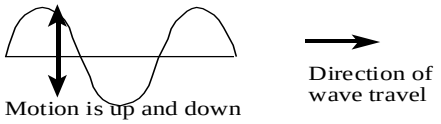
Sounds of Music

Definitions
1 Hz = 1 hertz = 1 cycle/second
wave speed c (or v) = $f\,\lambda$
$f = (k/m)^{1/2} / 2\pi$

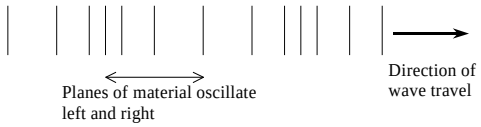
A calculator is not permitted and is not required. Any numerical answers may require multiplying or dividing by small whole numbers, or a comparison with such results. Many questions may be answered by considering your experience in building, tuning, and playing your instrument.

Some of the questions below ask about the nature of the vibrations in an instrument. Use the following definitions for important terms:

A. Transverse waves- the oscillating motions are in a direction perpendicular to the direction the wave travels.



B. Longitudinal waves - the oscillating motions are in the direction parallel to the direction the wave travels.



C. Bending waves - a combination of transverse and longitudinal motions, found in solid materials that have stiffness to bending.

This is a sample test for the Science Olympiad Sounds of Music event. It was used in 2002 at the Ohio state competition at the Ohio State University. There are many other questions that might be asked, of course. This test has a few questions on aspects of simple harmony. Its emphasis, however, is on the physics of natural frequencies of vibrating systems, as they might be found in musical instruments, and how those frequencies can be changed by the instrument maker. Most of these questions can be answered by observing carefully during the process of building the instrument.

If you are a coach or judge responsible for a Sounds of Music event, you are welcome to take ideas from this sample. Please contact me so that I can be aware of where these questions are being used, and so that we can share ideas.

If you are a student participant, I encourage you to find a way to figure out the answers BEFORE consulting the answer key on the back page. That will give you a more robust understanding and help you at your competition, and of course is the very process of science!

If you have any questions, please feel free to contact me.
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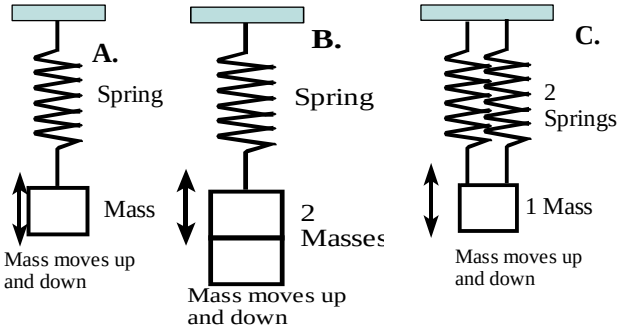
Theory, Part 1

Suppose you had a box full of identical springs and identical masses. If one spring is hung from a support at its top end, and a mass hung on its bottom end, then set in motion, the mass will move up and down, as in Figure A. Suppose its motion is observed to produce 8 cycles up and down in 10 seconds.

1. What is the frequency of this spring-mass oscillator?
   a) 0.8 Hz
   b) 1.25 Hz
   c) 8 Hz
   d) 80 Hz



2. Figure B shows two masses together attached to the bottom of one spring. Figure C shows two springs acting side-by-side on one mass. B and C are also moving up and down. Of A, B, and C, which will have the greatest number of cycles per second?
   a) A b) B c) C d) All the same.

3. Of A, B, and C, which will have the least number of cycles per second?
   a) A b) B c) C d) All the same.

4. If the note C_4 has the frequency about 250 Hz, what frequency will the note C_3 an octave lower have?
   a) 125 Hz b) 133 Hz c) 375 Hz d) 500 Hz

5. If the note C_4 has the frequency about 250 Hz, what frequency will the note G_4 a perfect fifth higher have?
   a) 125 Hz b) 133 Hz c) 375 Hz d) 500 Hz

6. A harmonic series is any series of numbers that have the relation 1:2:3:4:5, and so on. It occurs often in music, as the natural frequencies (playable notes) that can be played on a valveless bugle or on a single unstopped string, as the component sounds present in a musical tone, and as the foundation for harmony. If the note C_2 is the first member (fundamental) of a harmonic series of frequencies, the first five members of the harmonic series have what note names?
   a) C_2, D_2, E_2, F_2, G_2
   b) C_2, E_2, G_2, C_3, E_3
   c) C_2, C_3, G_3, C_4, E_4
   d) C_2, C_3, C_4, C_5, C_6

7. Two performers are playing the same note at the same time, but slightly out of tune, so that beats are heard in the sound. If the frequencies are 440 Hz and 446 Hz, how many beats are heard each second?
   a) 443 beats / sec
   b) 12 beats / sec
   c) 6 beats / sec
   d) 3 beats / sec

8. How many steps in a C major scale, for example, from C4 up to C5?
   a) 2 b) 5 c) 7 d) 12

9. How many semitones in a chromatic scale from C4 to C5?
   a) 2 b) 5 c) 7 d) 12

The group should answer the questions for two of the following instrument types. In most cases, these will correspond to the two instruments you brought. However, you may answer the questions for an instrument that you didn't bring, if you prefer, or if both your instruments are the same type. Indicate below which two instrument types you wish to have graded.

