s sense physically. When the gain is high enough, the active
n produce the energy needed to sustain an unbounded output.
bility is almost always undesirable, we usually state the conclu-
ier way around. That is, this active *RC* circuit is stable provided
< 3. It is common for active circuits to be stable when circuit pa-
e in one range and unstable when they are outside this range.
-pole circuits the stable range can be found by relating the
itio to circuit parameters. For single-pole circuits the stable
es that the pole lies on the negative real axis.

's laws apply to voltage and current waveforms in the time do-
to the corresponding transforms in the *s* domain.

nain models for the passive elements include initial condition
d the element impedance or admittance. Impedance is the pro-
ty factor in the expression $V(s) = Z(s)I(s)$ relating the voltage
it transforms. Admittance is the reciprocal of impedance.

lances of the three passive elements are $Z_R(s) = R$, $Z_L(s) = Ls$,
$= 1/Cs$.

nain circuit analysis techniques closely parallel the analysis
leveloped for resistance circuits. Basic analysis techniques,
rcuit reduction, Thévenin's and Norton's theorems, the unit
thod, or superposition, can be used in simple circuits. More
d networks require a general approach, such as the node-
mesh-current methods.

transforms are rational functions whose poles are zeros of the
rminant or poles of the transform of the input driving forces.
duced by the circuit determinant are called natural poles and
natural response. Poles introduced by the input are called
s and lead to the forced response.

rcuits, response transforms and waveforms can be separated
ate and zero-input components. The zero-state component is
tting the initial capacitor voltages and inductor currents to
zero-input component is found by setting all input driving
ro.

urpose of *s*-domain circuit analysis is to gain insight into cir-
nance without necessarily finding the time-domain response.
poles reveal the form, stability, and observability of the cir-
nse. The number of natural poles is never greater than the
nergy storage elements in the circuit.

stable if all of its natural poles are in the left half of the

PROBLEMS

OBJECTIVE 10–1 EQUIVALENT IMPEDANCE (SECTS. 10–1, 10–2)

Given a linear circuit, use series and parallel equivalences to find the poles and zeros of the equivalent impedance at specified terminal pairs. Select element values to obtain specified pole locations.

See Examples 10–2, 10–4, 10–5, 10–6 and Exercise 10–1, 10–2

10–1 Find $Z_{EQ}(s)$ in Figure P10–1. Express $Z_{EQ}(s)$ as a rational function and locate its poles and zeros.

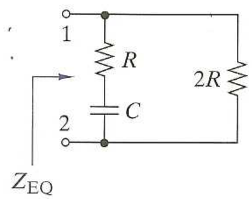


FIGURE P10–1

10–2 Find $Z_{EQ}(s)$ in Figure P10–2. Express $Z_{EQ}(s)$ as a rational function and locate its poles and zeros.

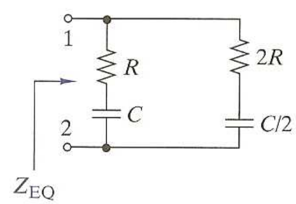
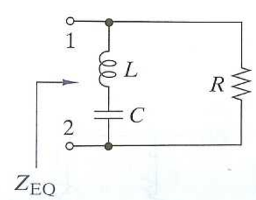


FIGURE P10–2

10–3 Find $Z_{EQ}(s)$ in Figure P10–3. Express $Z_{EQ}(s)$ as a rational function and locate its poles and zeros for $R = 4\ \text{k}\Omega$, $L = 0.4$ H, and $C = 100$ nF.



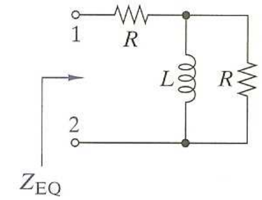


FIGURE P10–4

10–5 Find $Z_{EQ}(s)$ in Figure P10–5. Express $Z_{EQ}(s)$ as a rational function and locate its poles and zeros.

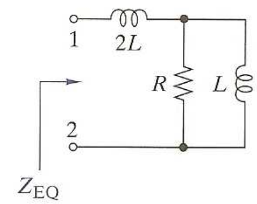


FIGURE P10–5

10–6 Find the poles and zeros of Z_{EQ} in Figure P10–6 for $R = 1\ \text{k}\Omega$, $L = 1$ H, and $C = 500$ nF.

