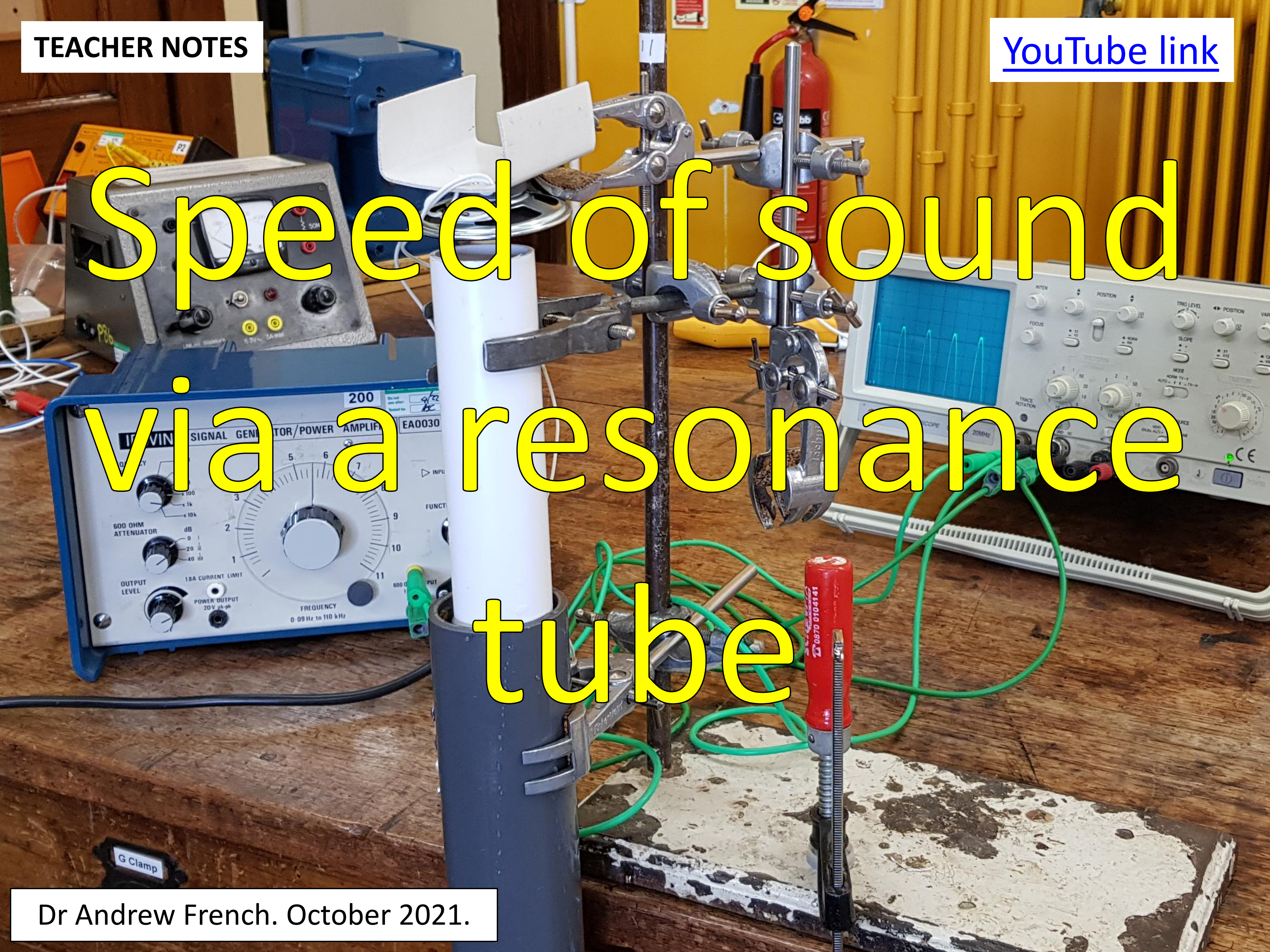
TEACHER NOTES

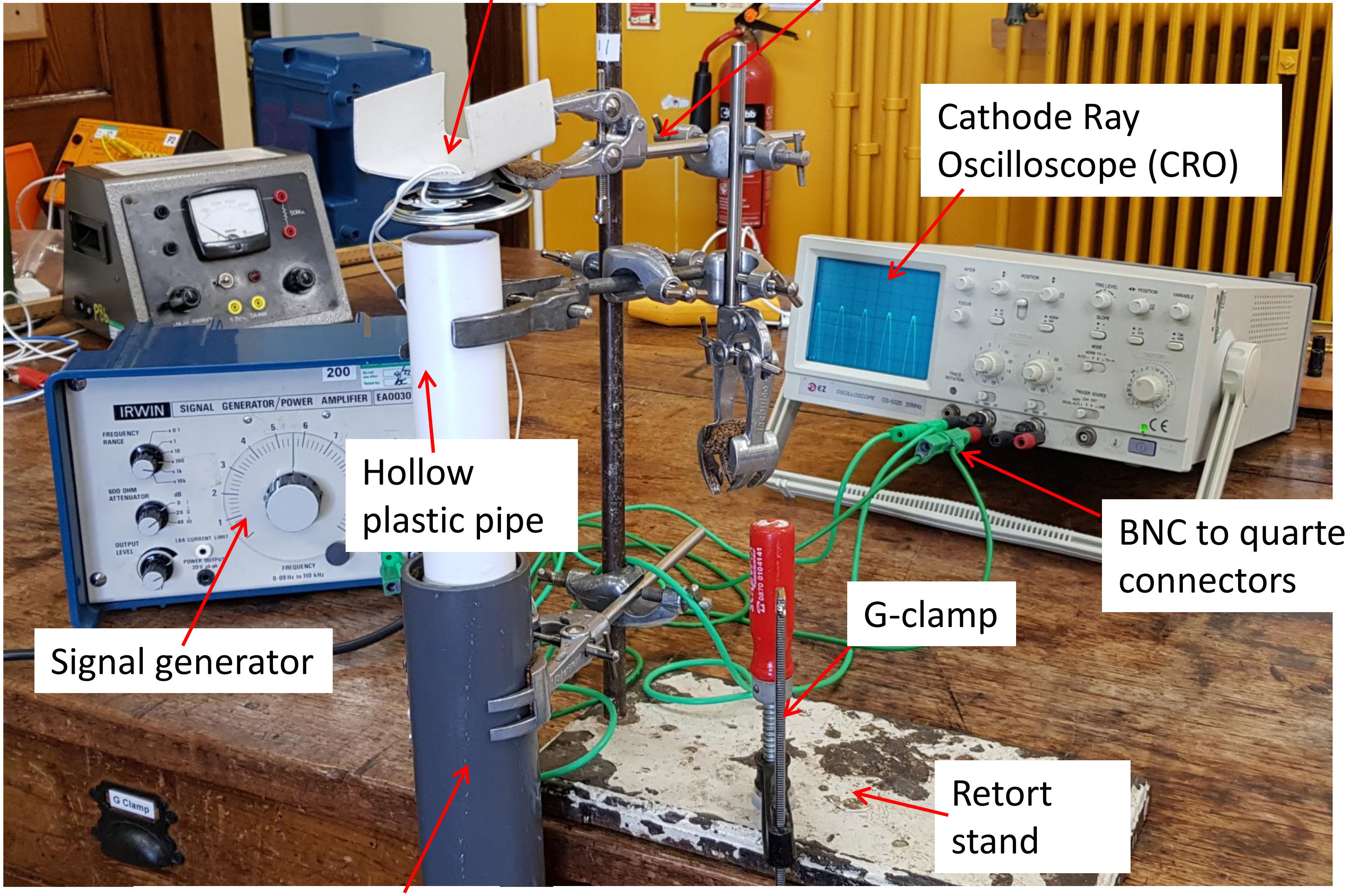
[YouTube link]

Speed of sound via a resonance tube



Dr Andrew French. October 2021.

Equipment



Loudspeaker

"Special" boss and clamp assembly (!)

