Year 13 Science: Standing waves, harmonics, resonance and beats

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. A string 0.500 m long carries waves at 200 m s^{-1}. Find its fundamental frequency.

2. Find the wavelength of the 4th harmonic on that string.

3. A pipe 0.250 m long is closed at one end. Using v = 340 m s^{-1}, find the next frequency it can play above its fundamental.

4. Two tuning forks of 256 Hz and 260 Hz are struck together. Find the beat frequency.

5. The tension in a string is quadrupled. What happens to its fundamental frequency?

Exam-style question: a pan flute

Wiremu makes a pan flute from plastic tubes, each closed at the bottom. Take sound's speed as 343 m s^{-1} and ignore end corrections.

6. Calculate the fundamental frequency of a tube 0.180 m long.

7. Describe the displacement pattern of the next harmonic this tube can produce and calculate its frequency.

8. He plays the tube next to a 480 Hz tuning fork. Calculate the beat frequency and explain how the beats form.

9. On a hot day the speed of sound rises to 349 m s^{-1}. Explain what happens to the tube's fundamental and to the beats with the fork.

Fix the mistake

10. Correct this statement: "Nodes on a string are one wavelength apart."

11. Correct this statement: "A closed pipe's next harmonic after f_1 is $2f_1$."

12. Correct this statement: "Two notes of 256 Hz and 260 Hz give a beat frequency of 258 Hz."

13. Correct this statement: "Doubling the tension doubles the frequency."

Answer key (for parents and tutors)

1. A string 0.500 m long carries waves at 200 m s^{-1}. Find its fundamental frequency.
   $f_1 = v \div 2L = 200 \div 1.00 = 200$ Hz.
2. Find the wavelength of the 4th harmonic on that string.
   $\lambda = 2L \div n = 1.00 \div 4 = 0.250$ m.
3. A pipe 0.250 m long is closed at one end. Using v = 340 m s^{-1}, find the next frequency it can play above its fundamental.
   $f_1 = v \div 4L = 340 \div 1.00 = 340$ Hz; the next harmonic is the 3rd, $3 \times 340 = 1020$ Hz.
4. Two tuning forks of 256 Hz and 260 Hz are struck together. Find the beat frequency.
   f_beat = 260 − 256 = 4 Hz.
5. The tension in a string is quadrupled. What happens to its fundamental frequency?
   $v = \sqrt{(T/\mu)}$ doubles when T is multiplied by 4, and $f = v/2L$, so the fundamental doubles.
6. Calculate the fundamental frequency of a tube 0.180 m long.
   $f_1 = v \div 4L = 343 \div 0.720 = 476$ Hz (Achieved).
7. Describe the displacement pattern of the next harmonic this tube can produce and calculate its frequency.
   A node at the closed bottom and an antinode at the open top, with one more node and antinode between: $L = 3\lambda/4$. $f_3 = 3 \times 476.4 = 1429$ Hz, about 1430 Hz (Merit for the pattern and frequency).
8. He plays the tube next to a 480 Hz tuning fork. Calculate the beat frequency and explain how the beats form.
   f_beat = 480 − 476.4 = 3.6 Hz. The two sounds drift in and out of phase; in phase they interfere constructively and the sound is loud, 180° out of phase they interfere destructively and it is quiet, so the loudness pulses 3.6 times a second (Merit for the explanation).
9. On a hot day the speed of sound rises to 349 m s^{-1}. Explain what happens to the tube's fundamental and to the beats with the fork.
   The tube length is fixed, so $\lambda = 4L = 0.720$ m stays the same; $f = v/\lambda$ rises to $349 \div 0.720 = 484.7$ Hz. It is now above the fork, so the beat frequency is 484.7 − 480 = 4.7 Hz: the beats first slowed and stopped as the note passed 480 Hz, then sped up again (Excellence for linking fixed λ, v and f to the beats).
10. Correct this statement: "Nodes on a string are one wavelength apart."
    Neighbouring nodes are $\lambda/2$ apart, so one loop is half a wavelength.
11. Correct this statement: "A closed pipe's next harmonic after f_1 is $2f_1$."
    Only odd harmonics fit a closed pipe, so the next one is $3f_1$.
12. Correct this statement: "Two notes of 256 Hz and 260 Hz give a beat frequency of 258 Hz."
    The beat frequency is the difference, 4 Hz; about 258 Hz is the pitch you hear.
13. Correct this statement: "Doubling the tension doubles the frequency."
    f is proportional to $v = \sqrt{(T/\mu)}$, so doubling T multiplies f by $\sqrt{2}$; quadrupling T doubles it.