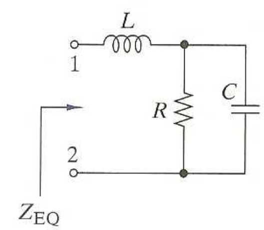
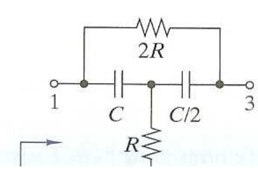


FIGURE P10–6

10–7 Find $Z_{EQ}(s)$ in Figure P10–7. Express $Z_{EQ}(s)$ as a rational function and locate its poles and zeros.



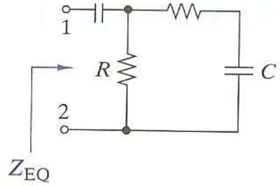


FIGURE P10–8

10–9 Find $Z_{EQ}(s)$ in Figure P10–9. Express $Z_{EQ}(s)$ as a rational function and locate its poles and zeros.

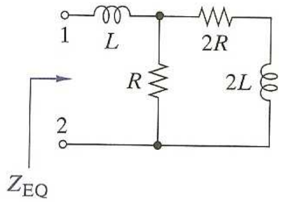


FIGURE P10–9

10–10 Find $Z_{EQ}(s)$ in Figure P10–10. Select values of R and L so that $Z_{EQ}(s)$ has a pole at $s = -1000$ rad/s. Locate the zeros of $Z_{EQ}(s)$ for your choice of R and L.

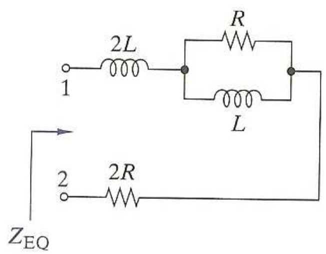


FIGURE P10–10

OBJECTIVE 10–2 BASIC CIRCUIT ANALYSIS TECHNIQUES (SECTS. 10–2, 10–3)

Given a linear circuit:

(a) Determine the initial conditions (if not given) and transform the circuit into the s domain.

(b) Solve for zero-state and/or zero-input response transforms and waveforms using basic analysis methods such as circuit reduction, unit output, Thévenin/Norton equivalent circuits, or superposition.

(c) Locate the forced and natural poles or select circuit parameters to place the natural poles at specified locations.

See Examples 10–2, 10–3, 10–4, 10–5, 10–6, 10–7, 10–8, 10–9

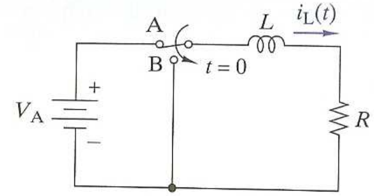


FIGURE P10–11

10–12 The switch in Figure P10–11 has been in position B for a long time and is moved to position A at $t = 0$. Transform the circuit into the s domain and solve for $I_L(s)$ and $i_L(t)$ in symbolic form.

10–13 The switch in Figure P10–13 has been in position A for a long time and is moved to position B at $t = 0$. Transform the circuit into the s domain and solve for $I_C(s)$ and $i_C(t)$ in symbolic form.

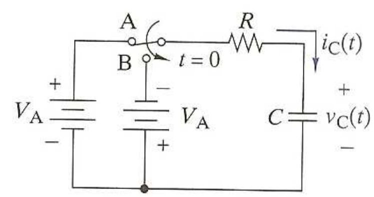


FIGURE P10–13

10–14 The switch in Figure P10–13 has been in position B for a long time and is moved to position A at $t = 0$. Transform the circuit into the s domain and solve for $V_C(s)$ and $v_C(t)$ in symbolic form.

10–15 There is no initial energy stored in the circuit in Figure P10–15. Transform the circuit into the s domain and find $I_L(s)$ and $i_L(t)$ when $v_1(t) = V_A\,u(t)$.

