is completely unnecessary since trumpets are already loud enough. The goldfinch disagrees and says that the bell does more than just project sound. What is something else (besides projecting sound) the bell contributes to the trumpet's sound?

46. (7 points) A metal bar that is 24 cm long plays a 300. Hz pitch when hit. What pitch will a metal bar that is 48 cm long play when hit?

    A. 150. Hz B. 387 Hz C. 424 Hz D. 539 Hz E. 600. Hz F. 622 Hz

47. (8 points) You have a Helmholtz resonator. If you kept everything else the same and increased one thing, which of the following would increase the fundamental frequency of the resonator? Select all that apply.

    ◯ Neck length ◯ Neck cross-sectional area ◯ Volume ◯ Temperature ◯ Air density

48. (5 points) Which of the following are membranophones?

    ◯ Timpani ◯ Snare Drum ◯ Oboe ◯ Kazoo ◯ Didgeridoo ◯ Piano

49. (5 points) Which of the following are chordophones?

    ◯ Timpani ◯ Violin ◯ Xiao ◯ Guitar ◯ Piano ◯ Organ

50. (5 points) Which of the following are aerophones?

    ◯ Snare Drum ◯ Oboe ◯ Xiao ◯ Kazoo ◯ Didgeridoo ◯ Organ

51. (7 points) You have a weird saxophone that has an air column 0.24m long. What is its fundamental frequency?

52. (6 points) The frequency of the saxophone's first overtone is how many times higher than its fundamental?

53. (11 points) Explain why a flugelhorn generally sounds darker than a cornet, and why both sound darker than a trumpet.

54. (13 points) It is well known that French Horn is about the same length as a trombone. Why is it that the French Horn has about an octave and a half more range?

Allen decides to design a new tuning system which uses the same method of deriving intervals as Pythagorean tuning, but instead of having perfect fifths have ratio $3/2$, he uses the ratio $11/7$.

55. (10 points) What is the frequency ratio of a major third up under this new tuning system?

56. (12 points) What is the frequency ratio of a major second up under this new tuning system?

57. (11 points) Using 29-tone equal temperament, define a pace to mean 1/29th of an octave. How many paces gives a frequency ratio closest to a 12-tone equal tempered perfect fourth?

58. (11 points) Why does blowing too hard on a single reed instrument lead to no sound being produced?

59. (8 points) Consider a flute that is 2.6 m long. How far from the end must a hole be drilled so that uncovering that hole raises the pitch the flute plays by an octave?

60. (12 points) Why do plucked strings sound louder on a guitar as compared to without the guitar's body?

5.a Building an Instrument!

We are not running the build portion for Sounds of Music, so let's draft up a potential instrument you could build.

For your reference, the requirements for the instrument are included below.

1. Constructed from any materials except:
   electronic components, toys, professional instruments (besides strings)
2. Must play an ascending major scale starting between F2 and F3 with an octave jump after the fourth note
3. Must be able to play "Twinkle Twinkle Little Star"
4. Energy to to produce pitches must not be stored and must be provided by participants; participants cannot sing or hum into instrument
5. Device must fit within a 60.0 cm x 60.0 cm x 100.0 cm box

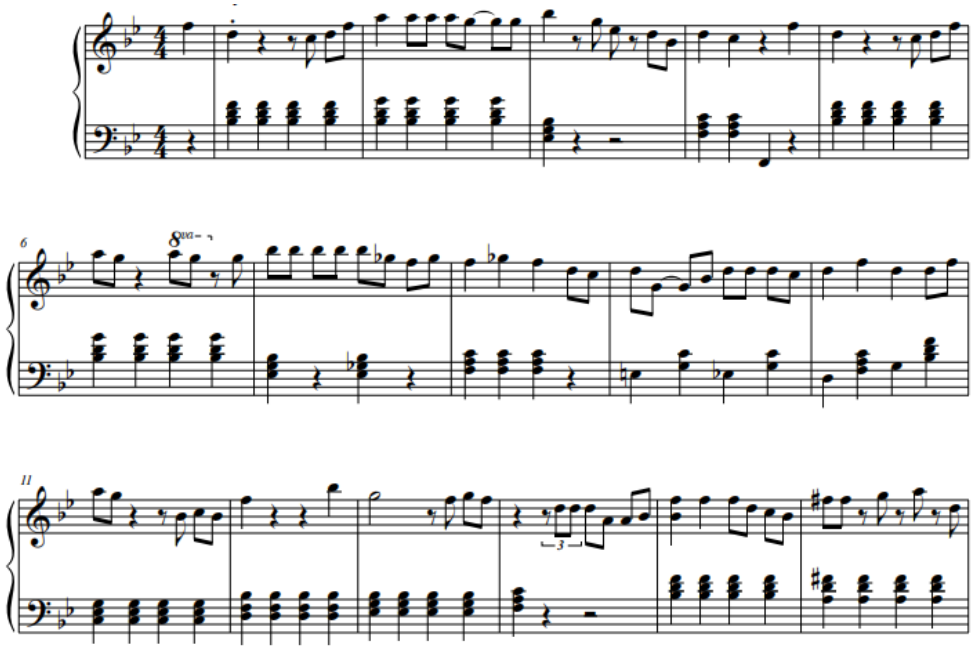
Suppose you wish to design a chordophone.

