19.29 This problem asks for us to determine to what temperature a cylindrical rod of nickel 120.00 mm long and 12.000 mm in diameter must be cooled from 70°C in order to have a 0.023-mm reduction in diameter if the rod ends are maintained rigid. There will be two contributions to the diameter decrease of the rod; the first is due to thermal contraction (which will be denoted as Δd_1), while the second is from Poisson's lateral contraction as a result of elastic deformation from stresses that are established from the inability of the rod to contract as it is cooled (denoted as Δd_2). The magnitude of Δd_1 may be computed using a modified form of Equation 19.3b as

$$\Delta d_1 = d_0 \alpha_l (T_f - T_0)$$

Now, Δd_2 is related to the transverse strain (ε_x) according to a modified form of Equation 6.2 as

$$\frac{\Delta d_2}{d_0} = \varepsilon_x$$

Also, transverse strain and longitudinal strain (ε_z) are related according to Equation 6.8:

$$\varepsilon_x = -\nu\varepsilon_z$$

where ν is Poisson's ratio. Substitution of this expression for ε_x into the first equation above leads to

$$\frac{\Delta d_2}{d_0} = -\nu\varepsilon_z$$

Furthermore, the longitudinal strain is related to the modulus of elasticity through Equation 6.5—i.e.,

$$\varepsilon_z = \frac{\sigma}{E}$$

And, therefore,

$$\frac{\Delta d_2}{d_0} = -\nu\frac{\sigma}{E}$$

Now, from Equation 19.8 stress is equal to

$$\sigma = E\alpha_l (T_0 - T_f)$$