Multiple Choice

1.) Answer: D
2.) Answer: A
3.) Answer: C
4.) Answer: C
5.) Answer: B
6.) Answer : B
7.) Answer: C
8.) Answer: C
9.) Answer: D
10.) Answer: C
11.) Answer: B
12.) Answer: A
13.) Answer: B
14.) Answer: C
15.) Answer: C
16.) Answer: D
17.) Answer: A
18.) Answer: C
19.) Answer: B
20.) Answer: C
21.) Answer: D
22.) Answer: D
23.) Answer: D
24.) Answer: C
25.) Answer: A

Short Answer:

1.)

2.) (1 pt for identifying at least 2 of the 3: the lungs, vocal folds within the larynx(voice box), and the articulators. 1 pt for identifying lungs provide necessary airflow to vibrate larynx. 1 pt for identifying larynx adjusts pitch and tone. 1 pt for identifying articulator(like tongue,cheek,lips...) as filtering and articulating the sound).

3a.)(Major Seventh, CM7, CΔ7, CΔ,Cmaj7)

3b.)(B Dominant Seventh)

3c.)(C# Augmented Triad)

3d.)(C Lydian Chord, major 7♯11 chord)

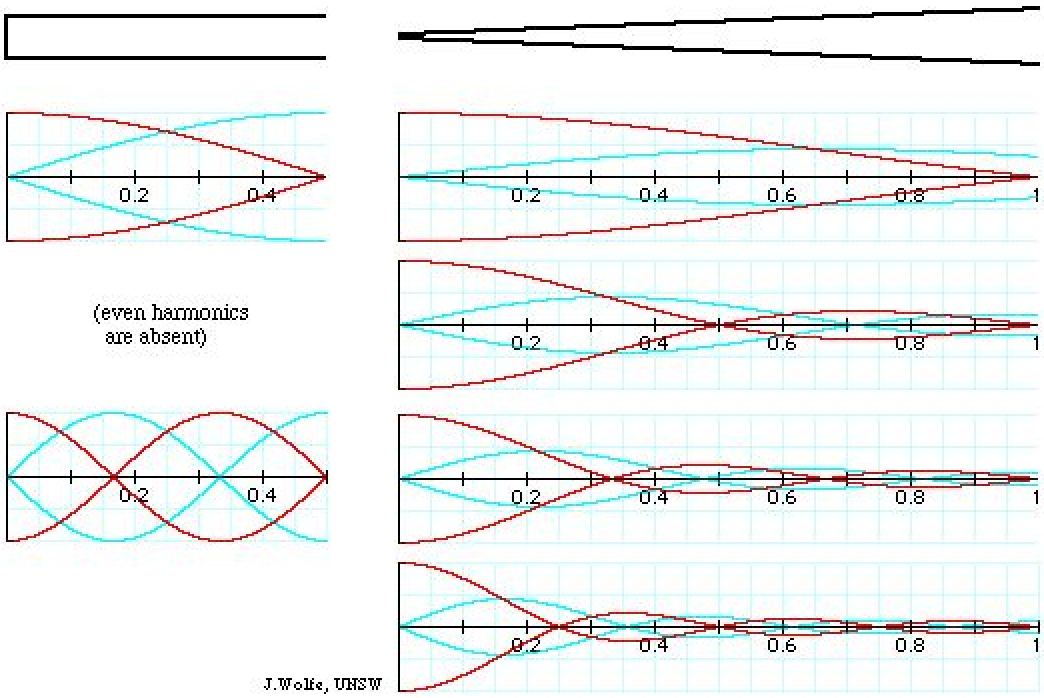
3e.)(Diminished Fifth)

3f.)(Perfect fifth)

2g.)(Major Seventh)
2h.)(Diminished Seventh)