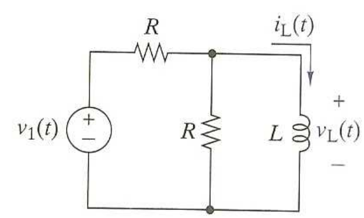


FIGURE P10–15

for a long time and is moved to position B at $t = 0$.

(a) Transform the circuit into the s domain and solve for $I_L(s)$ in symbolic form.

(b) Find $i_L(t)$ for $R_1 = R_2 = 500\ \Omega$, $L = 250$ mH, $C = 4\ \mu$F, and $V_A = 15$ V.

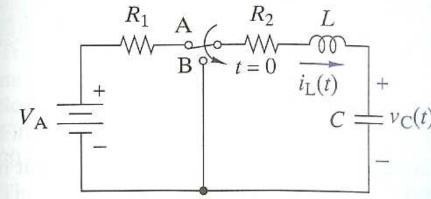


FIGURE P10–17

10–18 The switch in Figure P10–17 has been in position B for a long time and is moved to position A at $t = 0$.

(a) Transform the circuit into the s domain and solve for $V_C(s)$ in symbolic form.

(b) Find $v_C(t)$ for $R_1 = R_2 = 500\ \Omega$, $L = 500$ mH, $C = 1\ \mu$F, and $V_A = 15$ V.

10–19 The circuit in Figure P10–19 is in the zero state. Find the s-domain relationship between the input $I_1(s)$ and the output $I_R(s)$.

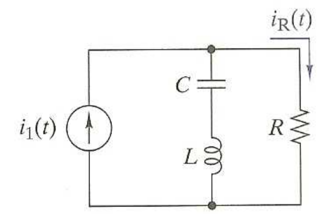


FIGURE P10–19

10–20 The circuit in Figure P10–20 is in the zero state. Find the s-domain relationship between the input $I_1(s)$ and the output $V_O(s)$.

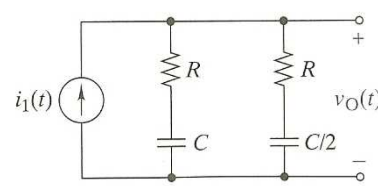


FIGURE P10–20

10–11 The switch in Figure P10–11 has been in position A for a long time and is moved to position B at $t = 0$. Transform the circuit into the s domain and solve for $I_L(s)$ and $i_L(t)$ in symbolic form.

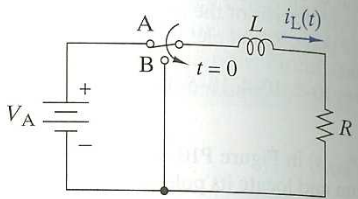


FIGURE P10–11

10–12 The switch in Figure P10–11 has been in position B for a long time and is moved to position A at $t = 0$. Transform the circuit into the s domain and solve for $I_L(s)$ and $i_L(t)$ in symbolic form.

10–13 The switch in Figure P10–13 has been in position A for a long time and is moved to position B at $t = 0$. Transform the circuit into the s domain and solve for $I_C(s)$ and $i_C(t)$ in symbolic form.

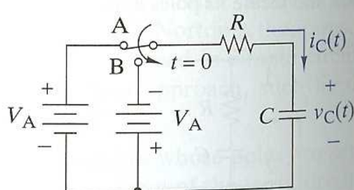
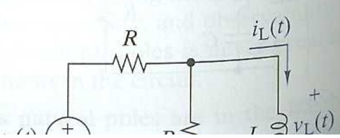


FIGURE P10–13

10–14 The switch in Figure P10–13 has been in position B for a long time and is moved to position A at $t = 0$. Transform the circuit into the s domain and solve for $V_C(s)$ and $v_C(t)$ in symbolic form.

10–15 There is no initial energy stored in the circuit in Figure P10–15. Transform the circuit into the s domain and find $I_L(s)$ and $i_L(t)$ when $v_1(t) = V_A\, u(t)$.



10–16 There is no initial energy stored in the circuit in Figure P10–15. Transform the circuit into the s domain and find $V_L(s)$ and $v_L(t)$ when $v_1(t) = V_A u(t)$.

10–17 The switch in Figure P10–17 has been in position A for a long time and is moved to position B at $t = 0$.

