52. (a) Our notation is as follows: $h$ is the height of the toroid, $a$ its inner radius, and $b$ its outer radius. Since it has a square cross section, $h = b - a = 0.12\,\text{m} - 0.10\,\text{m} = 0.02\,\text{m}$.. We derive the flux using Eq. 30-26 and the self-inductance using Eq. 31-35:

$$\Phi_B = \int_a^b B\,dA = \int_a^b \left(\frac{\mu_0 N i}{2\pi r}\right) h\,dr = \frac{\mu_0 N i h}{2\pi} \ln\left(\frac{b}{a}\right)$$

and $L = N\Phi_B/i = (\mu_0 N^2 h/2\pi)\ln(b/a)$. We note that the formulas for $\Phi_B$ and $L$ can also be found in the Supplement for the chapter, in Sample Problem 31-11. Now, since the inner circumference of the toroid is $l = 2\pi a = 2\pi(10\,\text{cm}) \approx 62.8\,\text{cm}$, the number of turns of the toroid is roughly $N \approx 62.8\,\text{cm}/1.0\,\text{mm} = 628$. Thus

$$\begin{aligned} L &= \frac{\mu_0 N^2 h}{2\pi} \ln\left(\frac{b}{a}\right) \\ &\approx \frac{\left(4\pi \times 10^{-7}\,\text{H/m}\right)(628)^2(0.02\,\text{m})}{2\pi} \ln\left(\frac{12}{10}\right) \\ &= 2.9 \times 10^{-4}\ \text{H}\ . \end{aligned}$$

(b) Noting that the perimeter of a square is four times its sides, the total length $\ell$ of the wire is $\ell = (628)4(2.0\,\text{cm}) = 50\,\text{m}$, the resistance of the wire is $R = (50\,\text{m})(0.02\,\Omega/\text{m}) = 1.0\,\Omega$. Thus

$$\tau_L = \frac{L}{R} = \frac{2.9 \times 10^{-4}\,\text{H}}{1.0\,\Omega} = 2.9 \times 10^{-4}\ \text{s}\ .$$