**PHYSICS 102 - PHYSICS OF MUSIC**
**Dr. Richard E. Berg**
FINAL EXAM – May 15, 2004

# INSTRUCTIONS

**When you get this:**

1. **Do not turn this page and look at the questions until you are so instructed.**

2. **Put your name and student number on the answer sheet, *letters and dots*.**

3. **Wait to start the test until you are so instructed.**

4. **You will have until 10:15 to finish your test, should you need that amount of time.**

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Before beginning the test please enter your name, last name first (both in letters and by blackening the letters in the columns under the name line) and your social security number (enter the numbers without hyphenation, leaving line J blank, both writing the numbers and blackening the numbers in the columns under the identification number line).

Each question is on a line numbered from 1 through 100. You are to answer each question either in the affirmative (Yes, True) or in the negative (No, False) by blackening either response A/1 for affirmative or response B/2 for negative. Leaving an answer blank or blackening responses C/3, D/4, or E/5 are not correct answers. Your score is the number of correct answers, so guessing may help.

Fruits used in grandma's old-fashioned apple-raisin pie include:
(1) apples.
(2) passion fruit.
(3) sugar.

Examples of periodic motion include:
(4) a pendulum swinging to and fro.
(5) a super ball bouncing without losing energy.
(6) swinging a rock around your head on a string.
(7) a mass bouncing up and down on a spring.
(8) a note played on a recorder.
(9) the tone produced by blowing across the neck of a Helmholtz resonator.
(10) the planet Venus revolving around the Sun.
(11) a sine wave.

Examples of simple harmonic motion include:
(12) a pendulum swinging to and fro.
(13) a super ball bouncing without losing energy.
(14) the tone produced by blowing across the neck of a Helmholtz resonator.
(15) a mass bouncing up and down on a spring without losing energy.
(16) a satellite revolving around the earth.
(17) a sine wave.

Examples of damped simple harmonic motion include:
(18) the motion of a mass on a spring as its amplitude slowly decreases.
(19) the sound of a struck tuning bar becoming softer as time passes.
(20) the motion of a pendulum as its amplitude slowly decreases.
(21) the motion of a child on a swing after it is released and the motion decreases.
(22) a ball bouncing to less height with each bounce.

(23) A resonance requires both a system with a natural frequency and a periodic force with the same frequency.

Examples of resonance include:
(24) the flame tube demonstration.
(25) breaking a glass beaker using sound waves.
(26) pushing a child on a swing so as to increase the amplitude of the oscillation.
(27) a loudspeaker with a 40 Hz resonant frequency driven by a 500 Hz sine wave.
(28) a loudspeaker with a 40 Hz resonant frequency driven by a 40 Hz sine wave.

Which of the following periods and frequencies go together?
(29) 10 milliseconds, 100 Hertz.
(30) 50 milliseconds, 50 Hertz.
(31) 10 seconds, 0.1 Hertz.
(32) 50 microseconds, 20 kilohertz.

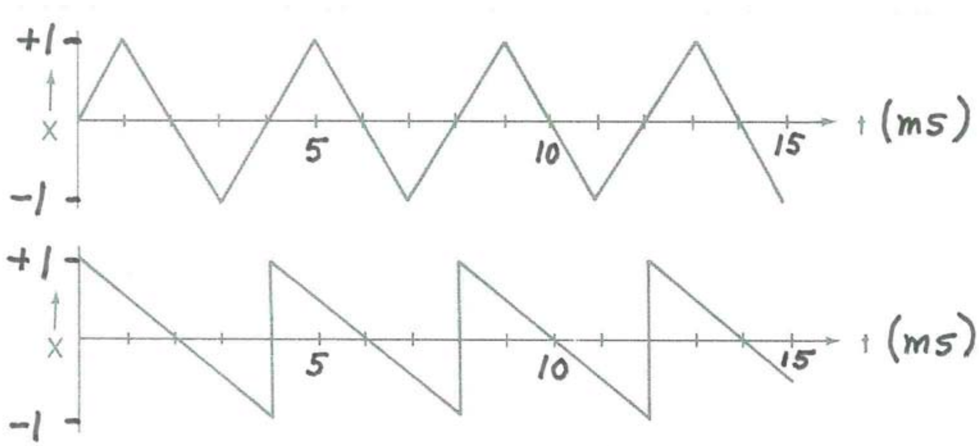
The "Flame Tube" shown in class demonstrates:
(33) standing waves.
(34) refraction.
(35) diffraction.