61. (7 points) Write a short description of how your instrument will function.
62. (9 points) Describe at least one method you could use to change pitches on your instrument.
63. (7 points) Describe how your instrument could cross the octave gap during the scale.
64. (11 points) Recall that the Bonus Pitch must be at least one octave lower than the lowest pitch of the scale or one octave higher than the highest pitch of the scale. Describe how your instrument could attain the bonus pitch.

6 Music Theory (Non-Aural)

6.a piano coffee

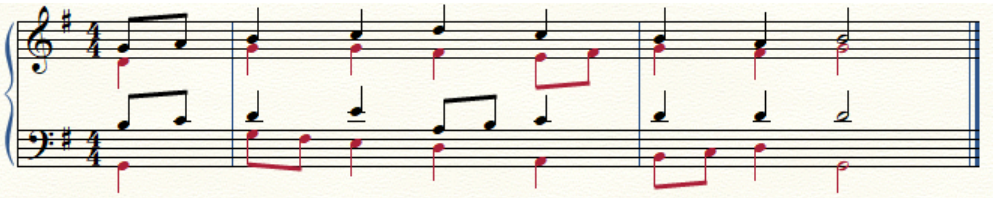
Questions 65 to 69 refer to the following excerpt taken from Lilypichu's "piano coffee." The piece is at about $\text{♩} = 120$ and eighths are swung.



65. (7 points) What does it mean that the eighth notes are swung?
66. (6 points) Identify the key with both a note name and quality.
67. (9 points) Identify the kind of musical texture exhibited in this piece. Explain how you arrived at your answer.
68. (12 points) Analyze the chords for the first 4 measures using Roman Numerals. Do not include inversions.
69. (9 points) Identify the kind of cadence found in measures 14-15.

6.b Allein Gott in der Höh sei Ehr

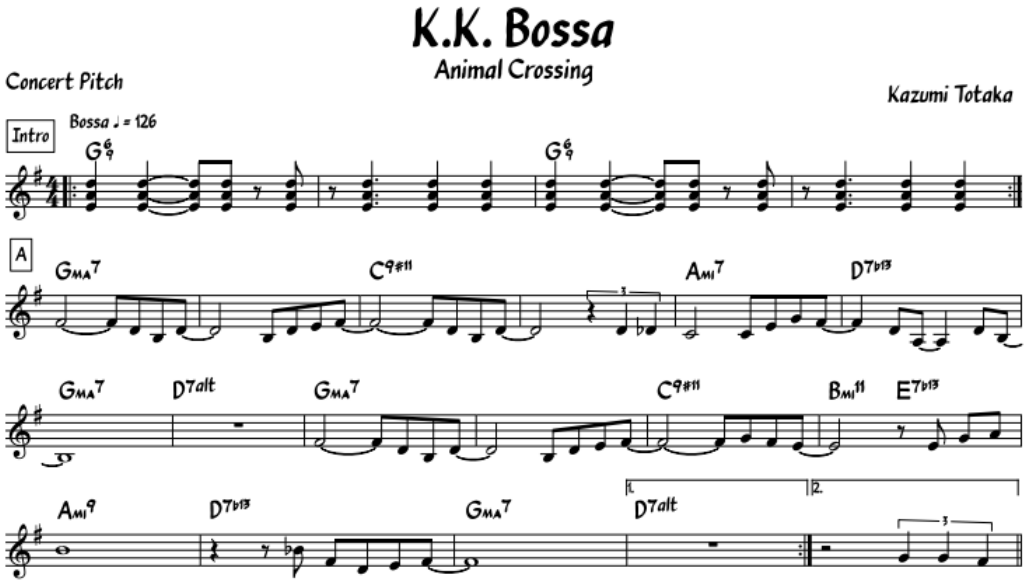
Questions 70 to 76 refer to the following excerpt from one of Bach's voicings of the hymn "Allein Gott in der Höh sei Ehr", which translates to "Alone to God in the Highest Be Glory."