4a.)(1 pt for identifying that in grands, the entire keyboard is shifted over slightly so that only 2 of 3 strings are hit by hammer. 1 pt for identifying that in uprights, pedal moves hammer closer so strings are struck with less energy. 1 pt for identifying that in uprights, this produces no change in timbre of the sound, only decreases volume)
4b.)(2 pts if correctly identify length, mass per unit length, tension, 1 point if identify 2 of 3, 0 point if any less. 1 pt if say that shorter length = higher pitch or longer length = lower pitch. 1 pt if say if thinner wire = higher pitch or thicker wire = lower pitch. 1 pt if say increase tension in string = higher pitch or decrease tension in string = lower pitch)
4c.)(1 pt for identifying spruce, 2 pts for identifying spruce high ratio of strength to weight = minimize acoustic impedance, 1 pt for identifying sufficiently strong to bear force of strings)
4d.)(2 pts for noting that attempts at harmonically tuning a piano via intervals like on a violin/guitar would not result in the next octave having exactly 2x the frequency of the octave below because (a/b)^n=/=2 for integers a,b and n>1. 1 pt for identifying Equal Temperament Tuning, 1 pt for identifying that each half step is tuned to be (2^(1/12)) times frequency of half step before it. 2 pts for identifying that because we are tuning with the piano with respect to an octave, each subsequent octave will be equally out of tune so the entire keyboard will be equally out of tune.)

5a.)(1 pt for identifying longitudinal waves. 1 pt for identifying that shape of air column is a pipe closed at one end and open at the other. 2 pts for discussing wave impedance in horn is higher than outside but reaches low impedance when reaching end of tube so part of wave will be reflected back down pipe and non reflected portion produces sound. 2 pts for identifying notes are produced as combination of resonant frequencies of waves that are reflected)
5b.)(2 pts for identifying that the bell raises lower resonances of instrument from a closed tube to a more useful harmonic sequence. 1 pt for noting that lowest resonance is shifted up the most. 1 pt for identifying “pedal tone” as consequence of the bell.)

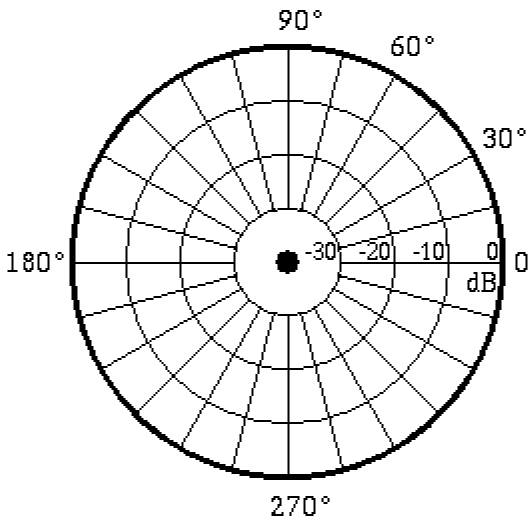


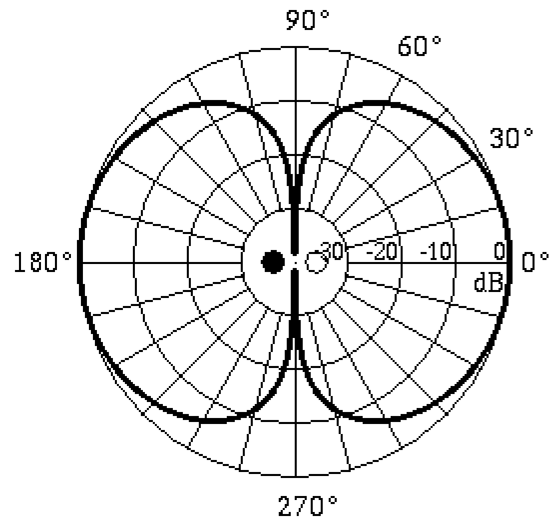
5c.)

