3. MUSIC (8 points) — *Lasse Frantti.* A band consisting of three physicists is on tour. The band plays progressive world music and is equipped with an electric guitar, pipe organ and tubular bells made of steel. Their first gig is at Tavastia-club in Helsinki, where they tune their instruments before the show. The air is comfortably dry and the temperature is 25 degrees Celsius.

i) *(6.5 points)* Their second gig is in Libya, where the temperature is 45 degrees Celsius. Their instruments are out of tune because of the scorching heat but all the tuning equipment has been left home. How badly out of tune are they? Estimate the audible change in the original 330 Hz tuning in all of the three instruments.

ii) *(1.5 points)* The tour ends with a private gig at a pulmonary clinic. The temperature in the treatment room is 25 degrees, but instead of air the room is filled with a mixture of helium and air (heliox). How does this affect the audible sound produced by the three instruments?

Speed of sound in air	$v_a = 331.3\,\mathrm{m/s}\sqrt{1 + \dfrac{t(^\circ\mathrm{C})}{273.15}}$
Speed of sound in heliox	$v_t = 1.7\,v_a$
Heat capacity of steel	$450\,\mathrm{J/kg \cdot K}$
Density of steel	$7900\,\mathrm{kg/m^3}$
Melting point of steel	$1540\,^\circ\mathrm{C}$
Heat conductivity of steel	$50\,\mathrm{W/mK}$
Young modulus of steel	$200\,\mathrm{GPa}$
Coefficient of thermal expansion (steel)	$12.0 \times 10^{-6}\,\mathrm{K^{-1}}$
Power of the guitar amplifier	$500\,\mathrm{W}$
Diameter of the guitar E string	$0.30\,\mathrm{mm}$
Free length of the E string	$65\,\mathrm{cm}$
Frequency of the E string	$330\,\mathrm{Hz}$

You can neglect the effects of temperature on the guitar body. The guitar string pitch is determined by the transverse standing wave frequency on the guitar string. The pipe organ pitch is determined by the longitudinal standing wave frequency of air in the pipe. The tubular bell pitch is determined by the transverse standing wave of the (steel) tube. You may use dimensional analysis where possible. Assume that the Young modulus of steel is constant in temperature.