The "Sound Lens" shown in class demonstrates:
(36) interference.
(37) refraction.
(38) diffraction.

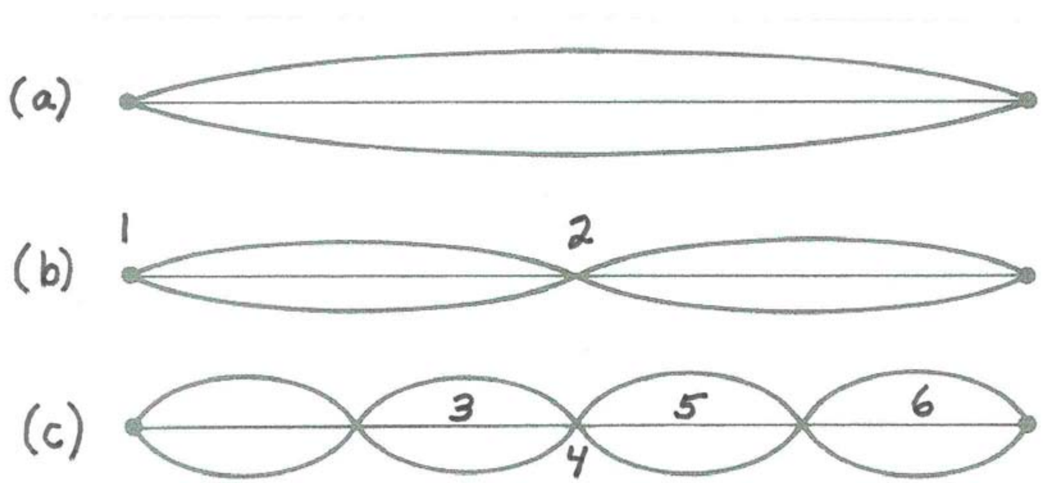
The "Acoustic Collimator" shown in class demonstrates:
(39) flatugation of frequencies below the cutoff level.
(40) diffraction of low frequencies is greater than that of high frequencies.
(41) interference and diffraction.

The following behave acoustically as closed tubes in that they produce complex waves with emphasis on odd harmonics:
(42) a flute.
(43) blowing across the opening of a large spherical jar.
(44) a clarinet.
(45) a Helmholtz resonator.
(46) a violin.

Standing waves can be created by:
(47) two identical sound sources aimed at each other along a line.
(48) a single sound source and its reflection by a metal plate along a line.
(49) two coregulating microphones.




Consider the waves in the Figures above.
(50) Wave (a) is a sawtooth wave.
(51) Wave (b) is a diagonal trace wave.
(52) Both have the same amplitude
(53) Both have the same period.
(54) Both have the same frequency.
(55) Both have the same pitch.
(56) Both have the same timbre.
(57) The difference between their shapes is primarily the phase of the harmonics.
(58) Both waves travel at the same speed in air.
(59) Wave (a) contains only two Fourier components.
(60) Both waves contain exactly three periods.
(61) The period of wave (a) is 2 milliseconds.
(62) Both contain the same Fourier components.
(63) The frequency of wave (b) is about 100 Hz.
(64) The wavelength in air of wave (a) is about 34.5 cm.
(65) Adding these two waves would create a pulse train of the same frequency.
(66) Wave (a) is a richer tone than wave (b) because of its greater articulation.