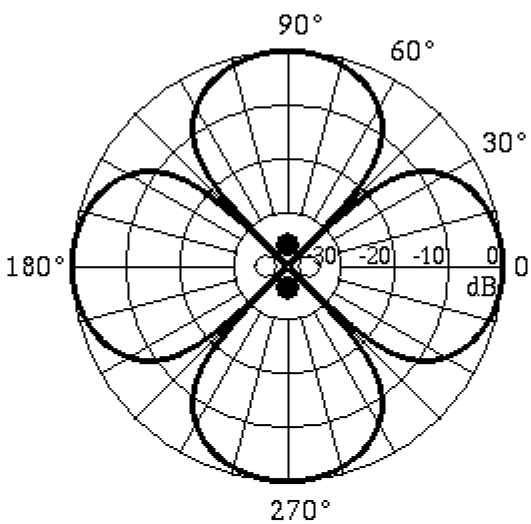
5d.)(1 pts for any sort of discussion about resonance of standing waves. 2 pts for identifying the horn bell as the main cause and that it is an impedance matcher in both outwards and inwards directions. 2 pts for identifying that amplification of standing waves from horn to mouthpiece could greatly injure players' lips for extended periods of time. Bonus 2 points if student correctly identifies a gain of 16-26 db at the mouthpiece).

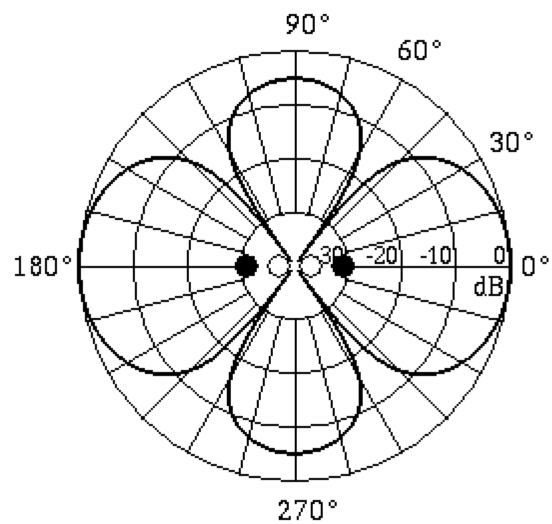
6a.)(1 pt for each definition: "A monopole is a source which radiates sound equally well in all directions", "A dipole source consists of two monopole sources of equal strength but opposite phase and separated by a small distance compared with the wavelength of sound. While one source expands the other source contracts.", "If two opposite phase monopoles make up a dipole, then two opposite dipoles make up a quadrupole source. In a Lateral Quadrupole arrangement the two dipoles do not lie along the same line (four monopoles with alternating phase at the corners of a square).", "If two opposite phase dipoles lie along the same line they make up a Linear Quadrupole source". Points awarded for any variation of the above definitions.)

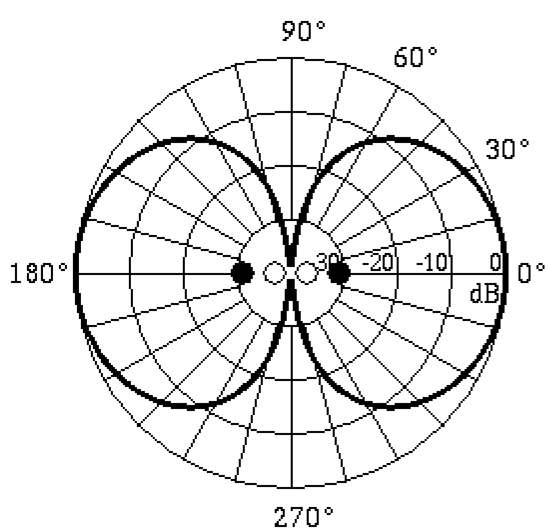
6b.)(From left to right, 1=Monopole, 2=Dipole, 3= Lateral Quadrupole, 4,5= Linear(longitudinal) Quadrupole [accept either for this part])









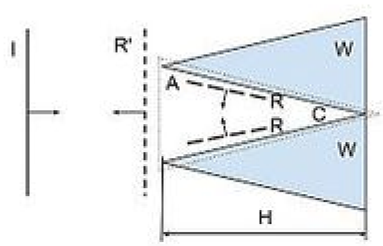


6c.)(Linear(longitudinal) quadrupole)

