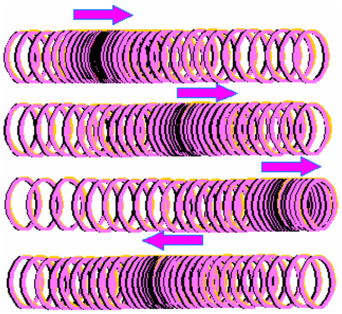
Spring Surge (Longitudinal vibration)

A Colorado State U ME lab shows this illustration of spring surge in a Slinky
http://www.engr.colostate.edu/~dga/me324/Labs/Lab%204/ME324%20-%20Lab%204.htm



And they give this expression for the surge frequency (From Norton's Machine Design. Prentice Hall, 2000, Eq. 13.11c):

$$f_n = \frac{2}{\pi N_a}\frac{d}{D^2}\sqrt{\frac{Gg}{32\rho}}\ Hz$$, where ρ is given as weight density, lb/in^3.

This is the same as Hamrock 2nd Edition, Equation 17.21.

In the 1st Edition, second printing of Hamrock, Equation 16.21 is the same as Norton's (including "g", the gravitational acceleration constant = 9.8 m/s^2 in the numerator of the square root). But, Hamrock (in his 1st Edition, second printing) specifies the density as kg/m^3, a mass density. That form would only be correct if the density was entered as a weight density (lb/in^3 or N/m^3) like Norton did. The 1st Edition, third printing corrects this by taking out the "g".

For steel springs where G and ρ are constants, this can be simplified to:

$$f_n = \frac{13{,}900d}{ND^2}\ Hz\quad (d\ \text{and}\ D\ \text{in inches})$$

$$f_n = \frac{353{,}000d}{ND^2}\ Hz\quad (d\ \text{and}\ D\ \text{in mm})$$

Incidentally, the units do come out to be correct. You get:

$$\frac{meters}{meters^2}\sqrt{\frac{Pascals}{kg/meters^3}} = \frac{1}{meters}\sqrt{\frac{Newton/meters^2}{kg/meters^3}}$$

$$= \frac{1}{meters}\sqrt{\frac{Newton}{kg/meters}} = \frac{1}{meters}\sqrt{\frac{kg*meters/seconds^2}{kg/meters}}$$

$$= \frac{1}{meters}\sqrt{\frac{meters^2}{seconds^2}} = \frac{1}{meters}\frac{meters}{seconds} = \frac{1}{seconds} = Hertz$$