(a) Transform the circuit into the s domain and solve for $I_L(s)$ in symbolic form.

(b) Find $i_L(t)$ for $R_1 = R_2 = 500\ \Omega$, $L = 250$ mH, $C = 4\ \mu$F, and $V_A = 15$ V.

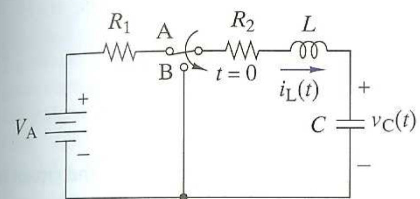


FIGURE P10–17

10–18 The switch in Figure P10–17 has been in position B for a long time and is moved to position A at $t = 0$.

(a) Transform the circuit into the s domain and solve for $V_C(s)$ in symbolic form.

(b) Find $v_C(t)$ for $R_1 = R_2 = 500\ \Omega$, $L = 500$ mH, $C = 1\ \mu$F, and $V_A = 15$ V.

10–19 The circuit in Figure P10–19 is in the zero state. Find the s-domain relationship between the input $I_1(s)$ and the output $I_R(s)$.

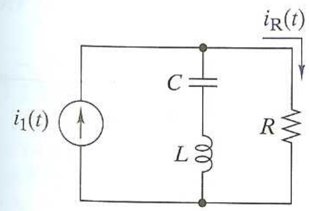
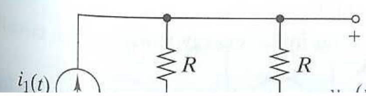


FIGURE P10–19

10–20 The circuit in Figure P10–20 is in the zero state. Find the s-domain relationship between the input $I_1(s)$ and the output $V_O(s)$.



10–21 The initial conditions in Figure P10–21 are $v_C(0) = V_0$ and $i_L(0) = 0$. Transform the circuit into the s domain and use superposition and voltage division to find the zero-state and zero-input components of $V_C(s)$.

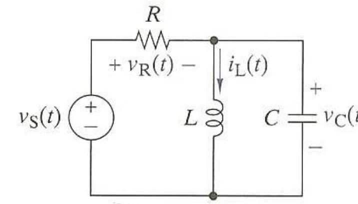


FIGURE P10–21

10–22 The initial conditions in Figure P10–21 are $v_C(0) = 0$ and $i_L(0) = I_0$. Transform the circuit into the s domain and use superposition and voltage division to find the zero-state and zero-input components of $V_R(s)$.

10–23 There is no energy stored in the capacitor in Figure P10–23 at $t = 0$. Transform the circuit into the s domain and use current division to find $v_O(t)$ when the input is $i_S(t) = 2.5\, e^{-100t}u(t)$ mA. Identify the forced and natural poles in $V_O(s)$.

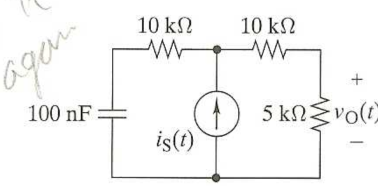
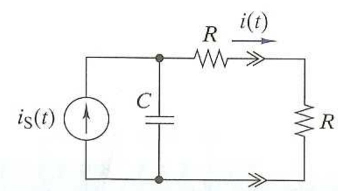


FIGURE P10–23

10–24 Repeat Problem 10–23 when $i_S(t) = 2.5\, e^{-1000t}u(t)$ mA.

10–25 The circuit in Figure P10–25 is in the zero state. Use a Thévenin equivalent to find the s-domain relationship between the input $I_S(s)$ and the interface current $I(s)$.



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Given a linear circuit:

(a) Determine the initial conditions (if not given) and transform the circuit into the s domain.

(b) Solve for zero-state and/or zero-input response transforms and waveforms using node-voltage or mesh-current methods.

(c) Identify the forced and natural poles or select circuit parameters to place the natural poles at specified locations.

See Examples 10–10, 10–11, 10–13, 10–14, 10–15, 10–16, 10–17

10–31 There is no initial energy stored in the circuit in Figure P10–31.

(a) Transform the circuit into the s domain and formulate mesh-current equations.

(b) Solve these equations for $I_2(s)$ in symbolic form.

