A. 1. They differ in how intense their harmonics are.

2. a) An air column must have a node at a closed end and an antinode at an open end. The lowest frequency corresponds to the longest wavelength, so put no other nodes or antinodes in between. Therefore, you get the pattern shown.

\[
\lambda = 4 \text{ (N to A)}
\]

\[
\lambda = \frac{v}{f} \implies 4L = \frac{v}{f} \implies L = \frac{v}{4f}
\]

\[
= \frac{\frac{343 \text{ m/s}}{4 \times 240 \text{ Hz}}} = \frac{343 \text{ m/s}}{960 \text{ m}} = 0.357
\]

b) The next pattern with a node at the closed end and an antinode at the open end is:

\[
\text{N-A dist. = } 1/4 \lambda
\]

\[
\frac{1}{3} L = 1/4 \lambda
\]

\[
4/3 L = \lambda
\]

\[
\lambda = \frac{v}{f} \implies 4/3 L = \frac{v}{f} \implies f = \frac{v}{4/3 L} = \frac{343 \text{ m/s}}{1.333(0.3573 \text{ m})} = \text{ans. 720 Hz}
\]

B. 1. a. If four segments are 120 cm long, each one is 120/4 = 30 cm long. Since N to N, 1/2, and A is, node to node is 30 cm. Since N to 1/2, \(\lambda = 60 \text{ cm}\).

\[
\frac{120 \text{ cm}}{f = 120 \text{ Hz}} \quad \text{That}
\]

b. There are a couple of ways to do this, but the quickest is to say that if the fourth harmonic is 120 Hz, the first harmonic would be 120/4 = 30 Hz.

2.
\[ \frac{I_M}{I_E} = \frac{r_E^2}{r_M^2} \]
\[ I_M = I_E \frac{r_E^2}{r_M^2} = (1340) \left( \frac{1.50 \times 10^{11}}{5.80 \times 10^{10}} \right)^2 = 8963 \]
\[ \text{rounds to } 8960 \text{ W/m}^2. \]

C. 1. The harmonics are whole number multiples of the fundamental:
\[ f_n = n (1300 \text{ Hz}) \]
To find the highest \( f_n \) under 20 000 Hz,
\[ n (1300 \text{ Hz}) < 20 000 \]
\[ n < 20 000/1300 \]
\[ n < 15.38 \]
The highest harmonic this person can hear is the 15\textsuperscript{th}. (\( n \) stands for a whole number.)
\[ f_n = n (1300 \text{ Hz}) = (15)(1300 \text{ Hz}) = 19 500 \text{ Hz} \]

2.

a. \( I = \text{Power/area} \). An area on which every point is 5.0 m from the speaker would be a sphere. That is, when 5.0 m from the speaker, the sound's energy passes through an imaginary sphere.
\[ \text{Area of a sphere} = 4\pi r^2, \text{ from formula sheet.} \]
\[ I = \frac{8.00 \text{ W}}{4\pi(5.0 \text{ m})^2} = \frac{8.00 \text{ W}}{314.16 \text{ m}^2} = .02546 = .0255 \text{ W/m}^2 \]

b. \[ \beta = 10 \log \left( \frac{I}{10^{-12}} \right) = 10 \log \left( \frac{.02546}{10^{-12}} \right) = 10 \log (2.546 \times 10^{10}) \]
\[ = 10 (10.4) = 104 \text{ dB} \]

D. 1. The superposition principle says to add one wave’s displacement to the other’s. The wave on the left is pulling the water 4 mm below equilibrium (count divisions on the graph). The one on the right is pulling it 5 mm above. \((-4) + 5 = 1 \text{ mm}.\)

2. (c). Twice as many speakers put out twice as much energy, doubling the intensity. To have 100 dB, you need something 100 000 times as intense as 50 dB, not twice as intense. (Every time you add 10 dB, you multiply the intensity by 10. So adding 50 dB means multiplying I by \( 10^5 \).)
3. \[ \frac{I_1}{I_2} = \frac{r_2^2}{r_1^2} \] Intensity is inversely proportional to the square of the distance. So, twice the distance means I is quartered. ans.

4. \[ \lambda = 2(\text{N to N}) = 2(.400 \text{ m}) = .800 \text{ m} \]
\[ f = \frac{v}{\lambda}; \text{ we need } v. \]

\[ v = \sqrt{\frac{F}{\mu}} \text{ where } \mu = \frac{\text{mass}}{\text{length}} = \frac{.003 \text{ kg}}{.4 \text{ m}} = .0075 \text{ kg/m} \]

\[ v = \sqrt{\frac{800 \text{ N}}{.0075}} = 326.6 \text{ m/s} \]

\[ f = \frac{v}{\lambda} = \frac{326.6}{.8} = 408 \text{ Hz} \]

E. 1. **Opposite.** From one antinode to the next is half a wavelength. Since a and b are half a wavelength apart, one of them goes up when the other goes down. As for zero, if these points were at rest at equilibrium, they would just stay there instead of vibrating.

2. \[ I = 10^{(\beta/10^{-12})} \]
\[ I_{400} = \text{Intensity from 400 cars} \]
\[ I_{400} = 10^{(80/10^{-12})} = 10^{-4} \text{ W/m}^2 \]

Assuming each car throws the same amount of energy into the air, reducing the number of cars by a factor of \( \frac{65}{400} \) would reduce the intensity by a factor of \( \frac{65}{400} \):

\[ I_{65} = \text{Intensity from 65 cars} = \frac{65}{400} I_{400} = (.1625)(10^{-4} \text{ W/m}^2) = 1.625 \times 10^{-5} \text{ W/m}^2 \]

\[ \beta = 10 \log \left(\frac{1}{10^{-12}}\right) = 10 \log \left(\frac{1.625 \times 10^{-5}}{10^{-12}}\right) = 10 \log (1.625 \times 10^7) = 10(7.21) = 72.1 \text{ dB} \]
Loop around the outside of the diagram:

\[ +5V - I_1(25\Omega) = 0 \implies I_1 = \frac{5}{25} = 0.200A \]

Apply point Rule to point P:

\[ I_2 = I_1 + 10\Omega = (0.2) + 10 = 1.200A \]

Loop around the bottom half:

\[ +5V + I_2(10\Omega) - \varepsilon = 0 \]

\[ 5 + (1.2)(10) = \varepsilon \implies \varepsilon = \underbrace{8\varepsilon}_{\text{Ans}} \]