6d.)(3 pts for any discussion of "What makes the linear quadrupole interesting is that there is a very obvious transition from near field to far field. In the near field there are four maxima and four minima, with the maxima along the quadrupole axis about 5dB louder than the maxima perpendicular to the quadrupole axis. In the far field there are only two maxima (along the quadrupole axis) and two minima (perpendicular to the quadrupole axis)" Also 2 pts for marking them on the graph, note less squashed version of dipole = far field and near field = the other linear quadrupole graph. Answer must include discussion of near/far field to gain any of these points)

7.) (1 pt for identifying echo as single reflection of sound off surface. 1 pt for identifying reverberation as superposition of echoes. 1 pt for identifying limiting either 17m or 0.1s as limiting cases for differing between echo and reverberation, award 2 pts if both identified. 1 more pt for any discussion of using echo to determine distance (but reverberation cannot) or that echoes can be heard in both open and closed space while reverberations are usually in closed spaces or any other discussion of their differences)

8.) (1 pt for identifying wall is composed of wedges. 1 pt for identifying wedges allows sound to bounce up and down and dissipate energy with each bounce. 1 pt for discussion of wall/wedge interaction to further dissipate sound energy. 2 pts for correct schematic diagram and 2 pts for



correctly diagramming/explaining how it works. Ex: the incident wave I is reflected as a series of waves R which in turn "bounce up-and-down" in the gap of air A (bounded by dotted lines) between the wedges W. Bouncing produces a temporary standing wave in A. Acoustic energy of the waves R gets dissipated via the air's molecular viscosity, particularly near corner C. Another dissipation mechanism happens during the wave/wall interactions -> the component of the reflected waves R along the direction of I that escapes the gaps A (and goes back to the source of sound), denoted R', is notably reduced)

Math

1a.) $f' = (\frac{v+v_o cos\theta_o}{v-v_s cos\theta_s})f$ where the θ_o and θ_s are the angles that the observer and source's velocities make with respect to the axis between the two. Award full points if correct formula is written down. If one of the cos(theta) is missing or signs are flipped, award 2 points and if an attempt was made at writing the solution, award 1 point

1b.) Since $v_o = 0,$ our equation simplifies to $f' = (\frac{v}{v-v_s cos\theta_s})f$. $cos(\theta_s) = \frac{21}{29}$, plugging in all our values: f'=339.3 Hz. Award full credit if work is shown and answer is correct. If answer is incorrect but work is correct, award half credit. If tester unable to get correct formula in part a, award 1 point for attempting question.

1c.) Use $f' = (\frac{v}{v-v_s cos\theta_s})f$. θ_s varies from 0 to 180 degrees as the train approaches from very far away and departs for a long time afterwards. Therefore, the observed frequency range is $296.6 \leq f' \leq 347.3$. Award full points for proper work and correct answer. Award half credit for proper work but incorrect answer. Award 1 point for an attempt at the answer.