(c) Find $i_2(t)$ for $v_1(t) = 100u(t)$ V, $R_1 = 1$ kΩ, $R_2 = 2$ kΩ, $L = 4$H, and $C = 500$ nF.

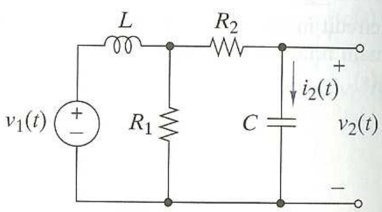

FIGURE P10–31

10–32 There is no initial energy stored in the circuit in Figure P10–31.

(a) Transform the circuit into the s domain and formulate node-voltage equations.

(b) Solve these equations for $V_2(s)$ in symbolic form.

(c) Find $v_2(t)$ for $v_1(t) = 10u(t)$ V, $R_1 = R_2 = 500$ Ω, $L = 0.5$ H, and $C = 2$ μF.

10–33 There is no initial energy stored in the circuit in Figure P10–33.

(a) Transform the circuit into the s domain and formulate node-voltage equations.

(b) Solve these equations for $V_2(s)$ in symbolic form.

(c) Find $v_2(t)$ for $v_1(t) = 30u(t)$ V, $R_1 = 10$ kΩ, $R_2 = 20$ kΩ, $C_1 = 1$ μF, and $C_2 = 0.5$ μF.

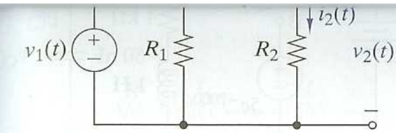

FIGURE P10–33

10–34 There is no initial energy stored in the circuit in Figure P10–33.

(a) Transform the circuit into the s domain and formulate mesh-current equations.

(b) Solve these equations for $I_2(s)$ in symbolic form.

(c) Find $i_2(t)$ for $v_1(t) = 4000r(t)$ V, $R_1 = 5$ kΩ, $R_2 = 20$ kΩ, $C_1 = 5$ μF, and $C_2 = C_1/3$.

10–35 There is no initial energy stored in the bridged-T circuit in Figure P10–35.

(a) Transform the circuit into the s domain and formulate mesh-current equations.

(b) Use the mesh-current equations to find the s-domain relationship between the input $V_1(s)$ and the output $V_2(s)$.

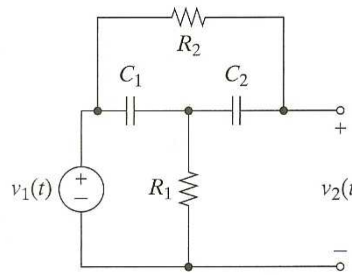

FIGURE P10–35

10–36 There is no initial energy stored in the bridged-T circuit in Figure P10–35.

(a) Transform the circuit into the s domain and formulate node-voltage equations.

(b) Use the node-voltage equations to find the s-domain relationship between the input $V_1(s)$ and the output $V_2(s)$.

10–37 There is no initial energy stored in the circuit shown in Figure P10–37. Find the zero-state mesh currents $i_A(t)$ and $i_B(t)$ when $v_1(t) = 100u(t)$ V.

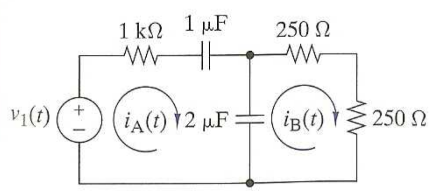

FIGURE P10–37

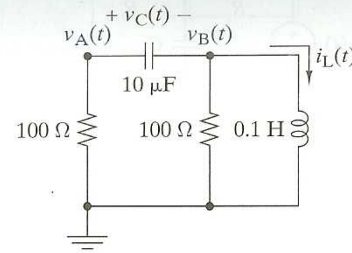

FIGURE P10–38

10–39 **D** The circuit in Figure P10–39 is in the zero state. Use node-voltage equations to find the circuit determinant. Select values of R, C, and μ so that the circuit has $\omega_0 = 5$ krad/s and $\zeta = 1/\sqrt{2}$.

