1. \[ R = 0.5 \ \Omega \quad L = 1.5 \ \mu H \quad C = 1.5 \ \mu F \]

a) Find the characteristic roots, \( s_1 \) and \( s_2 \), for the above circuit.

b) Is the circuit over-damped, critically-damped, or under-damped? Explain.

c) If the \( L \) and \( C \) values in the circuit are decreased by a factor of two, (and \( R \) remains the same), will the circuit be over-damped, critically-damped, or under-damped? Justify your answer with calculations.

2. \[ C = 1 \ \text{mF} \quad L = 25 \ \text{mH} \]

A relay is driven by a 24 V power supply, as shown above. Power is turned off at \( t = 0 \). The current, \( i(t) \), for \( t > 0 \) has two terms that decay exponentially without oscillation. One term dies out quickly, and the other term dies out with a time constant of \( \tau = 10 \ \text{ms} \), as in \( e^{-t/10\text{ms}} \). Given the time constant and the information in the diagram above, find the value of \( R \).

3. After being open for a long time, the switch closes at \( t = 0 \).

Find \( i(t) \) for \( t > 0 \).
4.

A 12 V power supply drives a long wire, (modeled as $L$ and $R_1$), followed by a short wire, $R_2$, and a smoothing capacitor, $C$. There is a safety switch, located before the smoothing capacitor, to turn off the output at the remote end. The switch is closed for a long time before opening at $t = 0$.

$L = 2 \mu H \quad R_1 = 2.0 \Omega \quad R_2 = 0.1 \Omega \quad C = 200 \mu F$

a) Find the characteristic roots, $s_1$ and $s_2$, for the above circuit.

b) Find $v_{out}$ for $t > 0$.

5.

After being open for a long time, the switch closes at $t = 0$.

a) Give expressions for the following in terms of no more than $v_g$, $R_1$, $R_2$, $L$, and $C$:

\[
i(t = 0^+) \quad \text{and} \quad \left. \frac{di(t)}{dt} \right|_{t=0^+}
\]

b) Find the numerical value of $R_2$ given the following information:

$R_1 = 150 \Omega \quad L = 40 \text{ mH} \quad C = 3.2 \mu F$

$\alpha = 1250 \text{ r/s} \quad \omega_d = 2500 \text{ r/s}$
Answers:
1.a) Duplicate roots = -2/3 Mr/s.  c) critically damped
2. R = 12.5 Ω
3. \( i(t) = -\frac{8}{9} e^{-160kt/s} \sin(120kt) + \frac{1}{3} \) A
4.a) Partial answer: \( s_1 = -2.4 \) kr/s overdamped.
   b) \( v_{out}(t > 0) = -12.06 e^{-2.4kst} + 0.06 e^{-1.05Mst} + 12 \) V Find a way to handle approximations.
5.a) Partial answer: \[ \frac{di(t)}{dt}_{t=0^+} = \frac{1}{R_2} \frac{ic(t = 0^+)}{C} = -\frac{v_g}{R_2C(R_1 + R_2)}. \] b) \( R_2 = 125 \) Ω.