Answers to Problems and Exercises

Chapter 1 Circuit Variables and Elements

P1.1.1 36 kWh.

P1.1.2 (a) 0, 2.5, 5.5, 8.5, 11, 11 mC.

(b) $0 \le t \le 1$: $p = 0$; $1 \le t \le 2$: $p = 2t^2 + 2t$ mW; $2 \le t \le 3$: $p = 6t$ mW;

$3 \le t \le 4$: $p = -6t + 36$ mW; $4 \le t \le 5$: $p = 2t^2 - 26t + 84$ mW;

$5 \le t \le 6$: $p = 0$.

(c) 45.3 μJ.

P1.1.3 (a) $0.75s$.

(b) $2s$.

(c) 9.3, –21.3 mJ.

P1.1.4 (a) Power is absorbed by device during the first and third quarter cycles, when *v* and *i* have the same sign, and is delivered during the second and fourth quarter cycles, when *v* and *i* have opposite signs.

(b) 0.5 W.

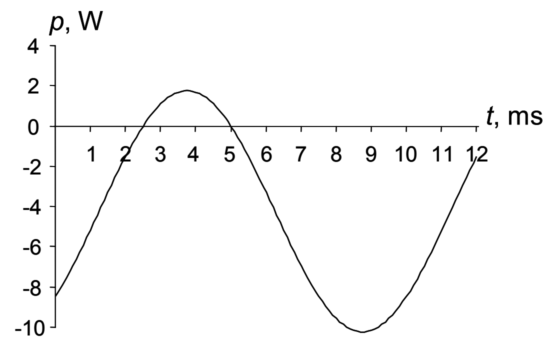
(c) 0.5 W.

(d) 0.

P1.1.5 -4.24 W.

(a) 1.76 W at t = 3.75 ms.

(b) -10.24 W at t = 8.75 ms.



P1.1.6 (a) *v* = 1 V: *p* = 6 W; *v* = 2 V: *p* = 0.

(b) $v = \frac{2\sqrt{3}}{3}$ V.

(c) q = 12.07 C.

P1.1.7 According to the assigned positive directions, the direction of power flow is indicated in the second row of the table below, where D denotes power delivered and A denotes power absorbed. The signed product of the voltage and current for each element is entered in the fifth row if there is a D in the second row, or is entered in the last row if the is an A in the second row. The remaining entries in the fifth and last rows are made so that they have opposite signs in a given column. The sum of the positive quantities in each of the fifth and last rows is 25 and the sum of the negative quantities is also 25. Thus, the total power delivered is 25 W and the total power absorbed is 25 W.

Element	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Power Flow	D	A	D	D	D	D	A
Voltage, V	5	-3	-2	5	-3	7	4
Current, A	3	-3	1	-2	-1	1	1
Power Delivered, W	15	-9	-2	-10	3	7	-4
Power Absorbed, W	-15	9	2	10	-3	-7	4

P1.2.1 I_{SRC} = 3 A; I_A = 2 A.

P1.2.2 V_{SRC} = -10 V; V_A = -40 V.

P1.2.3 I_{SRC} = -15 A.

P1.2.4 V_{SRC} = 80 V.

P1.2.5 V_B = -5 V.

P1.2.6 I_B = -6 A.

P1.2.7 i = 10 A; power absorbed by each element is 2 kW, and that delivered by source is 4 kW.

P1.2.8 $I_{SRC} = 20\sqrt{2}$ A; power absorbed by each element is $4\sqrt{2}$ kW, and that delivered by source is $8\sqrt{2}$ kW.

P1.2.9 $V_{SRC} = 20\sqrt{2}$ V; power absorbed by each element is $4\sqrt{2}$ kW, and that delivered by source is $8\sqrt{2}$ kW.

P1.2.10 V_{SRC} = 10 V; power absorbed by each element is 2 kW, and that delivered by source is 4 kW.

P1.3.1 (a) I = 45.5 A.

(b) R = 4.84 Ω.

(c) G = 0.21 S.

P1.3.2 62.7°C.

P1.3.3 866.0 V.

P1.3.4 10 mV; 10 μA.

P1.3.5 (a) 1.20 mA.

(b) -1 nA.

P1.3.6 (a) $i = 0.1t$ A, $0 \le t \le 1$ min; $i = -0.1t + 0.2$ A, $1 \le t \le 3$ min; $i = 0.1t - 0.4$ A, $3 \le t \le 4$ min.

(b) $p = t^2$ W, $0 \le t \le 1$ min; $p = \dfrac{(-10t + 20)^2}{100}$ W, $1 \le t \le 3$ min;

$p = \dfrac{(10t - 40)^2}{100}$ W, $3 \le t \le 4$ min.3≤ t ≤4 min.

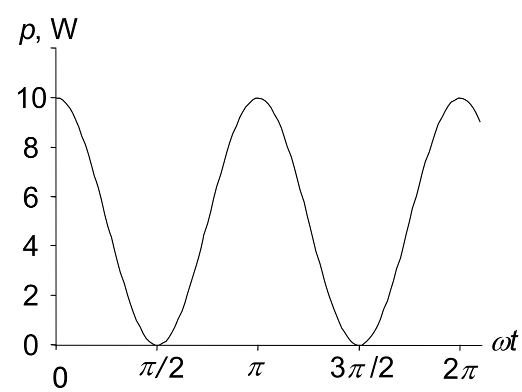
(c) $P = 5.56$ mJ.

(d) $V_{avg} = 0$, since the waveform is symmetrical about the horizontal axis. This makes $I_{avg} = 0$ as well. Thus, $V_{avg} \times I_{avg} = 0$, whereas $P \neq 0$. The average power in a resistor is not the product of the average voltage across the resistor and the average current through the resistor, because power, being the product of voltage and current, is a nonlinear quantity.