Cathode Ray Oscilloscope (CRO)

Hollow plastic pipe

BNC to quarter-inch connectors

G-clamp

Signal generator

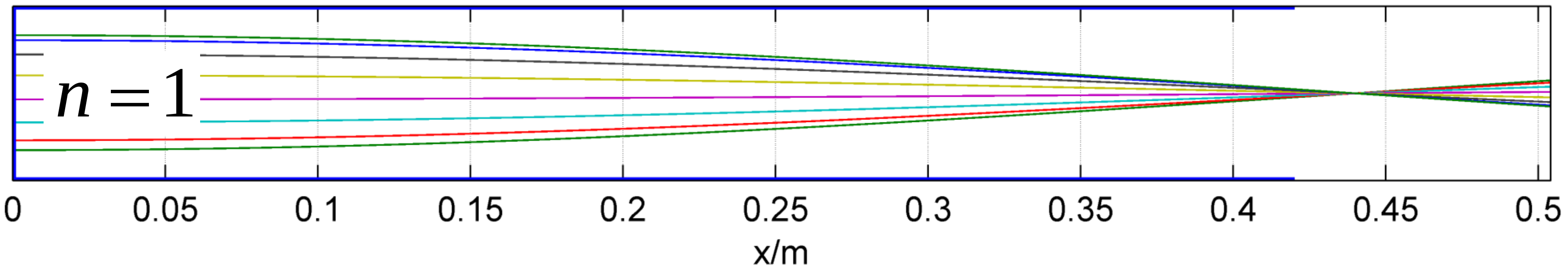
Retort stand

Plastic pipe filled with water (sealed lower end).

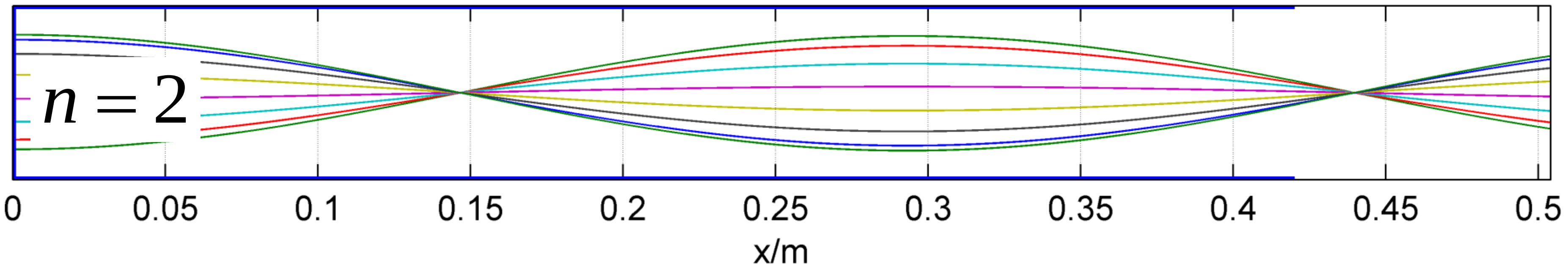
Plus:

- Overspill container underneath the water filled tube.
- Jug of water to top up water.