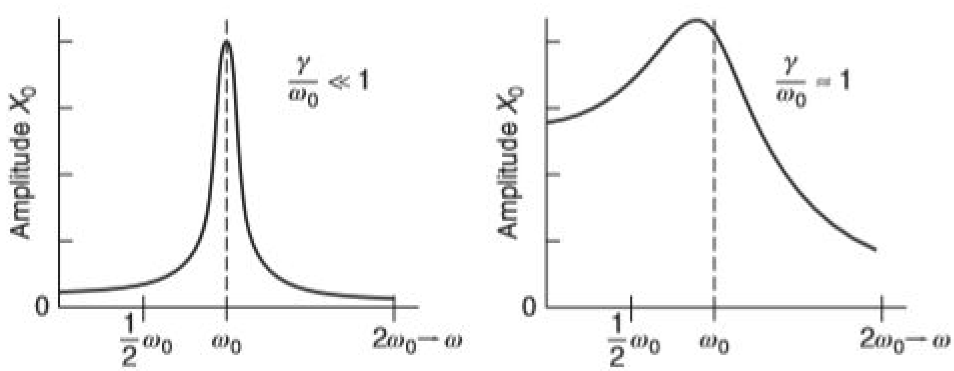
2a.) The force exerted by the pressures are p_1A_1 and p_2A_2. Therefore, the work done on the segment of the fluid in a time interval Δt is $W_1 = p_1 A_1 \Delta x_1 = p_1 V$ and $W_2 = -p_2 A_2 \Delta x_2 = -p_2 V$ where we have defined $\Delta x_1 = v_1 \Delta t$ and $\Delta x_2 = v_2 \Delta t$. Thus, the net work done in the time interval Δt on the segment of the fluid is $W = (p_1 - p_2)V$. Because we are assuming laminar flow, we can use the work energy relation to relate the work done on the segment by fluid outside the system $W = \Delta E = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 + mgh_2 - mgh_1$. Dividing through by V and using ρ = m/V, we arrive at $p_1 - p_2 = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2 + \rho gh_2 - \rho gh_1$. Rearranging gives us $p_1 + \frac{1}{2}\rho v_1^2 + \rho gh_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho gh_2$. Since we chose arbitrary points to denote h_1 and h_2, the sum of the terms on either the RHS or LHS must always remain constant (this is analogous to the conservation of energy equation). Thus, we arrive at Bernoulli's equation for an ideal fluid: $p + \frac{1}{2}\rho v^2 + \rho gh = c$, for an arbitrary constant c. Award full points for proper derivation. Award 4 points if got up to second to last equation but couldn't derive final step. Award half credit if derivation shows general procedure but unable to completely derive second to last equation. Award 1 point for an attempt that utilized work done on the segment of the fluid.

2b.) We first need to find the velocity of the water leaving the hole: $t = \sqrt{\frac{2(1.35)}{9.8}} = 0.52s$, so the velocity of the exiting water is $v = \frac{0.315}{.52} = 0.61\ m/s$. We then note that $p_1=p_2=p_{atm}$ where point 1 is at the surface of the water and point 2 is at the hole, and apply Bernoulli's equation: $\frac{1}{2}\rho v_1^2 + \rho g h_1 = \frac{1}{2}\rho v_2^2 + \rho g h_2$, since $v_1 = 0$ at point 1, $\rho g h_1 = \frac{1}{2}\rho v_2^2 + \rho g h_2$, solving for h: $h = h_1 - h_2 = \frac{v_2^2}{2g} = \frac{(0.61)^2}{2g} = 1.9\ cm$. Margin of error is $\pm 0.2\ cm$ for answer depending on how answers were rounded. Award full credit if proper work and answer within margin of error. Award half credit for application of Bernoulli equation but incorrectly using it, or failing to realize $p_1=p_2=p_{atm.}$ Award 1 point for attempting to use Bernoulli equation or realizing that velocity of water exiting hole could be calculated like that of projectile motion.

2c.) The differential form of Bernoulli's equation is $\frac{dp}{\rho} + vdv + gdh = 0$ where in the case of incompressible flow, $\int \frac{dp}{\rho} = \frac{p}{\rho}$. Utilizing our given relation for isentropic flow, we solve for $\rho = (\frac{p}{c})^{(1/k)}$. So $\int \frac{dp}{\rho} = \int c^{(1/k)} p^{(-1/k)} dp = (\frac{p}{\rho^k})^{(1/k)} p^{((k-1)/k)} (\frac{k}{k-1}) = (\frac{k}{k-1})(\frac{p}{\rho})$. So re-evaluating the differential form of Bernoulli's equation, we arrive at $\frac{k}{k-1}(\frac{p}{\rho}) + \frac{1}{2}v^2 + gh = \alpha$ for some constant α. Award full points for proper derivation. Award 4 points for writing down the correct differential form of Bernoulli's Equation but failing to calculate the correct answer. Award 2 points for attempting to derive differential form of Bernoulli's equation and award 1 point for attempting to work the given relation into Bernoulli's equation.