String instrument
(One or more long, thin strings or wires, stretched tight and secured at both ends; possibly attached to a resonator.)

Which of your instruments is of this type?_____

Strings can be played by either bowing or striking, or something like one of these. How do you play your instrument (Choose one only) Bow Strike (or pluck)

Wind instrument
(a long, thin tube which makes a sound when blown; often has holes in the side.)

Which of your instruments is of this type?_____

10. How do you create higher-pitched notes on your instrument, as you play up the scale?

String instruments (A,B)	Wind instruments (C,D)	Melodic Percussion (E,F)	Water-filled (G,H)
a) Make the string shorter. b) Increase the string tension. c) Use a thicker string of the same type. d) Play louder.	a) Use hotter air b) Make the tube shorter. c) Use larger diameter tube. d) Play softer.	a) Use thicker material b) Hit harder c) Make the bar or tube shorter d) Play softer.	a) Shorter vibrating length above water b) Smaller area loaded by water c) Use thinner container wall d) Play louder

11. Which of the following changes (while keeping other variables constant) would also raise the pitch of a note (different from the answer in Q.1)?

String instruments	Wind instruments		Melodic Percussion		Water-filled
(A,B)	C. w/tone holes	D. No holes	E. Free ends	F. Clamped	(G,H)
a) Making the string longer. b) Increasing the string tension. c) Using a thinner string of the same type. d) Playing softer	a) Make the tube longer. b) Make the first open hole larger. c) Using a larger diameter tube. d) Playing softer	a) Make the tube longer. b) Use warmer air c) Use larger diameter tube. d) Playing softer	a) Grind or file material at center (half-length) b) Grind or file material at an end (but don't change length) c) Play louder d) Use longer piece	a) Grind or file near clamped end. b) Grind or file at free end (but don't change length) c) Play louder d) Use longer piece	a) Shorter vibrating length above water b) Smaller area loaded by water c) Use thinner container wall d) Play louder

String instruments (A,B)	Wind instruments (C,D)	Melodic Percussion (E,F)	Water-filled (G,H)
12. If a (string, tube, bar) of length 70 cm plays a note of frequency 250 Hz, what should be the length of a (string, tube,bar) of the same type in order to play a note of frequency 500 Hz? (Note that answers will depend on instrument type!)			12. If a container were found of the same shape and size but thicker walls, and with the same amount of water, how would its pitch compare to the original?
(Note: both strings under same tension, etc.) a) 35 cm b) 50 cm c) 100 cm d) 140 cm	a) 35 cm b) 50 cm c) 100 cm d) 140 cm	a) 35 cm b) 50 cm c) 100 cm d) 140 cm	a) higher pitch b) same pitch c) lower pitch d) no way to tell

13. The best description of the sound waves in the primary vibrating section of the instrument is…

String instruments (A,B)	Wind instruments (C,D)	Melodic Percussion (E,F)	Water-filled (G,H)
(in the string) a) Transverse b) Longitudinal c) Bending d) None of the above	(in the air in the tube) a) Transverse b) Longitudinal c) Bending d) None of the above	(in the material of the bar) a) Transverse b) Longitudinal c) Bending d) None of the above	(in the walls of the container) a) Transverse b) Longitudinal c) Bending d) None of the above

14. Pick the best explanation below for what happens to the energy you supply as you play a single note on the instrument.

a) Energy supplied once by player to instrument, then gradually decays from instrument as sound is radiated.
b) Energy supplied continuously by player to instrument, to make up for radiation from instrument; this keeps energy in instrument approximately constant.
c) Energy supplied once by player; energy in instrument stays constant as sound is radiated.
d) Energy supplied continuously by player to instrument; energy in instrument increases as sound is radiated.

String instruments (A,B)	Wind instruments (C,D)	Melodic Percussion (E,F)	Water-filled (G,H)
a) b) c) d)	a) b) c) d)	a) b) c) d)	a) b) c) d)

KEY to Sounds of Music written test, given at the Ohio state competition, 2002.

1. a
2. c
3. b
4. a
5. c
6. c
7. c
8. c
9. d

The next questions are designed to be adapted to the type of instrument, and therefore the answers vary.

String instrument, bowed:

10. a
11. b, c
12. d
13. a
14. b

String instrument, plucked:

10. a
11. b, c
12. d
13. a
14. a

Wind instrument w/ tone holes (finger holes)

10. b
11. b
12. d
13. b
14. b

Wind instrument with no side holes

10. b
11. b
12. d
13. b
14. b

Melodic percussion with two free ends

10. c
11. b
12. c
13. c
14. a

.

Melodic percussion with one end clamped

10. c
11. b
12. c
13. c
14. a

Water filled

10. a OR b, depending on shape
11. c
12. c
13. c
14. a, unless being rubbed continuously, as with a finger on the rim