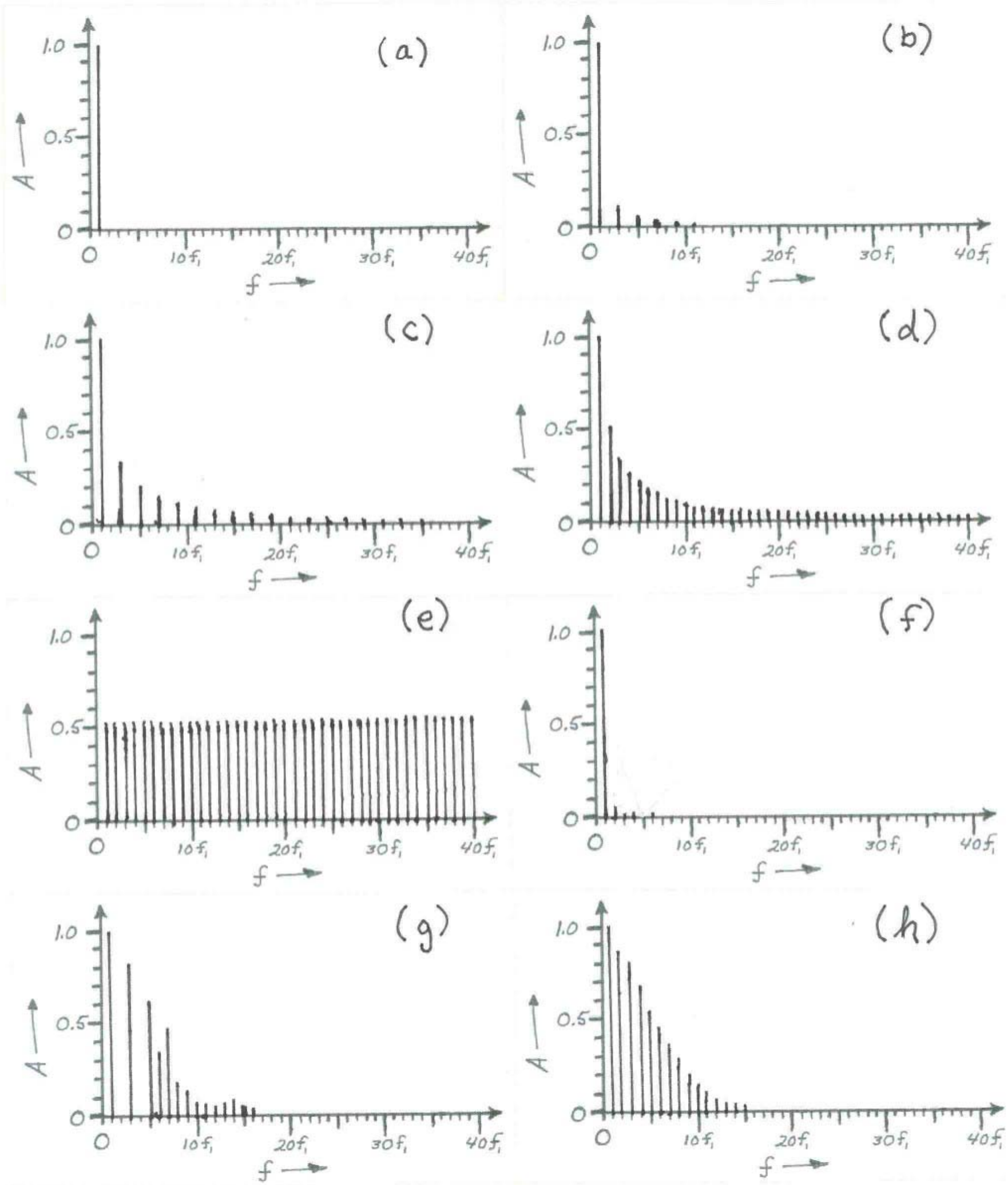


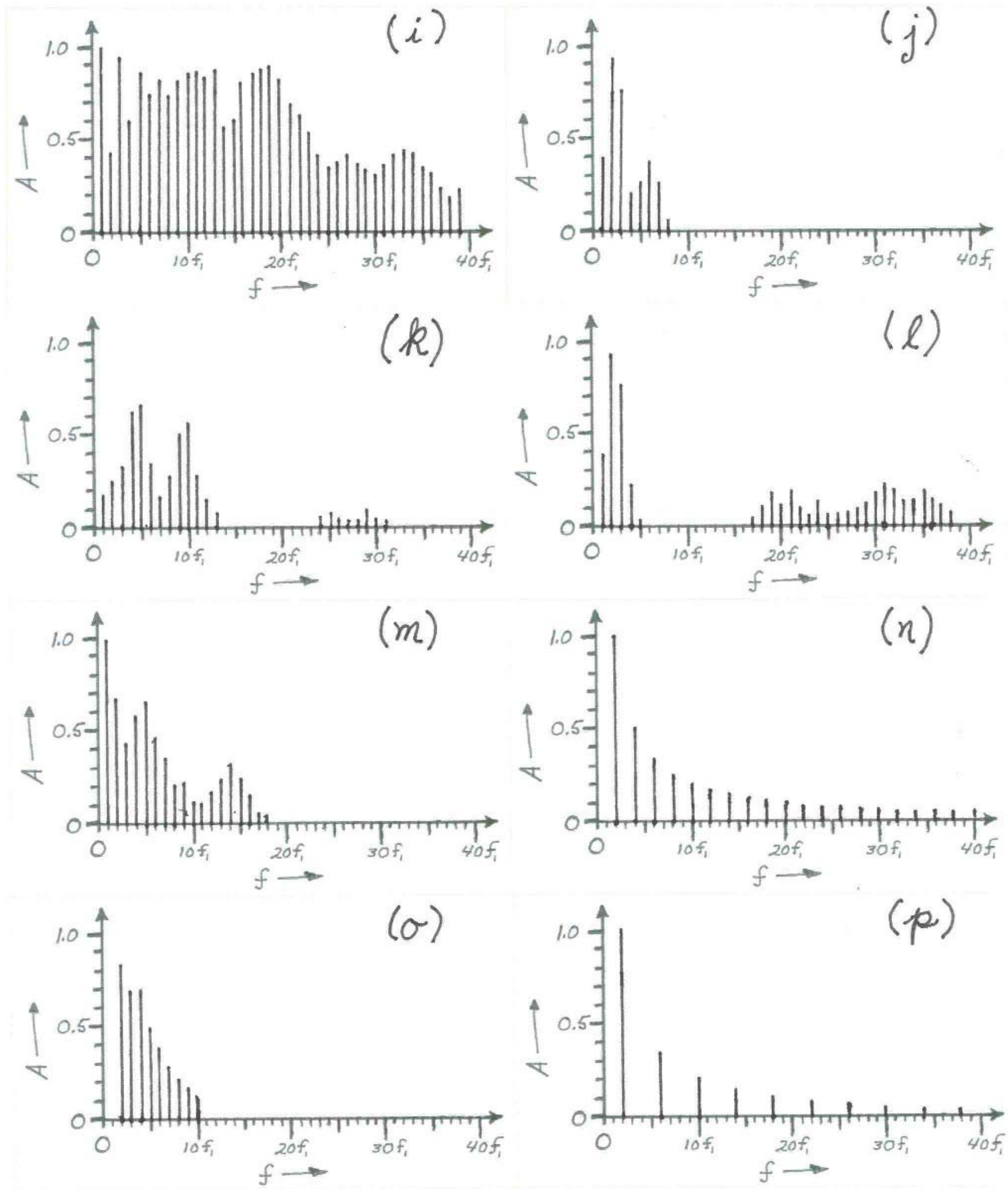
The three drawings at the bottom of the previous page represent standing waves in a stretched string, where in all cases the length, the tension, and the mass per unit length of the string are the same.