PRESSURE: L = 0.42m, Fundamental frequency = 193.3Hz, λ = 1.759m



Harmonic #1 frequency = 579.8Hz, λ = 0.5864m



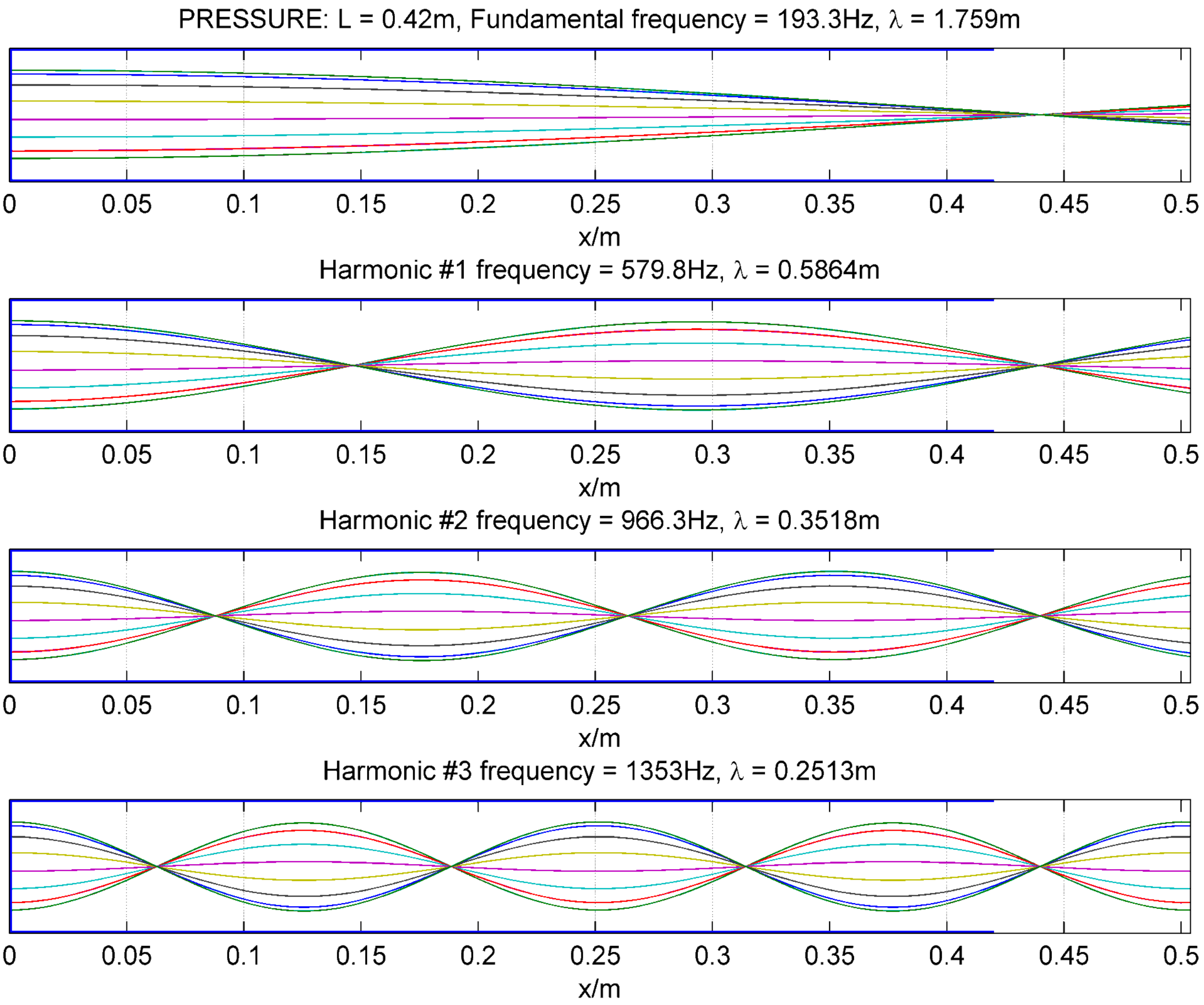
Standing waves in a tube of length L and radius r that is open at one end must have a **pressure antinode at the blocked end** (the water interface in our case) and **atmospheric pressure (i.e. a pressure node) at the open end**. *Note nodes and antinodes swap when describing displacement. i.e. a* ***displacement antinode*** *is a* ***pressure node*** *and vice versa.*