70. (6 points) Identify the key with both a note name and quality.
71. (9 points) What kind of cadence is present in the last two chords?
72. (7 points) What kind of contrapuntal motion is exhibited by the soprano and alto in the last 3 chords?
73. (7 points) What kind of contrapuntal motion is exhibited by the soprano and tenor in the last 3 chords?
74. (7 points) What kind of contrapuntal motion is exhibited by the soprano and bass in beats 1 to 3 of measure 2?
75. (16 points) Analyze the chords for the chorale using Roman Numerals, including inversions.
76. (12 points) Write the melody in the soprano part using moveable "do" solfege.

6.c K.K. Bossa

For questions 77 to 80, refer to the following lead sheet of K.K. Bossa, a tune from the *Animal Crossing* series.



77. (11 points) Bossa has many of its roots in samba, a related form of Latin jazz. It is often described as "swaying." Especially using the Intro section, identify rhythmic elements of the music that create this "swaying" feeling.
78. (8 points) Identify the notes in the melody in the first 8 measures of A that are non-harmonic. Explain each note's purpose.
79. (10 points) Spell out the notes of the `D7alt` chord. What is its purpose in the piece?
80. (12 points) Starting at the 9th measure of A (the `GMA7` after the `D7alt`) analyze the chords until the final `GMA7` before the first ending. Use a combination of Roman Numerals/chord symbols and words to explain the relationships between the chords.

7 Music Theory (Aural)

7.a Family

Questions 81 to 86 refer to the audio here. It is the track "Family", from Assassin's Creed Syndicate. The first note is a G5, the time signature is 4/4, and the tempo is about ♩ = 62.

81. (8 points) Identify the two instruments involved playing melody and countermelody in the duet at the beginning.
82. (9 points) Identify at least 3 instruments present in the final chord, after the melody fades away.
83. (11 points) Notice that, starting at about 0:29, the vocalist sings a repeated pattern underneath the melody. What is this an example of? Why?
84. (8 points) Identify the notes the vocalist sings repeatedly every two measures.
85. (10 points) At around 0:51, a second vocal voice joins in parallel to the earlier one. What does it mean that they move in parallel, and what interval separates the two voices?
86. (6 points) What key is this piece in?

7.b Golden Battle

Questions 87 to 94 refer to the audio here, which is an excerpt from Carlos Eiene's latest composition, "Golden Battle." The piece's meter is 12/8, and the tempo is about ♩. = 136. The melody, which comes in after a few seconds, begins with F# E A G F#.

87. (11 points) Notice the ornaments that Carlos adds in during the recording: grace notes, slides, etc. None of these are written into the part, which only has the simpler general melody. Explain how this is an example of ad lib.
88. (9 points) One of the key musical elements that Carlos employs in his melodies here is sequences. The excerpt contains three main sections in a kind of verse (beginning to 0:32), pre-chorus (0:32 to 0:47), chorus (0:47 to end) structure. Identify an example of sequences in each of the three sections; include a time-stamp and a brief description of the part you are referring to.
89. (7 points) Explain how the "verse" section employs an antecedent-consequent structure in its phrasing.
90. (6 points) Identify the two melodic instruments in the excerpt.
91. (13 points) In the measure at 0:28 (it begins with a snare hit with the other instruments dropping out), identify the five block chords the piano plays.
92. (7 points) What is the piano playing during the "pre-chorus" section, taking the underlying chords and playing them note by note?
93. (8 points) In the fourth measure of the "chorus" section (about 0:53), what is the bass line? Identify the four notes in that measure and the first note of the measure after.
94. (10 points) What chords are played on top of this bass line? In which inversion is each chord?

8 Bonus - Name That Tune!

You will receive 2 bonus points for each piece you name correctly. Only the title is necessary, though including the composer(s)/artist(s) would be preferred. Each of the pieces is bird-related in some way. You will receive an extra 2 points for a quick explanation as to how the piece is related to birds.

95. (4 points) Audio 1
96. (4 points) Audio 2
97. (4 points) Audio 3
98. (4 points) Audio 4
99. (4 points) Audio 5

9 Tiebreaker

100. Estimate the highest frequency that Klebb can hear in Hz.