15 A plumber and electrician decide to start a side business making 96Ω coaxial transmission lines. Their first product uses an outer conductor made from copper water pipe with an inside diameter of 0.5 inch. The inner conductor is made from solid copper wire with an outside diameter of 0.1 inch. They will use air as a dielectric.

a) Initially, they do not have enough 0.5 inch diameter water pipe. Having not taken ECE391, the plumber thought it would be fine to substitute copper water pipe with an inside diameter 0.625 inch. How will the current and voltage of an incident wave traveling down this transmission line change? Why? (give two reasons) [2]

The larger outside diameter of the outer conductor will decrease the parallel plate capacitance and slightly raise the per unit length inductance, thus Z_0 will go up. Thus the incident wave voltage will be higher & the incident wave current will be less.

b) The electrician thought they could save money and weight by using an inner conductor of hollow tubing with the same outside diameter of the solid copper wire. If they continue to use an outer conductor of 0.625 inch diameter copper pipe, how will the characteristic impedance of this new cable be different from the cable with the solid center conductor? Why?

The Z_0 of the new cable with hollow center conductor will be the same. This is because the capacitance between inner & outer conductors will not have changed. [2]

c) To help stabilize the inner conductor mechanically and to make use of all the Styrofoam packing peanuts they had accumulated, the plumber and electrician decide to replace the air dielectric with the peanuts. This changes the per unit length capacitance to 50pf/meter, and the Z_o to 92Ω. For the packing peanut enhanced line, determine the lines:

ii) inductance per meter [2]

ii) its velocity of propagation [2]

iii) its ϵ_r [2]

$Z_0 = \frac{1}{v^2 C}$

$92 = \frac{1}{v^2 C}$

$v = 2.17 \times 10^8 \, m/s$

$L = \frac{1}{v^2 C}$

$= \frac{1}{(2.17\times10^8)^2 (50\times10^{-12})}$

$= 424.7 nH$

$v = \frac{c}{\sqrt{\epsilon_r}}$

$2.17\times10^8 \, m/s = \frac{3\times10^8 \, m/s}{\sqrt{\epsilon_r}}$

$\epsilon_r = 1.9$