# (SW.L1.4-212.sols) 212 Mastery Stage Solutions

Tuesday, February 18, 2020 6:01 PM

# SW.L1.4 | Standing Wave Resonance in Tubes and on Strings | Challenge Homework

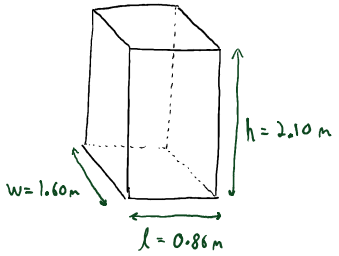
Submit a digital copy (PDF, jpg, etc.) to gradescope.com. Every page should be labeled on the top left with the question code (e.g. GR.L1.4-01) and there should be only be one solution per page. The questions should be in order. If a solution takes more than one page, be sure to label that it is a continuation of the previous page's solution (e.g. GR.L1.4-01 continued). One question will be randomly selected and graded. Challenge homework for a given week are due the following week by Tuesday at midnight. If data is needed to complete a problem, be sure to cite the source you've acquired your data from. See the course website for further details.

You will be asked to apply sense-making in most problems. Use the list below as a reference to the different sense-making techniques. More information about sense-making can be found on the BoxSand menu under Math Tools => Sense-making.

- *Sign:* Check the **sign** of each quantity makes sense.
- *Dimensionality:* Check the **dimensionality** and units of each quantity makes sense.
- *Order of Magnitude:* Check the **order of magnitude** of the final answer and other important quantities is within a a factor of 10 of what you think it should be.
- *Graphical Analysis:* Use a **graph** to see if the behavior of a solution makes sense.
- *Proportionality:* Using a symbolic solution, check the behavior of the answer when you change a given quantity on which it is dependent. Does the answer vary **proportionally** to what you expect?
- *Special Cases:* Check the behavior of a derived equation in limiting (**special**) cases makes sense, e.g. as x goes to 90 degrees in sin(x).
- *Self-consistency:* Check derived equations, functions, or values, are **self-consistent**, e.g. check that the slope of a derived position plot matches the values of the given velocity plot
- *Known Values:* Compare given or derived quantities with common well **known values**.
- *Related Quantities:* Compare the relative magnitude of two **related quantities**.

**SW.L1.4-01**

Standing wave resonance can be heard when singing in the shower. Assume your shower stall has dimensions 86cm x 160cm x 210cm. Which frequencies will sound loudest when singing? Assume the range of your voice is 130Hz to 2000Hz and let the speed of sound in the hot shower be 355 m/s. State any assumptions you have to make .




* ASSUME ALL HARD (CLOSED) WALLS
→ SYMMETRIC BCs FOR ALL POSSIBILITIES
→ 3 STANDING WAVE POSSIBILITIES
ALONG l, w, OR h

SYMMETRIC

$f_m = \frac{mv}{2L}$ $m = 1, 2, 3, 4 \ldots$

knowns
v = 355 m/s
l
w
h

CASE l

$f_m = \frac{m(355)}{2(0.86)}$ Hz

$f_m = 206.4\,m$ Hz

| m | $f_m$ (Hz) |
|---|---|
| 1 | 206 |
| 2 | 413 |
| 3 | 619 |
| 4 | 826 |
| 5 | 1030 |
| 6 | 1240 |
| 7 | 1440 |
| 8 | 1650 |
| 9 | 1860 |

CASE w

$f_m = \frac{m(355)}{2(1.6)}$ Hz

$f_m = 110.9\,m$ Hz

| m | $f_m$ (Hz) |
|---|---|
| 1 | 111 |
| 2 | 222 |
| 3 | 333 |
| 4 | 444 |
| 5 | 555 |
| 6 | 665 |
| 7 | 776 |
| 8 | 887 |
| 9 | 998 |
| 10 | 1100 |
| 11 | 1220 |
| 12 | 1330 |
| 13 | 1440 |
| 14 | 1550 |
| 15 | 1660 |
| 16 | 1770 |
| 17 | 1890 |
| 18 | 2000 |

CASE h

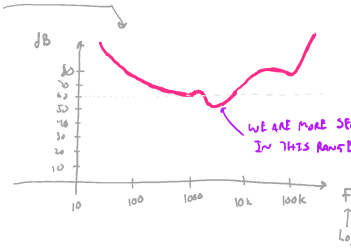
$f_m = \frac{m(355)}{2(2.1)}$ Hz

$f_m = 84.5\,m$ Hz

| m | $f_m$ (Hz) |
|---|---|
| 1 | 84.5 |
| 2 | 169 |
| 3 | 253 |
| 4 | 338 |
| 5 | 423 |
| 6 | 507 |
| 7 | 592 |
| 8 | 676 |
| 9 | 761 |
| 10 | 845 |
| 11 | 930 |
| 12 | 1010 |
| 13 | 1100 |
| 14 | 1183 |
| 15 | 1270 |
| 16 | 1352 |
| 17 | 1440 |
| 18 | 1520 |
| 19 | 1610 |
| 20 | 1690 |
| 21 | 1770 |
| 22 | 1860 |
| 23 | 1940 |

* LOUDEST WHEN ALL 3 DIMENSIONS SUPPORT NORMAL MODES

* ALSO WE PERCEIVE LOUDNESS NON-UNIFORMLY FOR DIFFERENT FREQUENCIES OF SAME dB. THIS PERCEIVED LOUDNESS IS QUANTIFIED W/ EQUAL LOUDNESS CURVES




WE ARE MORE SENSITIVE TO FREQUENCIES IN THIS RANGE ~ 2000 → 4000 Hz

THUS ≈ 1860 Hz WOULD PROBABLY SOUND THE LOUDEST IN THIS SHOWER