



(iii) in general, at what frequencies are there resonances?

We have to fit an odd number of quarter waves in the length of the line in general, so the frequencies are $(2m-1)f_{1short}$ where m is a positive integer (starting at 1)

(c) Returning again to case (a) (open circuit at both ends), what is the effect on the resonances of adding a resistor with value $R_{shunt} \ll Z$ across the line at the middle?

It will have no effect on all of the resonances with m odd, because they all have a zero in the voltage at the middle, so there will be no current across the resistor in those cases, and the resistor does nothing. For all of the resonances with m even, there is a maximum in the voltage there (without the resistor). Adding the resistor in the middle therefore suppresses those resonances because they would now become very lossy.

(d) For the case (b) above of the line short circuited at one end,

(i) where would you place a resistor so as to suppress the lowest frequency resonance of the line, but leave the next higher frequency resonance approximately unchanged?

The resistor should be placed one third of the wave along the line from the open end, so as to coincide with the zero in the second resonance (hence not affecting it). Though not at a maximum of the first resonance, the amplitude of the first resonance is substantial, and so it would experience significant loss from this resistor, and is therefore suppressed.

[Note for interest: This is the reason why the register key in a clarinet is placed 1/3 of the way along the pipe from the mouthpiece end of the instrument. The mouthpiece behaves as a stopped end on the pipe; the other end of the pipe is open. In this acoustic case, though, one should consider the pressure, in which case the mouthpiece end is a pressure maximum, so that stopped end is analogous to the open end of this transmission line if we are drawing an analogy between pressure and voltage, and the open end of the pipe is a pressure minimum, analogous to the closed end of the transmission line. The register key hole is therefore placed at a pressure node for the next resonance of the entire pipe. Opening this hole makes the clarinet play in its second, "clarion" register, a frequency three times higher than that of the lower, "chalumeau" register.]