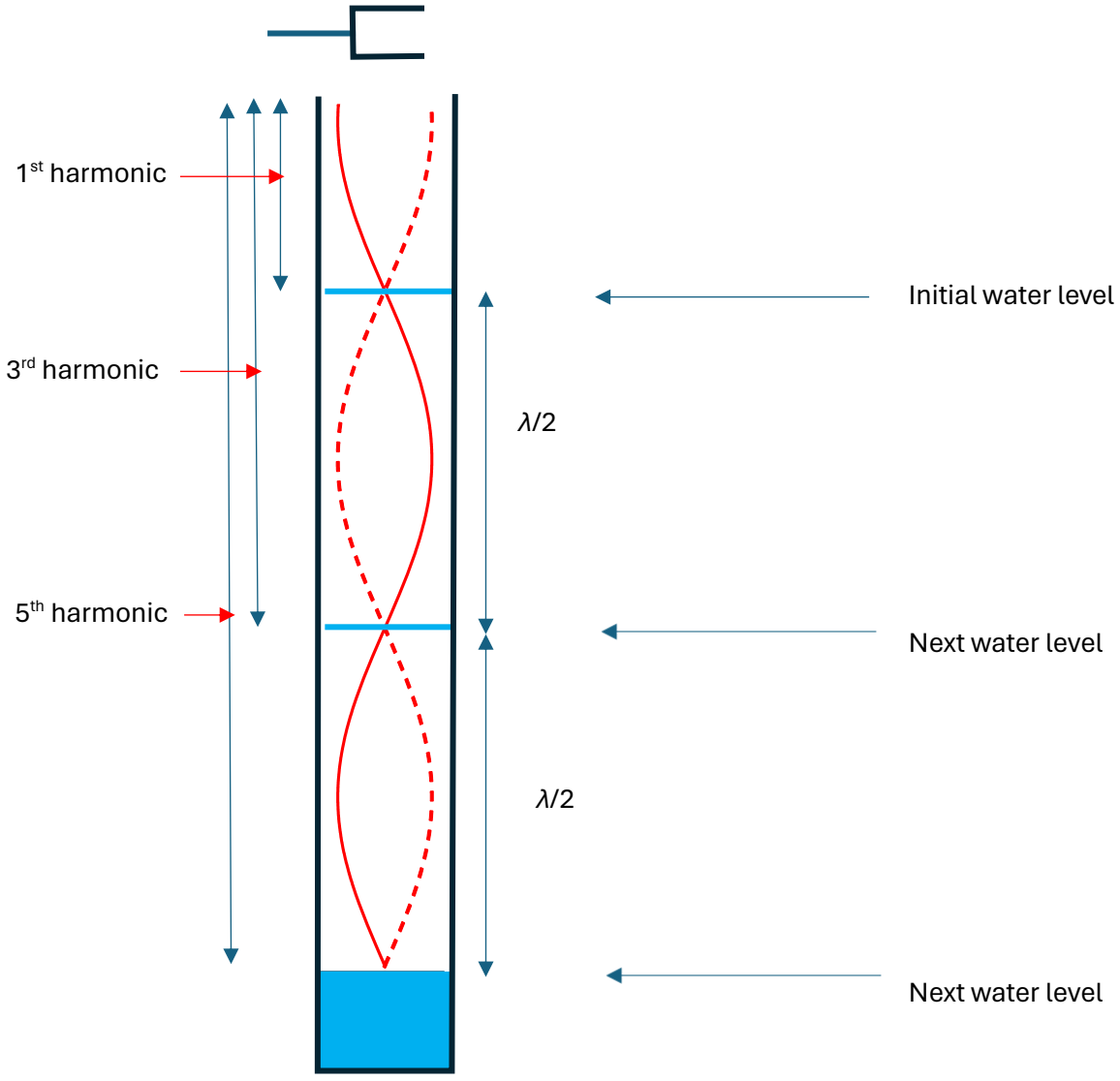
Teacher notes
Topic C

A common exam question.

A common exam question involves a tube filled with water and a tuning fork that sounds above the tube. A standing wave is established for a particular depth of water. Water is being taken out slowly. What is the next water level at which the next harmonic is established?

The tuning fork is the same, so all the standing waves formed have the same wavelength. So, draw a wave with a node on one end and an antinode on the other (red curve).



The horizontal lines show the level of the water for each harmonic. It is clear from the diagram that the water level has to be lowered by a distance equal to half a wavelength to get the next harmonic.

It is much preferable to explain this in terms of the diagram rather than the mathematical explanation which goes as:

The first harmonic has wavelength $\lambda = \frac{4L_1}{1}$ where L_1 is the length of the air column. The next harmonic has the same wavelength but different air column: $\lambda = \frac{4L_2}{3}$.

The difference in length of the air columns is then

$$L_2 - L_1 = \frac{3\lambda}{4} - \frac{\lambda}{4} = \frac{\lambda}{2}$$

as expected.

[In general, for two consecutive harmonics and *n* odd:

$\lambda = \frac{4L_n}{n}, \lambda = \frac{4L_{n+2}}{n+2}$ so that $L_{n+2} - L_n = \frac{(n+2)\lambda}{4} - \frac{n\lambda}{4} = \frac{\lambda}{2}$.

(We add 2 and not 1 because we only have the odd harmonics in a closed-open tube.)]

Questions

1. A standing wave is established in a tube partially filled with water when a tuning fork is sounded over the tube. Some water is slowly removed until the next harmonic is heard. The water level is decreased by 12 cm. By how much should the water level be decreased so that the next harmonic is heard?
2. A standing wave is established in a tube partially filled with water when a tuning fork of frequency 680 Hz is sounded over the tube. Some water is slowly removed until the next harmonic is heard. The water level has decreased by 25 cm. Estimate the speed of sound.

Answers

1. The water level is decreased by 12 cm so this is half a wavelength. The next harmonic will be heard when the level is decreased by another half a wavelength i.e. by 12 cm.
2. The wavelength is $2 \times 0.25 = 0.50 \text{ m}$ so $v = \lambda f = 0.50 \times 680 = 340 \text{ m s}^{-1}$.