17.19 A spring balance for weighing fish needs to be dimensioned. The weighing mechanism is a sharp hook hanging in a helical extension spring. To make it easy to read the weight of the fish in the range from zero to 10 kg, the length of the scale should be 100 mm. The spring material is music wire.

Notes: This is an open-ended problem in that there are more unknowns than equations. This solution demonstrates the design approach used for $C = 10$ and $d = 2$ mm.

Solution: Take $C = 10$, $d = 2$ mm, so $D = 20$ mm. From Table 17.1, for music wire, $G = 11.5$ Mpsi $= 79.3$ GPa. From Table 17.2 for music wire, $A_p = 2170$ MPa, $m = 0.146$. Therefore, the allowable shear stress is calculated from Eqs. (17.3) and (17.2) as:

$$S_{sy} = \tau_{\text{all}} = 0.4S_{ut} = 0.4\frac{A_p}{d^m} = 0.4\frac{2170 \text{ MPa}}{2^{0.146}} = 784 \text{ MPa}$$

The spring has a load ranging from 0 to (10 kg)(9.81 m/s^2) = 98.1 N. The deflection over this load is 100 mm, so the spring rate is $k = P/\delta =$ (98.1 N)/(0.1 m) = 981 N/m. From Eq. (17.18), the number of active coils is

$$k = \frac{Gd}{8C^3N_a} \quad \rightarrow \quad N_a = \frac{Gd}{8C^3k} = \frac{(79.3 \text{ GPa})(0.002 \text{ m})}{8(10^3)(981 \text{ N/m})} = 20.2$$

This spring will be loaded in a cyclic manner; therefore Eq. (17.11) should be used for the shear stress. The Wahl correction factor is given by Eq. (17.12) as

$$K_w = \frac{4C-1}{4C-4} + \frac{0.615}{C} = \frac{39}{36} + \frac{0.615}{10} = 1.14$$

The maximum shear stress is then, from Eq. (17.11),

$$\tau_{\max} = \frac{8DK_wP}{\pi d^3} = \frac{8(0.02 \text{ m})(1.14)(98.1 \text{ N})}{\pi(0.002 \text{ m})^3} = 712 \text{ MPa}$$

which is, fortunately, less than the allowable shear stress. The unloaded spring length, without the hook ends, is $N_a d = (20.2)(0.002 \text{ m}) = 0.0404$ m. The extended length is then 0.1404 m.