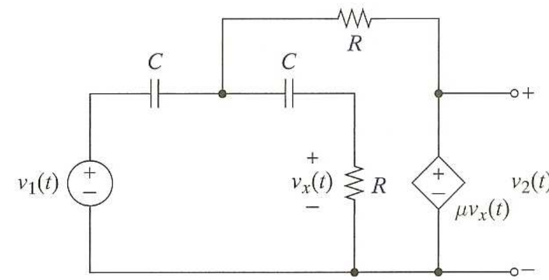

FIGURE P10–39

10–40 **D** The circuit in Figure P10–40 is in the zero state. Use mesh-current equations to find the circuit determinant. Select values of R, L, and C so that the circuit has $\omega_0 = 5$ krad/s and $\zeta = 1/\sqrt{2}$.

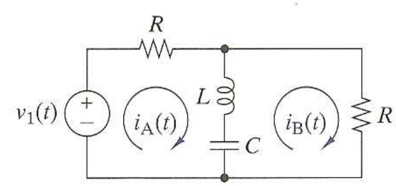

FIGURE P10–40

10–41 **D** The circuit in Figure P10–41 is in the zero state. Use node-voltage equations to find the circuit determinant. Select values of R, L, and C so that the circuit has $\omega_0 = 5$ krad/s and $\zeta = 1/\sqrt{2}$.

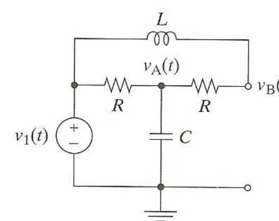

FIGURE P10–41

10–42 Three node voltages are shown in Figure P10–42.

(a) Explain why only one of the node voltages is independent.

(b) Write a node-voltage equation in the independent node voltage.

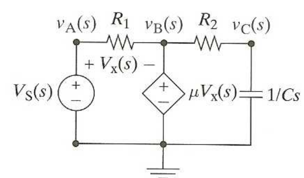

FIGURE P10–42

10–43 Three mesh currents are shown in Figure P10–43.

(a) Explain why only two of these mesh currents are independent.

(b) Write s-domain mesh-current equations in two independent mesh currents.

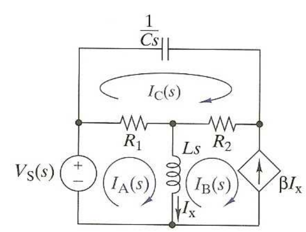

FIGURE P10–43

10–44 The switch in Figure P10–44 has been in position A for a long time and is moved to position B at $t = 0$. Solve for $V_C(s)$ and $v_C(t)$.

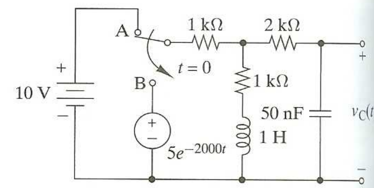

FIGURE P10–44

10–45 There is no energy stored in the circuit in Figure P10–45 at $t = 0$. Transform the circuit into the s domain and solve for $V_O(s)$ and $v_O(t)$.

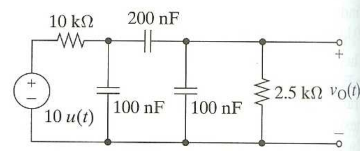

FIGURE P10–45

10–46 The switch in Figure P10–46 has been open for a long time and is closed at $t = 0$. Transform the circuit into the s domain and solve for $I_O(s)$ and $i_O(t)$.

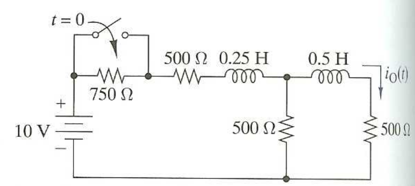

FIGURE P10–46

10–47 There is no initial energy stored in the circuit in Figure P10–47.

(a) Transform the circuit into the s domain and solve for $V_O(s)$ in symbolic form.

(b) Find $v_O(t)$ when $v_S(t) = 10^4 tu(t)$ V, $R_1 = R_2 = 2$ kΩ, $C = 0.5$ μF, and $L = 2$ H.

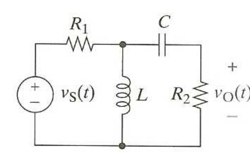

FIGURE P10–47