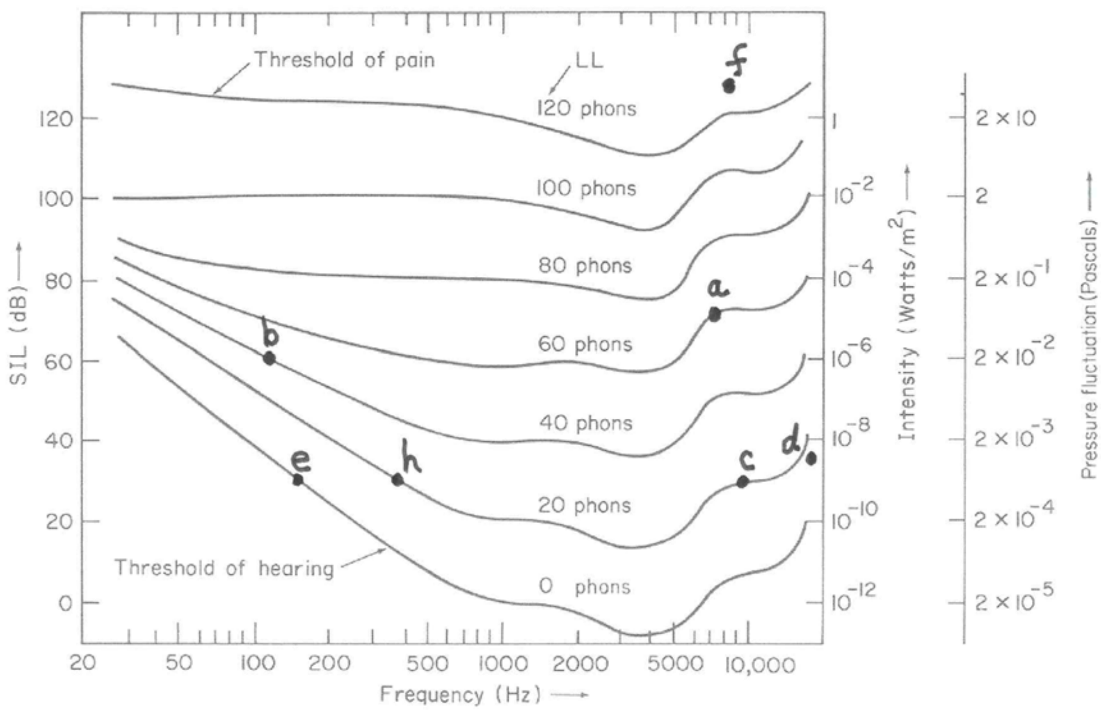
(67) Figure (a) is the fundamental.
(68) Figure (c) is the third harmonic.
(69) These standing waves are all harmonics of the fundamental frequency of the string.
(70) Standing wave (a) is a resonance in the string.
(71) The wave speed is the same in all three strings.
(72) Points (1) and (2) are nodal points.
(73) Points (3) and (4) are antinodes.
(74) Points (4) and (5) vibrate in phase with each other.
(75) Points (5) and (6) vibrate out of phase with each other.
(76) Stretching the string tighter increases the wave speed in the string.
(77) Stretching the string tighter increases the wavelength of the fundamental in the string.
(78) Stretching the string tighter increases the fundamental frequency of the string.
(79) Increasing the tension of (b) by a factor of two produces (a).
(80) Wave (b) is one octave higher than wave (a).
(81) Wave (c) is one octave higher than wave (b).
(82) The laws for stretched strings are known as Dalton's laws.
(83) Stretching the string tighter increases the frequency of the string but not the frequency of the sound wave in air.

Consider the set of Fourier spectra on pages 6 and 7 to answer the questions below. The vertical and the horizontal scales for all spectra are identical. Harmonics are shown up to about 4000 Hertz, although the amplitudes of some components may be too small to be seen on these graphs. Any existing pattern will continue beyond that point.

(84) Spectrum (a) is a pure tone.
(85) Spectrum (b) is that of a square wave.
(86) Spectrum (e) is that of a sawtooth wave.
(87) Spectrum (g) sounds a lot like a recorder.
(88) Spectrum (p) has a frequency one octave above (n).
(89) Spectrum (l) is likely to sound similar to a square wave.
(90) Spectrum (h) belongs more to a violin than to a recorder.
(91) Spectra (j), (k), and (l) are probably vowel sounds sung by the human voice
(92) Spectrum (l) might be the vowel sound "ah" sung by a female voice.
(93) Spectrum (f) sounds more like a recorder than spectrum (h).
(94) Spectrum (p) is missing its fundamental.
(95) The sound of spectrum (p) is an octave higher than that of spectrum (o).
(96) Spectra (c) and (g) might have similar timbre.
(97) Spectrum (d) is a louder sound than spectrum (e).
(98) Sound (n) is one octave above spectrum (d) but has the same timbre.
(99) Spectrum (p) illustrates formants.
(100) Spectrum (i) might be a crumhorn.


