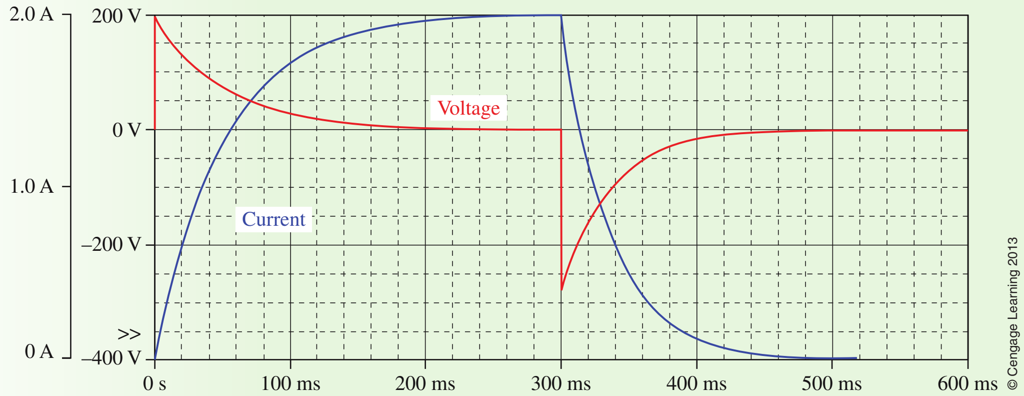
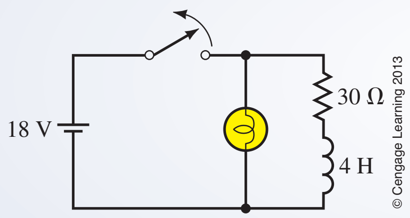


FIGURE 14–36 Inductor voltage and current for the circuit of Figure 14–35.

Putting It into Practice



The first sample of a new product that your company has designed has an indicator light that fails. (Symptom: When you turn a new unit on, the indicator light comes on as it should. However, when you turn the power off and back on, the lamp does not come on again.) You have been asked to investigate the problem and design a fix. You acquire a copy of the schematic and study the portion of the circuit where the indicator lamp is located. As shown in the accompanying figure, the lamp is used to indicate the status of the coil; the light is to be on when the coil is energized and off when it is not. Immediately, you see the problem, solder in one component and the problem is fixed. Write a short note to your supervisor outlining the nature of the problem, explaining why the lamp burned out and why your design modification fixed the problem. Note also that your modification did not result in any substantial increase in power consumption (i.e., you did not use a resistor). Note: This problem requires a diode. If you have not had an introduction to electronics, you may not be able to do this problem.

Problems

14.1 Introduction

1. a. What does an inductor carrying no current look like at the instant of switching?
   b. For each circuit of Figure 14–37, determine i_S and v_L immediately after the switch is closed.
2. Determine all voltages and currents in Figure 14–38 immediately after the switch is closed.
3. Repeat Problem 2 if L_1 is replaced with an uncharged capacitor.

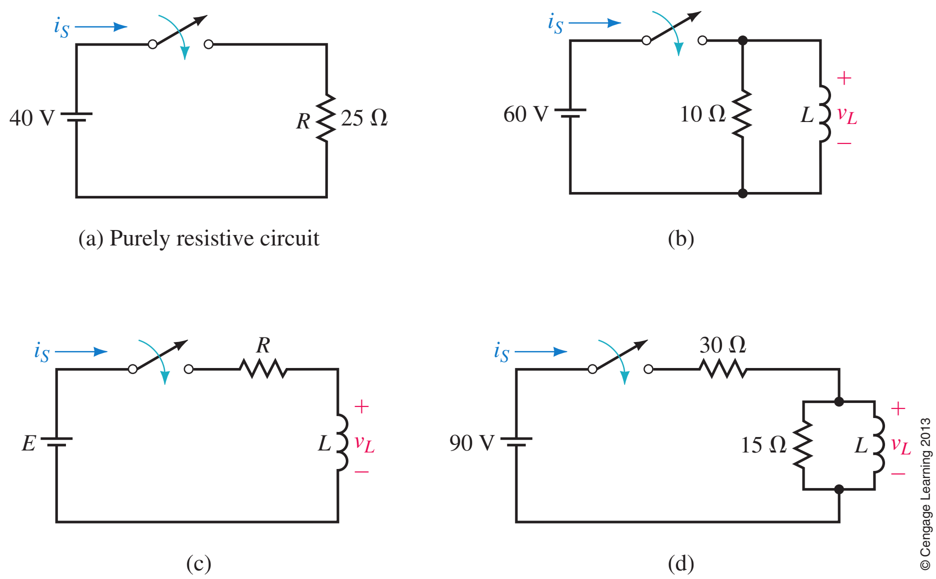


FIGURE 14–37 No value is needed for L here as it does not affect the solution.