Tube length →

$$L_n + 0.66r = (2n-1)\tfrac{1}{4}\lambda_n$$

End correction

odd number of *quarter* wavelengths

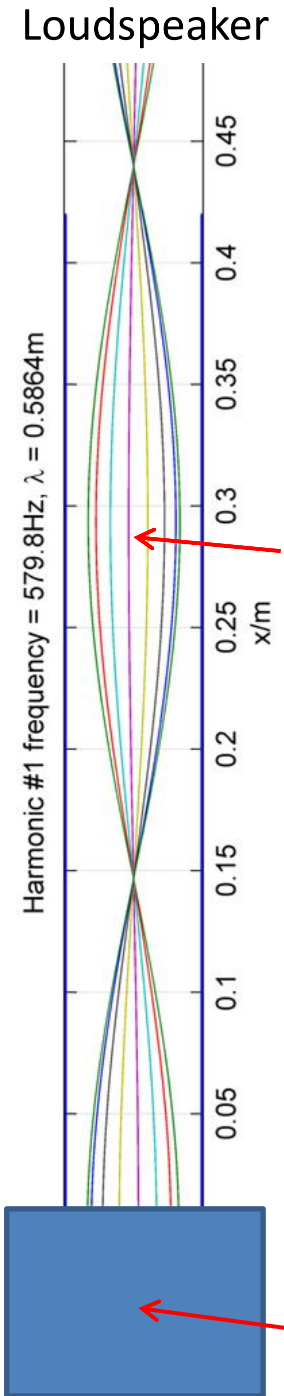


PRESSURE: L = 0.42m, Fundamental frequency = 193.3Hz, λ = 1.759m

Harmonic #1 frequency = 579.8Hz, λ = 0.5864m

Harmonic #2 frequency = 966.3Hz, λ = 0.3518m

Harmonic #3 frequency = 1353Hz, λ = 0.2513m



Sound pressure standing waves in tube at resonance

water

Open ended tube resonance condition

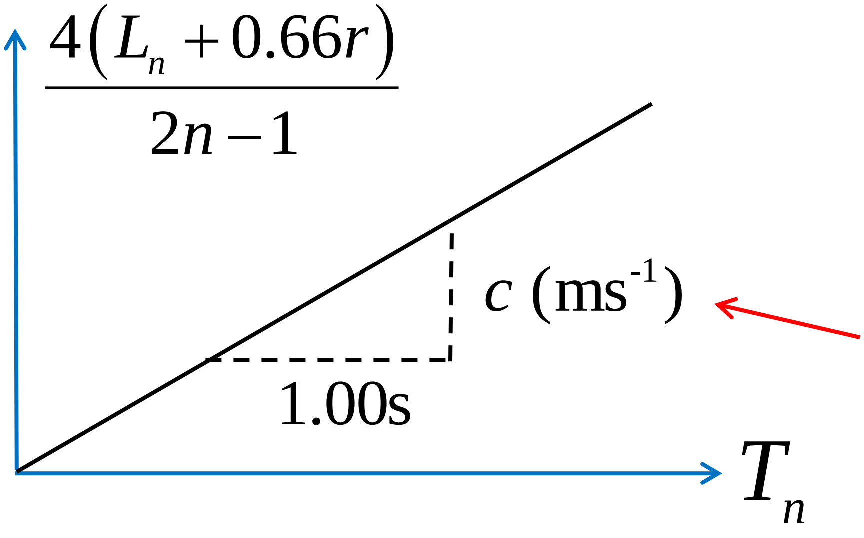
$$L_n + 0.66r = (2n-1)\tfrac{1}{4}\lambda_n$$