(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
1.0
0.5
0
A
10f₁
20f₁
30f₁
40f₁
f


(i)
(j)
(k)
(l)
(m)
(n)
(o)
(p)
1.0
0.5
0
A
0
10f1
20f1
30f1
40f1
f




Referring to the Figure above showing equal loudness contours:

(101) Point (a) has a loudness level of 60 phons.
(102) Point (b) has an intensity of $10^{-6}$ watts per square meter.
(103) Point (c) and point (h) sound at the same loudness to your average human.
(104) Point (f) cannot be heard by your average human.
(105) Point (e) sounds the same loudness as point (h) to the average human.
(106) Point (d) sounds softer than point (c) to the average human.
(107) The dynamic range of the human ear is about 120 dB.
(108) 120 dB corresponds to a factor of about $10^8$ in intensity.
(109) The vertical scale is linear in intensity.
(110) The horizontal scale is logarithmic in frequency.
(111) One phon is equal to one dB at 1000 Hz.
(112) The unit of loudness level is the decibel.

(113) Ring modulation is used in the musical synthesizer production of the sound of a bell.
(114) Amplitude modulation in the musical synthesizer produces pure tremolo.
(115) Frequency modulation in the musical synthesizer produces pure vibrato.
(116) The "vibrato" of the singing voice is generally a combination of tremolo and pure vibrato.
(117) Moving your trombone slide rapidly in and out during a note creates vibrato.
(118) Double sideband modulation creates a uniquely electronic sound.
(119) Pulse width modulation is used to produce the slight inharmonicities in the piano sound.
(120) A square wave would be used to synthesize the sound of a flute.
(121) A sine wave would be used to synthesize the sound of a clarinet.

(122) White noise contains all frequencies of the audio spectrum.
(123) Pink noise contains all frequencies of the audio spectrum.
(124) Pink noise is used to model the frequency spectrum of the typical acoustical instrumental ensembles.
(125) FM radio has a greater frequency range than AM radio.
(126) FM radio transmits music with the full audio frequency range of 20 Hz to 20 kHz.
(127) A sine wave can be used to frequency modulate a sawtooth wave.
(128) A square wave cannot be used to amplitude modulate a sine wave.
(129) Frequency modulation of a wave by itself can be used to create a number of wave shapes and sounds.
(130) MIDI devices are connected together using standardized cables and plugs.
(131) One typical MIDI feature uses a computer program allowing the user to play music on a keyboard and have the computer write it down in musical notation.
(132) Old analog synthesizers used base 2 (binary) encoding, whereas newer digital synthesizers have increased their dynamic range by using base 10.

(133) The outer, middle and inner ears are included in the peripheral auditory system.
(134) The central auditory system includes signal processing in the brain.
(135) The semicircular canals aid in balance.
(136) There are four semicircular canals, corresponding to the four-vector in Einsteinian relativity.
(137) The cochlea lies within the largest of the semicircular canals.
(138) The cochlea contains the fluid through which the sound wave passes from the oval window to the round window.
(139) The Eustachian tube connects the nasal cavity to the back of the throat.
(140) The vocal folds close so that water cannot get into your nose when you drink.
(141) The eardrum alone separates the ear canal from the adjacent fluid of the inner ear.
(142) The frequency response as a function of position along the basilar membrane is approximately logarithmic.
(143) The width along the basilar membrane most sensitive to the frequency region 100-200 Hz is about the same length as the region sensitive to 10,000-20,000 Hz.
(144) The frequency region 100-200 Hz includes one octave.
(145) The frequency region 10,000-20,000 Hz includes more than one octave.
(146) A factor of 1.25 in intensity corresponds to approximately 1 dB.
(147) The JND of intensity is about 1 dB over virtually all of the dynamic range of the ear.
(148) The dynamic range of the ear is considerable less than that of a good consumer model loudspeaker.
(149) The ear responds to intensity approximately logarithmically.
(150) Logarithmic response of the ear to intensity allows the ear to be sensitive over a large dynamic range.
(151) If two 10 dB sounds played together create a 13 dB sum, then two 20 dB sounds played together create a 23 dB sum.
(152) The vocal tract acts acoustically as a closed tube about 17.5cm long.
(153) In the vocal tract, the lips act as an open end and the vocal folds act as a closed end.
(154) Resonances in the vocal tract lead to vocal formants.

