5. (20 pts) A cellist tunes the C-string of her instrument to a fundamental frequency of $65.4\,\text{Hz}$. The vibrating portion of the string is $0.60\,\text{m}$ long and has a mass of $14.4\times10^{-3}\,\text{kg}$. What fractional increase in tension is required to increase the frequency from $65.4\,\text{Hz}$ to $73.4\,\text{Hz}$ (an increase from a C note to a D note)? (Recall that fractional increase is defined as $\frac{new-old}{old}$.)

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$$f_n = \frac{n}{2L}\sqrt{\frac{F_T}{\mu}} \Rightarrow F_T = \frac{4L^2 f_n^2 \mu}{n^2}$$

here, $L = 0.60\,m$

$m = 14.4\times10^{-3}\,kg$

$\mu = \frac{m}{L} = 0.024\,kg/m$

$n = 1$ (fundamental).

F_C = tension for C-note f_C = frequency of C-note

F_D = tension for D-note f_D = frequency of D note

$$\frac{F_D - F_C}{F_C} = \frac{4L^2 f_D^2 \mu/n^2 - 4L^2 f_C^2 \mu/n^2}{4L^2 f_C^2 \mu/n^2} = \frac{f_D^2 - f_C^2}{f_C^2}$$

$$= \frac{(73.4)^2 - (65.4)^2}{(65.4)^2} = \boxed{0.260}$$

[You don't need to calculate F_D and F_C, since almost all the constants cancel. The correct values are

$$F_C = \frac{4L^2 f_C^2 \mu}{n^2} = \frac{(4)(0.6)^2(65.4)^2(0.024)}{1^2} = 147.8\,N$$

$$F_D = \frac{4(0.6)^2(73.4)^2(0.024)}{1^2} = 186.2$$

$$\frac{F_D - F_C}{F_C} = 0.260.\ ]$$