speed of sound → $c = \dfrac{\lambda_n}{T_n}$ ← wavelength, ← period

$$f_n = 1/T_n$$

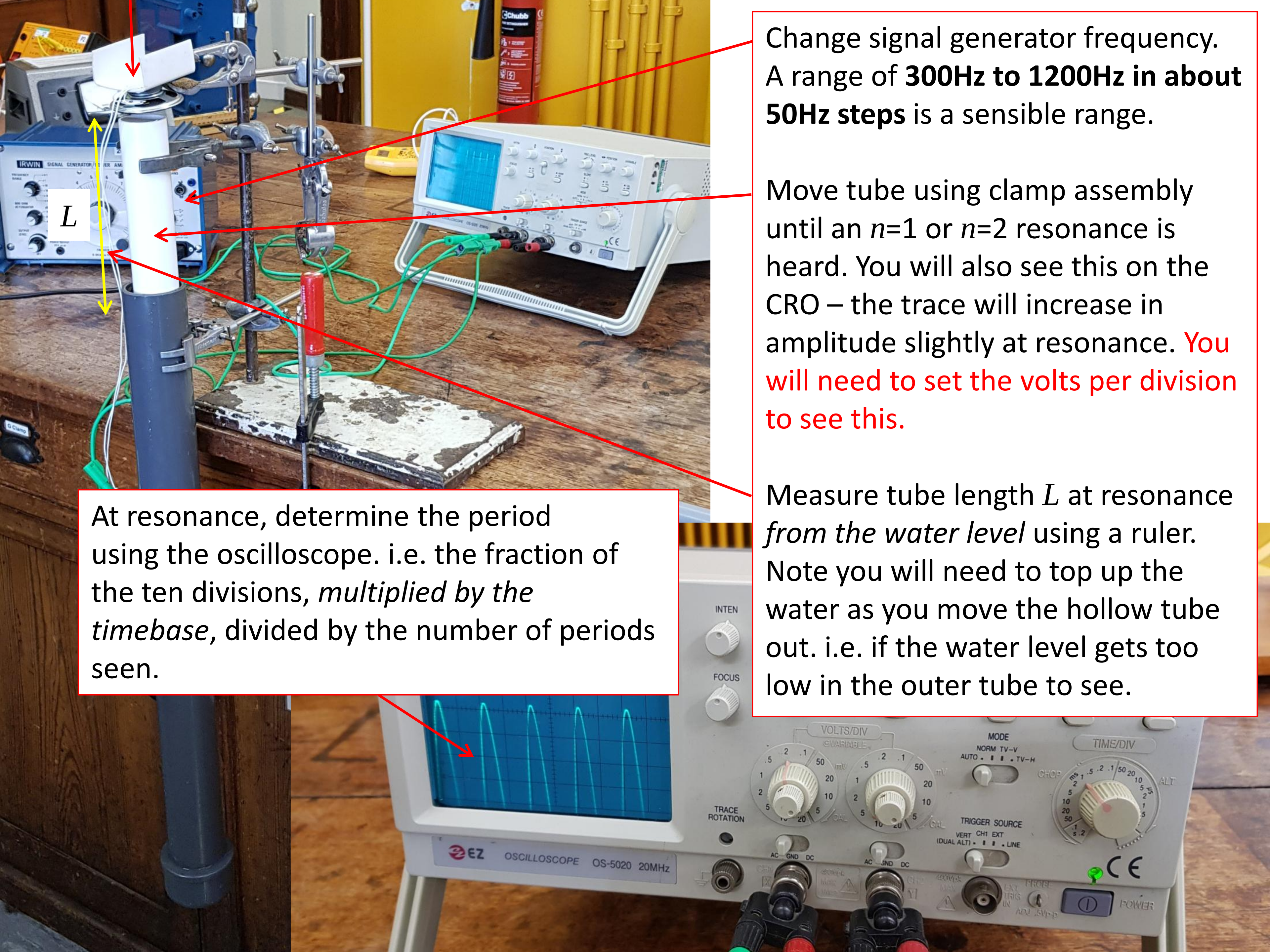
frequency

$$\therefore \frac{4(L_n + 0.66r)}{2n-1} = cT_n$$



Vary signal generator frequency and change tube length until resonance (n=1 or n=2) is achieved.

Plot this graph. The **gradient** should be the **speed of sound in air.** (About 330m/s).



Change signal generator frequency. A range of **300Hz to 1200Hz in about 50Hz steps** is a sensible range.

Move tube using clamp assembly until an n=1 or n=2 resonance is heard. You will also see this on the CRO – the trace will increase in amplitude slightly at resonance. You will need to set the volts per division to see this.

Measure tube length L at resonance *from the water level* using a ruler. Note you will need to top up the water as you move the hollow tube out. i.e. if the water level gets too low in the outer tube to see.

At resonance, determine the period using the oscilloscope. i.e. the fraction of the ten divisions, *multiplied by the timebase*, divided by the number of periods seen.

Measure this

Tube radius r /cm 3

If period T is in ms and L is in cm, multiply the gradient by 10 to get the speed of sound in m/s.

