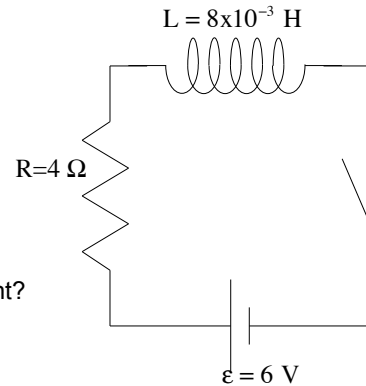


## Problem 20.48

For the circuit shown, determine:

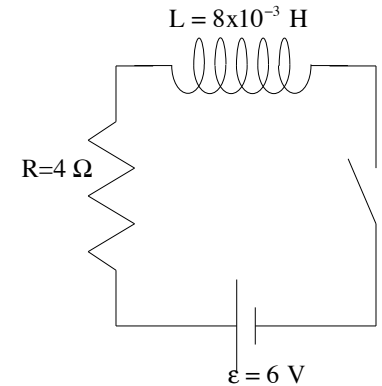
- what is the time constant?
- what is the current in the circuit after two-hundred fifty microseconds (00025 seconds)?
- what is the final steady-state current?
- how long does the current take to reach 80% of its maximum value?



1.

Putting in the numbers:

$$\begin{aligned}
 I &= \frac{\varepsilon}{R} \left( 1 - e^{-t/(L/R)} \right) \\
 &= \frac{(6 \text{ V})}{(4 \ \Omega)} \left( 1 - e^{-\left(2.5 \times 10^{-4}\right) / \left( \frac{8 \times 10^{-3} \text{ H}}{4 \ \Omega} \right)} \right) \\
 &= .176 \text{ A}
 \end{aligned}$$



3.

- what is the time constant?

$$\begin{aligned}
 \tau_L &= L/R \\
 &= \frac{(8 \times 10^{-3} \text{ H})}{(4 \ \Omega)} \\
 &= 2 \times 10^{-3} \text{ seconds}
 \end{aligned}$$

- what is the current in the circuit after  $2.5 \times 10^{-4}$  seconds?

Though I don't usually use relationships like this, this is the easiest way to calculate this:

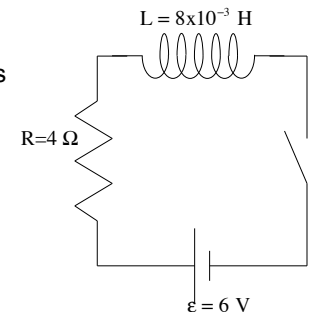
$$\begin{aligned}
 I &= \frac{\varepsilon}{R} \left( 1 - e^{-t/\tau} \right) \\
 &= \frac{\varepsilon}{R} \left( 1 - e^{-t(L/R)} \right)
 \end{aligned}$$

2.

- what is the final steady-state current?

Once the current hits steady-state, there is no longer a change in current, which means there is no longer a changing magnetic flux through the coil (or it's associated "back EMF"). In other words, the current is what you would expect for a circuit in which there are only resistors.

$$\begin{aligned}
 V_R &= iR \\
 \Rightarrow i &= \frac{V}{R} \\
 &= \frac{(6 \text{ V})}{(4 \ \Omega)} \\
 &= 1.5 \text{ A}
 \end{aligned}$$

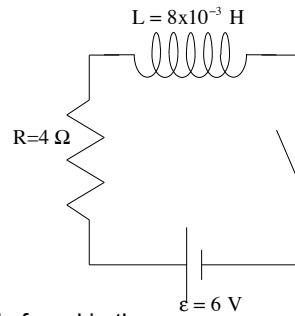


4.

d.) how long does the current take to reach 80% of its maximum value?

The general expression for the time dependent current in an RL circuit is shown below.

$$I = \frac{\varepsilon}{R} \left( 1 - e^{-t(L/R)} \right)$$



When the current is at .8i, the fractional part is found in the

$$\left( 1 - e^{-t(R/L)} \right)$$

term. In other words, the time we are looking for is such that:

$$.8 = \left( 1 - e^{-t(R/L)} \right)$$

5.

Solving this, we get:

$$.8 = 1 - e^{-t(R/L)}$$

$$\Rightarrow .2 = e^{-t(R/L)}$$

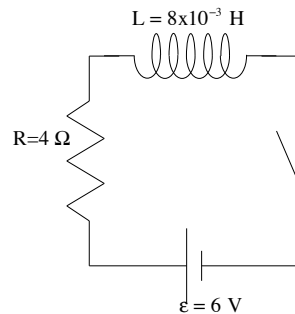
$$\Rightarrow \ln(.2) = \ln\left(e^{-t(R/L)}\right)$$

$$\Rightarrow \ln(.2) = -t\left(\frac{R}{L}\right)$$

$$\Rightarrow t = -\left(\frac{L}{R}\right)\ln(.2)$$

$$\Rightarrow t = -\left(\frac{(8 \times 10^{-3} \text{ H})}{(4 \Omega)}\right)\ln(.2)$$

$$\Rightarrow t = 3.3 \times 10^{-3} \text{ seconds}$$



6.