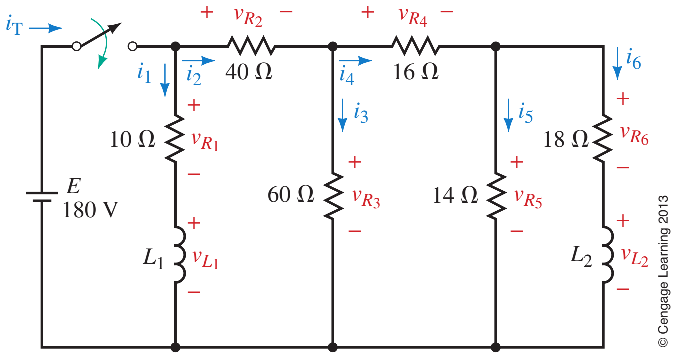


FIGURE 14–38

14.2 Current Buildup Transients

4. a. If $i_L = 8(1 - e^{-500t})$ A, what is the current at $t = 6$ ms?
   b. If $v_L = 125e^{-500t}$ V, what is the voltage v_L at $t = 5$ ms?
5. The switch of Figure 14–39 is closed at $t = 0$ s.
   a. What is the time constant of the circuit?
   b. How long is it until current reaches its steady value?
   c. Determine the equations for i_L and v_L.
   d. Compute values for i_L and v_L at intervals of one time constant from $t = 0$ to 5 τ.
   e. Sketch i_L and v_L. Label the axis in τ and in seconds.
6. Close the switch at $t = 0$ s and determine equations for i_L and v_L for the circuit of Figure 14–40. Compute i_L and v_L at $t = 1.8$ ms.
7. Repeat Problem 5 for the circuit of Figure 14–41 with $L = 4$ H.
8. For the circuit of Figure 14–39, determine inductor voltage and current at $t = 50$ ms using the universal time constant curve of Figure 14–10.

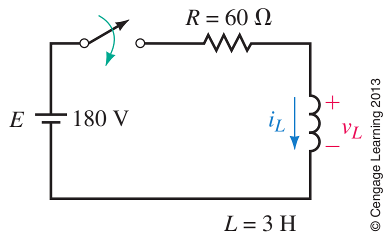


FIGURE 14–39

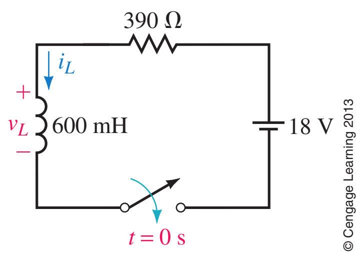


FIGURE 14–40

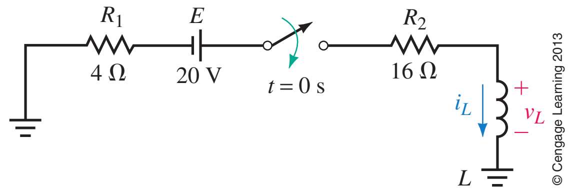


FIGURE 14–41

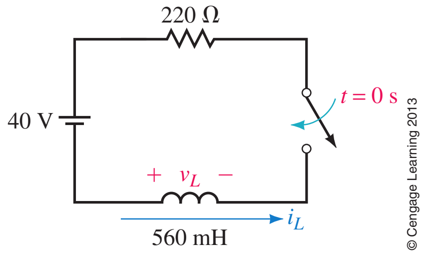


FIGURE 14–42

9. Close the switch at $t = 0$ s and determine equations for i_L and v_L for the circuit of Figure 14–42. Compute i_L and v_L at $t = 3.4$ ms.
10. Using Figure 14–10, find v_L at one time constant for the circuit of Figure 14–42.
11. For the circuit of Figure 14–1(b), the voltage across the inductance at the instant the switch is closed is 80 V, the final steady state current is 4 A, and the transient lasts 0.5 s. Determine E, R, and L.
12. For an RL circuit, $i_L = 20(1 - e^{-t/\tau})$ mA and $v_L = 40e^{-t/\tau}$ V. If the transient lasts 0.625 ms, what are E, R, and L?
13. For Figure 14–1(b), if $v_L = 40e^{-2000t}$ V and the steady state current is 10 mA, what are E, R, and L?