3a.) For sufficiently small damping, the amplitude equation becomes $X_0 = \frac{F_0}{m}\left(\frac{1}{(\omega_0^2-\omega^2)}\right)$, from which it is clear that the resonant frequency is simply $\omega = \omega_0$ as that is when the denominator $\left(\frac{1}{(\omega_0^2-\omega^2)}\right)$, approaches zero and our amplitude blows up. Award full points for proper reasoning and correct explanation. Award 2 points for correct answer, but no explanation. Award 1 point if tester tried to take derivative of amplitude with respect to ω but came up with the wrong answer.

3b.) For sufficiently large damping, γ can no longer be ignored and thus, we have to take the derivative of $X_0 = \frac{F_0}{m}\left(\frac{1}{((\omega_0^2-\omega^2)^2+(\omega\gamma)^2)^{1/2}}\right)$ with respect to ω, and set it equal to 0 to solve for ω. Doing so gives us $\omega^2 = \omega_0^2 - \frac{\gamma^2}{2}$. Award full points for correct work and answer. Award half credit for attempting to take derivative but not getting correct answer. Award 1 point for attempting to solve it in the same way as in 3a.

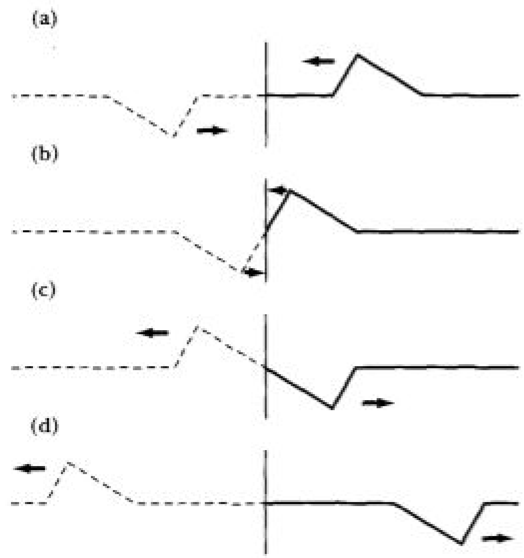


3c.)

Example sketches. The x axis need not be as detailed but ω_0 must be labeled. Generally, for small damping, sketches should match exactly with left side graph and for large damping, graph should be similar to right side graph, with the peak being less defined and to the left of ω_0. Award full points for both correct graphs. Half credit for 1 correct graph. 1 pt for attempting to draw graphs with a peak at resonance frequencies.

4a.) The physical interpretation of the solution is that of two waves, with $f(x+vt)$ describing a wave propagating to the left and $g(x-vt)$ describing a wave propagating to the right. This solution also describes the law of superposition when the two approaching waves meet each other. Award full credit for properly describing each component of the solution as well as identifying the law. Subtract 1 pt for each component that isn't correctly described.

4b.) The correct expression is -f(-x+vt). This describes an "imaginary wave" behind the boundary that is approaching x=0 from the left and is one way of describing the reflection of a wave at a rigid boundary point. A sketch similar to that to the right should be provided. Note the function must be approaching the boundary from the right as I claimed the wave function was of the form f(x+vt). The term "reflection" should also be used in the answer. Full credit for including everything all parts. 4 points for an incomplete sketch but having everything else correct.



3 pts for correct answer and explanation but no sketch.
2 points only for the correct answer.
1 pt for attempting to write an answer of the form f(x+vt).

4c.) The harmonic nature of this wave function implies that it is not propagating at all. Physical interpretation when $\psi = 0$ implies a node and specifically, a standing wave. $\psi = 0$ at x = $\frac{(2n+1)\pi}{2k}$ where n is an integer. Note: in order to solve for x, tester had to first derive $\psi = Re(2Ae^{-ikx}cos(\omega t)) = 2Acos(kx)cos(\omega t)$ via proper application of Euler's formula. Full credit for correctly identifying all components. 6 points if only the first part is not correctly identified. 4 points for getting correct form of wave function and solving for nodes but not identifying that they are standing waves. 3 points for getting correct form of wave function but not solving for position of standing waves and 1 point for attempting to use Euler's formula but incorrectly using given hints.