SPEED OF SOUND USING A RESONANCE TUBE, LOUDSPEAKER AND CRO

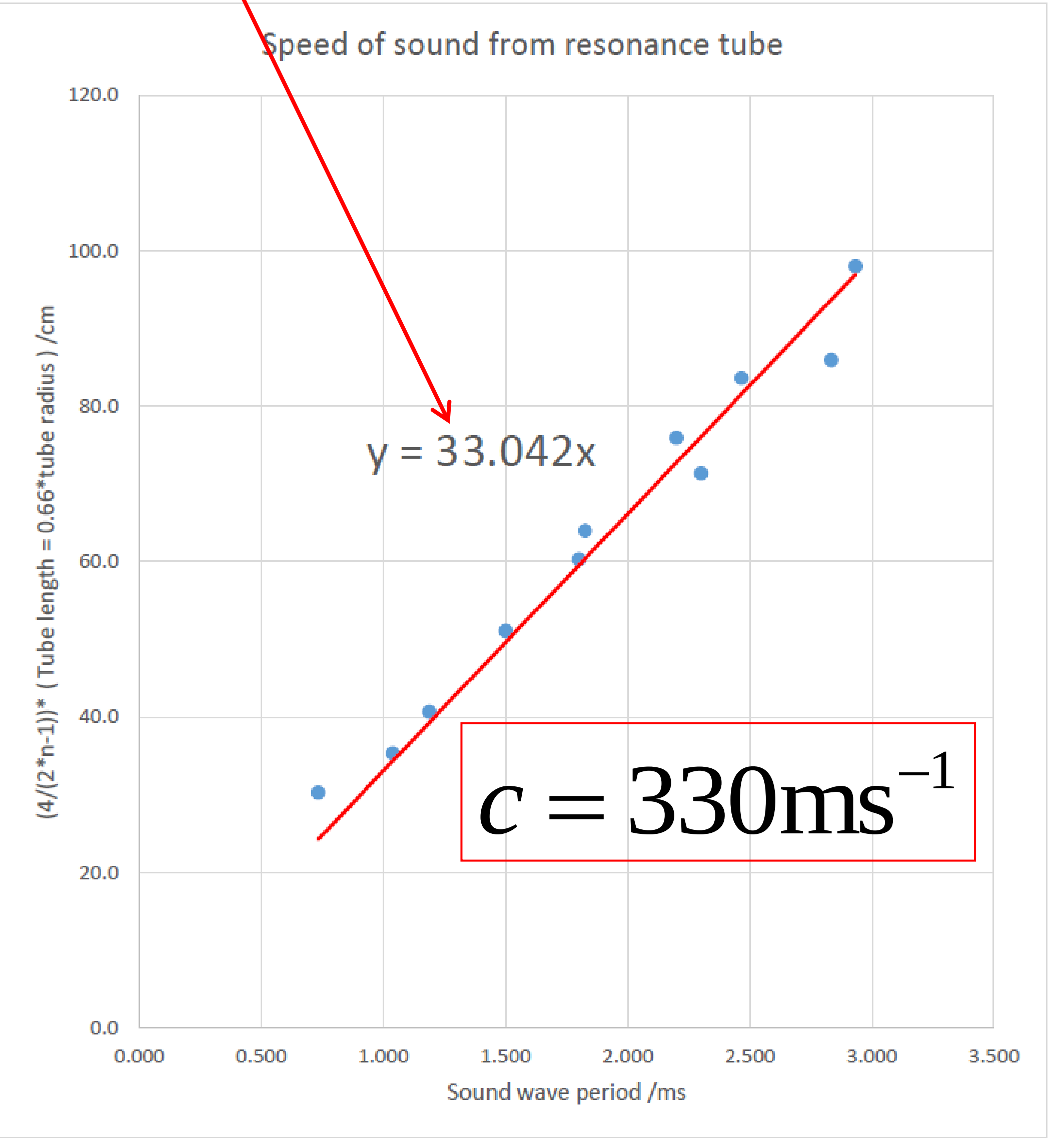
A. French 11/10/2021

Note (!) tuning fork range is 256Hz to 512Hz

Tube length /cm	Wave period /ms	f /Hz	n	4(L + 0.66r)/(2n-1)
20.7	0.733	1364	2	30.2
24.5	1.038	964	2	35.3
28.5	1.188	842	2	40.6
36.3	1.500	667	2	51.0
43.2	1.800	556	2	60.2
51.5	2.300	435	2	71.3
60.7	2.467	405	2	83.6
71.5	2.933	341	2	98.0
19.5	2.833	353	1	85.9
17	2.200	455	1	75.9
14	1.825	548	1	63.9

$$\frac{4\left(L_n+0.66r\right)}{2n-1}=cT_n$$

Both n=1 and n=2 measurements at 50Hz intervals between 300Hz and 1200Hz would yield an even more comprehensive dataset



$$c = 330\mathrm{ms}^{-1}$$