14.4 De-Energizing Transients

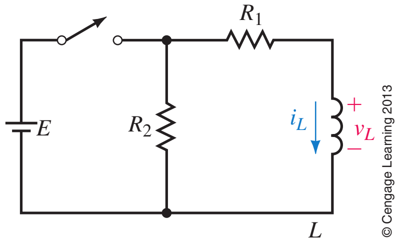


FIGURE 14–43

14. For Figure 14–43, $E = 80$ V, $R_1 = 200\ \Omega$, $R_2 = 300\ \Omega$, and $L = 0.5$ H.
    a. When the switch is closed, how long does it take for i_L to reach steady state? What is its steady state value?
    b. When the switch is opened, how long does it take for i_L to reach steady state? What is its steady state value?
    c. After the circuit has reached steady state with the switch closed, it is opened. Determine equations for i_L and v_L.
15. For Figure 14–43, $R_1 = 20\ \Omega$, $R_2 = 230\ \Omega$, and $L = 0.5$ H, and the inductor current has reached a steady value of 5 A with the switch closed. At $t = 0$ s, the switch is opened.
    a. What is the decay time constant?
    b. Determine equations for i_L and v_L.
    c. Compute values for i_L and v_L at intervals of one time constant from $t = 0$ to $5\ \tau$.
    d. Sketch i_L and v_L. Label the axis in τ and in seconds.
16. Using the values from Problem 15, determine inductor voltage and current at $t = 3\tau$ using the universal time constant curves shown in Figure 14–10.
17. Given $v_L = -2700\ \mathrm{V}e^{-100t}$. Using the universal time constant curve, find v_L at $t = 20$ ms.
18. For Figure 14–43, the inductor voltage at the instant the switch is closed is 150 V and $i_L = 0$ A. After the circuit has reached steady state, the switch is opened. At the instant the switch is opened, $i_L = 3$ A and v_L jumps to -750 V. The decay transient lasts 5 ms. Determine E, R_1, R_2, and L.
19. For Figure 14–43, $L = 20$ H. The current during buildup and decay is shown in Figure 14–44. Determine R_1 and R_2.
20. For Figure 14–43, when the switch is moved to energization, $i_L = 2$ A $(1 - e^{-10t})$. Now open the switch after the circuit has reached steady state and redefine $t = 0$ s as the instant the switch is opened. For this case, $v_L = -400\ \mathrm{V}e^{-25t}$. Determine E, R_1, R_2, and L.

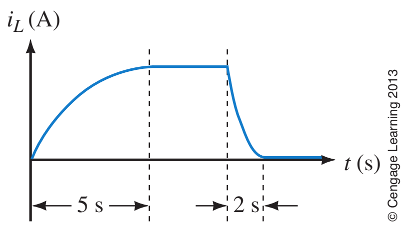


FIGURE 14–44

14.5 More Complex Circuits

21. For the coil of Figure 14–45, $R_\ell = 1.7\ \Omega$ and $L = 150$ mH. Determine coil current at $t = 18.4$ ms.

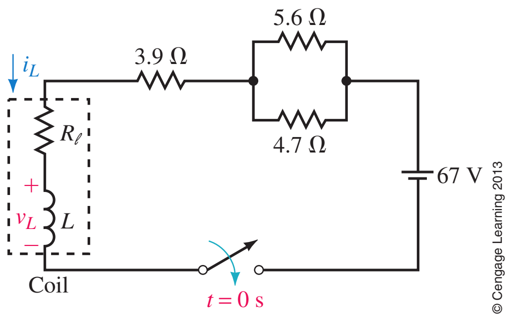


FIGURE 14–45

22. Refer to Figure 14–46:
    a. What is the energizing circuit time constant?
    b. Close the switch and determine the equation for i_L and v_L during current buildup.
    c. What is the voltage across the inductor and the current through it at $t = 20\ \mu$s?
23. For Figure 14–46, the circuit has reached steady state with the switch closed. Now open the switch.
    a. Determine the de-energizing circuit time constant.
    b. Determine the equations for i_L and v_L.
    c. Find the voltage across the inductor and current through it at $t = 17.8\ \mu$s using the equations determined previously.
24. Repeat part (c) of Problem 23 using the universal time constant curves shown in Figure 14–10.
25. a. Repeat Problem 22, parts (a) and (b) for the circuit of Figure 14–47.
    b. What are i_L and v_L at $t = 25$ ms?