(155) Certain Tibetan monks appear to sing two notes simultaneously by manipulating their vocal tracts.
(156) The higher of the two notes sung by the Tibetan monks is a harmonic of the lower note.
(157) The frequencies of vocal formants are varied by changing the shape of the throat and lips.
(158) The frequency of the singer's formant can be raised by constricting the volume of the nasal cavity.
(159) The frequencies of the first and second vocal formants are critical in distinguishing between "s" and "z.".
(160) A sound spectrogram and a Fourier spectrum are two ways of graphically displaying vocal formants.
(161) The sound "ss" is largely noise.
(162) The sound "zz" is a combination of noise and the harmonics of a voiced tone.

(163) An audio system consists of several distinct components, some or all of which may be housed together.

A microphone signal may not work properly when input into the CD input of your stereo pre-amplifier due to:
(164) incorrect impedance matching.
(165) incorrect output level.
(166) the microphone may have too long a reverberation time.

(167) A typical CD containing about 75 minutes of stereo music has over three miles of tracks of pits.
(168) An audiocassette tape records music as varying magnetization of a tape.
(169) Dolby noise reduction is necessary to compensate for random magnetization of magnetic domains on the tape that creates tape hiss.
(170) Tape hiss consists primarily of low-frequencies.
(171) Saturation of the magnetic domains on the tape limits the dynamic range of music on a tape recording.
(172) Tape bias is a sine wave of about 100 kHz superimposed on the music signal recorded on the tape.
(173) Tape bias is used to compensate for hysteresis in the magnetic domains on the tape.
(174) The dynamic range of a CD is greater than that of a magnetic tape recording.
(175) The dynamic range of a CD is about 90 decibels.
(176) The digital coding of music on a CD uses base 16 (hexadecimal) counting.
(177) The binary number 11001010 is greater than decimal 100.
(178) The binary digit "1" is the surface of the CD and the binary digit "0" is at the bottom of a pit.

Burst error corrections in the playback of a CD compensate for:
(179) small defects in manufacturing the CD.
(180) scratches on the CD.

(181) holes drilled into the CD.

Reasons why the DVD format contains more material than a standard CD include:
(182) the pits are deeper.
(183) the playback system uses radiation with a shorter wavelength.
(184) the DVD disc is about six times the diameter of the standard CD.

Several types of error avoidance and/or correction are used in CDs, including:
(185) eight-to-fourteen modulation.
(186) pit evaporation.
(187) Cross Interleave Reed-Solomon Code.

(188) The acoustical properties of a room or auditorium are largely a result of its reverberation time.
(189) The reverberation time is usually a bit longer for frequencies below about 500 Hz than for higher frequencies.
(190) RT60 means that the sound level of the reverberant sound drops by a factor of 60 during that time interval.
(191) Acoustical warmth and brilliance are opposing characteristics.
(192) The reverberation time can be adjusted by appropriate choice of building materials.
(193) Late arriving strong reflections can be caused by a concave surface at the rear of the stage.
(194) Clarity is required to understand speech, except where the ethereal quality is required in large cathedrals.
(195) Intimacy requires having a very large initial reflection 50 ms after the direct sound.
(196) The reverberation time of a concert hall can effect the type of music that sounds best in that hall.
(197) Concert halls have a variety of reverberation times.

(198) MP3 compression removes frequency components below the threshold of hearing as well as sounds masked by other, more important sounds.
(199) The MP3 example used for the class test was composed by Brahms and uses only a small string orchestra.
(200) When you compress music using MP3 it may be helpful to try various MP3 bit rates to select the one that best suits your needs best.