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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 $V_R(t)$.

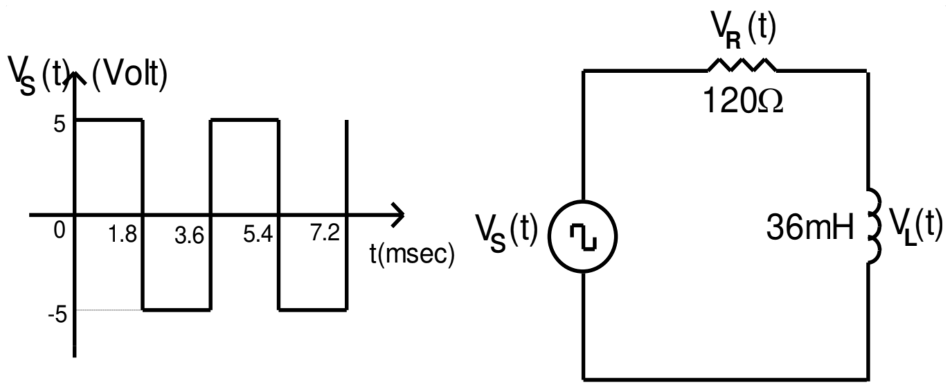

Figure 1

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

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

Rearrange the equation.

$$\frac{10^3}{36}\, dt = \frac{dI_S}{V_S - 120 I_S} \implies \frac{10^3}{36} \int_0^t d\tau = \int_{I_S(0)}^{I_S(t)} \frac{dx}{V_S - 120x}$$

$$\implies \left.\frac{10^3 \tau}{36}\right|_{\tau=0}^{\tau=t} = -\frac{1}{120} \ln |V_S - 120x| \Big|_{x=I_S(0)}^{x=I_S(t)} \implies -\frac{250t}{9} = \frac{1}{120} \ln \left(\frac{V_S - 120 I_S(t)}{V_S - 120 I_S(0)} \right)$$

$$\implies e^{-10000t/3} = \frac{V_S - 120 I_S(t)}{V_S - 120 I_S(0)} \implies I_S(t) = \frac{V_S}{120} + \left(I_S(0) - \frac{V_S}{120} \right) e^{-10000t/3}$$

The voltages across the inductor and the resistor, respectively, are

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

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

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 $I_S = -\dfrac{V_S(0^+)}{120}$, then

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

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

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

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