4 A. A violin string is given a tension of 200 N. The string has a mass density of 0.004 kg/m.
(a) Find the velocity of waves in this string.
(b) Find the wavelength of a 440 Hz wave in this string.
(c) If the string is attached between supports 0.5 m apart, find a general formula for the allowed wavelengths in the system.
(d) For the three longest wavelengths you obtain in (c), find the frequency, in Hz.

\[ a. \quad V = \sqrt{\frac{200N}{0.004 \text{ kg/m}}} = \sqrt{\frac{2 \times 10^2}{4 \times 10^{-2}}} = \sqrt{.5 \times 10^5} = \sqrt{5 \times 10^2} \text{ m/s} = 224 \text{ m/s} \]

\[ b. \quad V = \lambda \nu \quad \text{at 440 Hz (c/s)} \]
\[ \lambda = \frac{\sqrt{5 \times 10^2}}{4 \times 10 \text{ Hz}} = \frac{\sqrt{5}}{4.4} = 0.508 \text{ m} \]

Since the ends of string at the ends are fixed, the allowed or natural standing waves must have nodes at these endpoints. The longest wavelength that meets this condition is:

\[ \lambda \text{ = wavelength} \]
\[ \frac{\lambda}{2} = l \quad l = \text{lengths between fixed endpoints} \]

Other wavelengths are then:
\[ \lambda = \frac{2n \nu}{k} \quad (n=1, 2, 3, \ldots) \]

\[ d. \quad \text{3 longest are} \]
\[ \lambda_1 = 1 \text{ m} \quad (n=1) \]
\[ \lambda_2 = .5 \text{ m} \quad (n=2) \]
\[ \lambda_3 = .333 \text{ m} \quad (n=3) \]

\[ \text{from } \lambda V = V = 224 \text{ m/s} \]
\[ V_1 = 224 \text{ Hz} \quad V_2 = 448 \text{ Hz} \quad V_3 = 672 \text{ Hz} \]