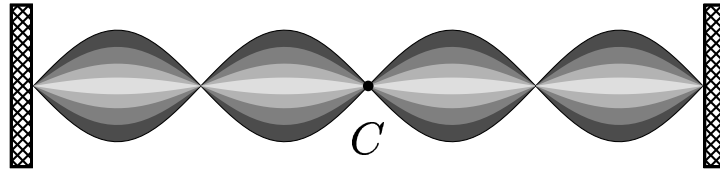


Consider a string of length  $L$  fixed at both ends. Its fundamental frequency gives a note A above middle C with frequency  $f_A = 440$  Hz. Now consider a second string of the same length, again fixed at both ends. Its mass per unit length is one-half of that of the first string and its tension is twice as large.



The frequency of second harmonics of the second string is given by

- A)  $f'_2 = \frac{1}{4} f_A$ .
- B)  $f'_2 = \frac{1}{2} f_A$ .
- C)  $f'_2 = f_A$ .
- D)  $f'_2 = 2 f_A$ .
- E)  $f'_2 = 4 f_A$ .

$$f_A = \frac{1}{2L} \sqrt{\frac{F}{\mu}} \quad \text{and} \quad f'_2 = 2 f'_1.$$

$$f'_1 = \frac{v'}{\lambda'} = \frac{1}{\lambda'} \sqrt{\frac{F'}{\mu'}}.$$

From the givens, both strings are fixed at both ends and have the same strength  $L$ .

The fundamental mode corresponds to half of a wavelength, or  $\lambda'_1 = 2L$ .

Also from the givens,  $F' = 2F$  and  $\mu' = 0.5\mu$ .

This leads to

$$f'_1 = \frac{1}{\lambda'} \sqrt{\frac{F'}{\mu'}} = \frac{1}{2L} \sqrt{\frac{2F}{0.5\mu}} = 2 \frac{1}{2L} \sqrt{\frac{F}{\mu}} = 2 f_A.$$

$$f'_2 = 2 f'_1 = 4 f_A.$$

Answer **E**