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1. EXPERIMENT 4 - PRELIMINARY WORK

1.1 For the circuit given in Fig. 1, sketch roughly the waveforms of $V_L(t)$ and $V_R(t)$.

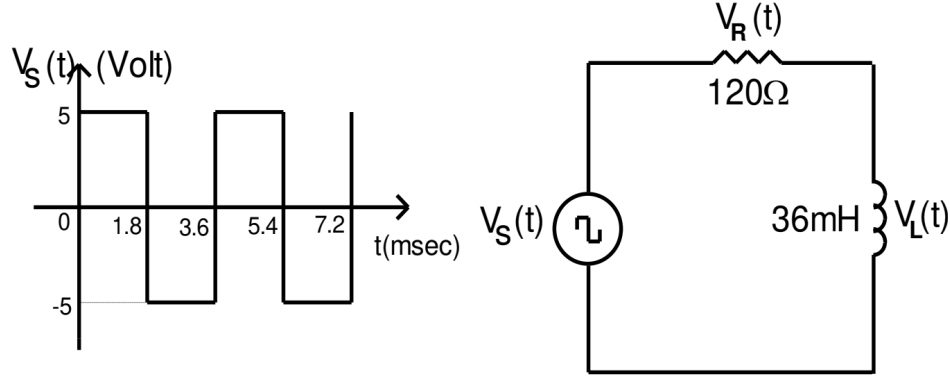


Figure 1

Answer: Let I_S be the current in the circuit. Use a KVL equation for $0 < t < 1.8$ ms.

$$V_S - V_R - V_L = 0 \implies V_S = 120I_S + 36 \times 10^{-3} \frac{dI_S}{dt} \implies \frac{V_S - 120I_S}{36 \times 10^{-3}} = \frac{dI_S}{dt}$$

Rearrange the equation.

$$\begin{aligned} \frac{10^3}{36} dt &= \frac{dI_S}{V_S - 120I_S} \implies \frac{10^3}{36} \int_0^t d\tau = \int_{I_S(0)}^{I_S(t)} \frac{dx}{V_S - 120x} \\ \implies \frac{10^3 \tau}{36} \Big|_{\tau=0}^{\tau=t} &= -\frac{1}{120} \ln |V_S - 120x| \Big|_{x=I_S(0)}^{x=I_S(t)} \implies -\frac{250t}{9} = \frac{1}{120} \ln \left(\frac{V_S - 120I_S(t)}{V_S - 120I_S(0)} \right) \\ \implies e^{-10000t/3} &= \frac{V_S - 120I_S(t)}{V_S - 120I_S(0)} \implies I_S(t) = \frac{V_S}{120} + \left(I_S(0) - \frac{V_S}{120} \right) e^{-10000t/3} \end{aligned}$$

The current in the circuit decays exponentially over time. The voltages across the inductor and the resistor, respectively, are

$$V_L = L \frac{dI_S}{dt} = 36 \times 10^{-3} \cdot \left(I_S(0) - \frac{V_S}{120} \right) e^{-10000t/3} \cdot \left(-\frac{10000}{3} \right) = (V_S - 120I_S(0)) e^{-10000t/3}$$

$$V_R = I_S R = V_S + (120I_S(0) - V_S) e^{-10000t/3}$$

One problem is that we need to know the value of $I_S(0)$, which is not given in the question. Let's assume that $I_S = -\frac{V_S(0^+)}{120}$, then

$$\left. \begin{aligned} V_L(t) &= 10e^{-10000t/3} \text{ V} \\ V_R(t) &= 5 - 10e^{-10000t/3} \text{ V} \end{aligned} \right\} 0 < t < 1.8 \text{ ms}$$

For $1.8 \text{ ms} < t < 3.6 \text{ ms}$, the polarity of the source changes. Assume that the final voltages are attained, i.e., the difference in the voltage at $t = 1.8 \text{ ms}$ and the final voltage is negligible. Therefore, the equations also change sign.

$$\left. \begin{aligned} V_L(t) &= -10e^{-10000(t-1.8 \text{ ms})/3} \text{ V} \\ V_R(t) &= -5 + 10e^{-10000(t-1.8 \text{ ms})/3} \text{ V} \end{aligned} \right\} 1.8 \text{ ms} < t < 3.6 \text{ ms}$$

Since $0 < t < 3.6 \text{ ms}$ comprises one square wave, we can sketch the entire graph.