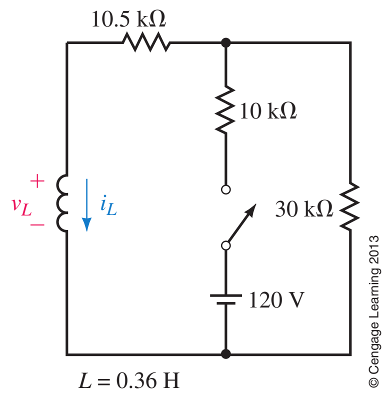


FIGURE 14–46

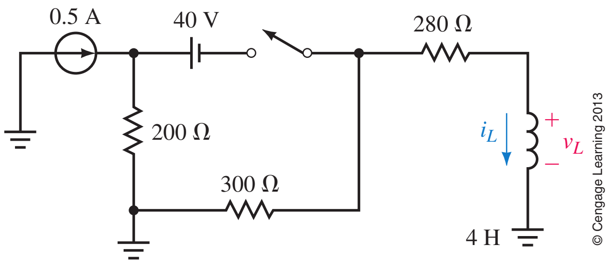


FIGURE 14–47

26. Repeat Problem 23 for the circuit of Figure 14–47, except find v_L and i_L at $t = 13.8$ ms.
27. An unknown circuit containing dc sources and resistors has an open-circuit voltage of 45 volts. When its output terminals are shorted, the short-circuit current is 0.15 A. A switch, resistor, and inductance are connected (Figure 14–48). Determine the inductor current and voltage 2.5 ms after the switch is closed.
28. The circuit of Figure 14–49 is in steady state with the switch in position 1. At $t = 0$, it is moved to position 2, where it remains for 1.0 s. It is then moved to position 3, where it remains. Sketch curves for i_L and v_L from

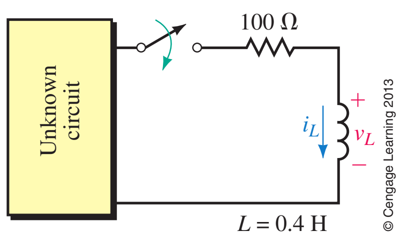


FIGURE 14–48

$t = 0^-$ until the circuit reaches steady state in position 3. Compute the inductor voltage and current at $t = 0.1$ s and at $t = 1.1$ s.

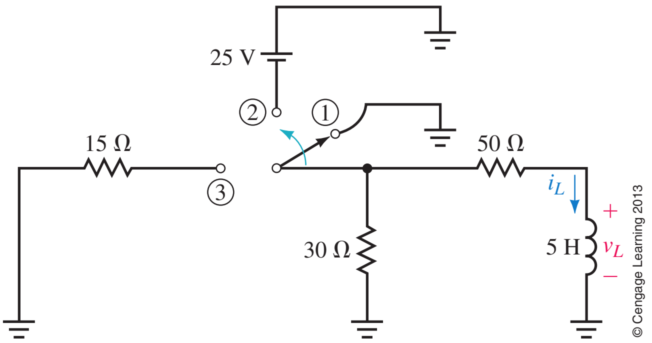


FIGURE 14–49

14.6 *RL* Transients Using Computers

Multisim PSpice
29. The circuit of Figure 14–46 is in steady state with the switch open. At $t = 0$, it is closed and remains closed. Graph the voltage across L and find v_L at 20 μs using the cursor.

Multisim PSpice
30. For the circuit of Figure 14–47, close the switch at $t = 0$ and find v_L at $t = 10$ ms. (For PSpice, use current source IDC.)

Multisim PSpice
31. For Figure 14–6, let $L_1 = 30$ mH and $L_2 = 90$ mH. Close the switch at $t = 0$ and find the current in the 30 Ω resistor at $t = 2$ ms.

Multisim PSpice
32. For Figure 14–41, let $L = 4$ H. Solve for v_L and i_L. Using the cursor, measure values at $t = 200$ ms and 500 ms. (Multisim users: You may have to create a separate vertical axis for the current waveform.)

PSpice
33. We solved the circuit of Figure 14–22(a) by reducing it to its Thévenin equivalent. Using PSpice, analyze the circuit in its original form and plot the inductor current. Check a few points on the curve by computing values according to the solution of Example 14–8 and compare to values obtained from screen.

PSpice
34. The circuit of Figure 14–46 is in steady state with the switch open. At $t = 0$, the switch is closed. It remains closed for 150 μs and is then opened and left open. Compute and plot i_L and v_L. With the cursor, determine values at $t = 60$ μs and at $t = 165$ μs.

ANSWERS TO IN-PROCESS LEARNING CHECKS

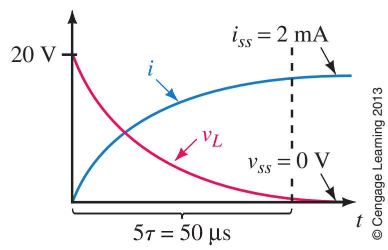
IN-PROCESS LEARNING CHECK 1

1. a. $20e^{-100\,000t}$ V; $2(1 - e^{-100\,000t})$ mA

b.

t(μs)	v_L(V)	i_L(mA)
0	20	0
10	7.36	1.26
20	2.71	1.73
30	0.996	1.90
40	0.366	1.96
50	0.135	1.99

c.



2. 11.5 V; 1.47 A
3. 4 V
4. 3.88 A