P1.3.7 15 Ω; 120 W.

P1.3.8 (a) $p = 10\cos^2 100\pi t$.

(b) 5 W ; 0.05 J. Since the power dissipated is 5 W, the energy dissipated during one half cycle is 5(W)×0.01(s) = 0.05 J. Note that the average power, i.e., average energy per unit time, is independent of the time scale, but the energy is the integral of instantaneous power with respect to time.

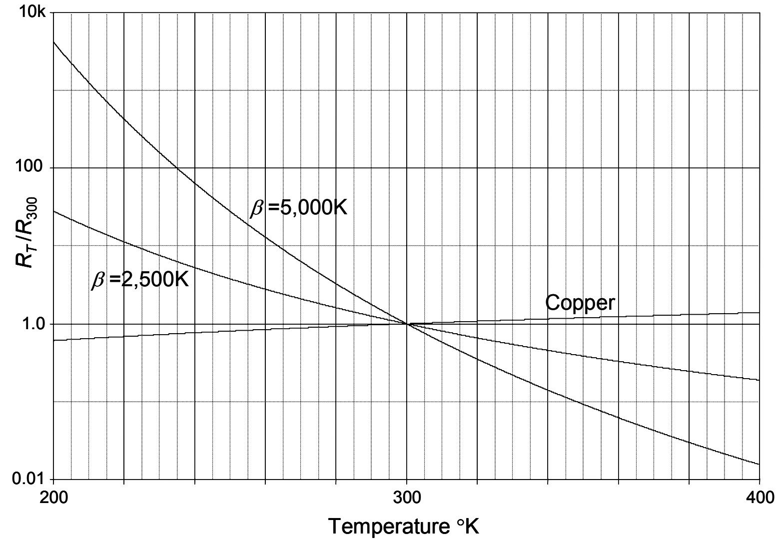


P1.3.9 (a) $0 \le t \le 60$ s, $p = \dfrac{t^2}{720}$ W, where t is in s.

(b) $w = 700$ J.

P1.3.10 $5 + 5\cos\omega t + 2.5\cos 2\omega t + 5\cos 3\omega t + 2.5\cos 4\omega t$ V.

P1.3.11 Three plots are shown for thermistors having β = 5,000K and β = 2,500K, as well as copper. The large, negative temperature variation for the thermistors is evident from the values of R_T/R_{300} on a logarithmic scale. The range of values is: 4,160 to 0.0155 (β = 5,000), 64.5 to 0.125, and 0.61 to 1.39 (copper).



P1.4.1 0.14 nF.

P1.4.2 9.

P1.4.4 C_{min} = 15.25 nF; C_{max} = 1.525 pF.

P1.4.5 A = 200 V/s; B = 10 V.

P1.4.6 $i = C_0V_0\left(2t - 2te^{-\alpha t} + \alpha t^2 e^{-\alpha t}\right)$.

P1.4.7 5 pulses.

P1.4.8 $v = 50t$ V; $0 \le t \le 200$ ms; v = 10 V for $t \ge 200$ ms.

P1.4.9 $v = 50$ V for $0 < t < 200$ ms and $v = 0$, $t > 200$ ms.

P1.4.10 Current Pulse: $v = 50t - 10$ V, $0 \le t \le 200$ ms; v = 0 V for $t \ge 200$ ms;
Current impulses: v = 40 V, $0 < t < 200$ ms and v = -10 V, $t \geq 200$ ms.

P1.4.11 (a) $0 \le t \le 10$: $v = 1.5t^2$ mV where t is in μs. At t = 10 μs, v = 150 mV ;
$10 \le t \le 40$ μs: $v = -t^2 + 50t - 250$ mV. At t = 40 μs, v = 150 mV ;
$40 \le t \le 60$ μs: $v = -30t + 1350$ mV. At t = 60 μs, v = -450 mV ;
$60 \le t \le 80$ μs: $v = 0.75t^2 - 120t + 4050$ mV. At t = 80 μs, v = -750 mV;
$t \ge 80$ μs: v = -750 mV.

(b) At t = 10 μs, q = 75 nC;
At t = 50 μs, q = -75 nC.

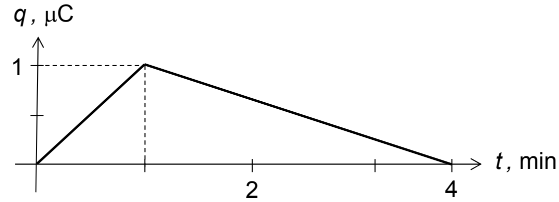
(c) At t = 80 μs, w = 0.14 μJ.

(d) All the expressions derived above for the voltage are increased by 0.5 V.

P1.4.12 (a) $q = \dfrac{t}{60}$ μC, $0 \le t \le 60$ s;

$q = \dfrac{-t}{180} + \dfrac{4}{3}$ μC, $60 \le t \le 240$ s;

$q = 0$, $t \ge 240$ s.



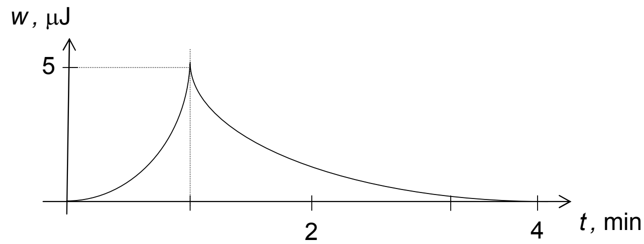
(b) $w = \dfrac{t^2}{720}$ μJ, $0 \le t \le 60$ s;

$w =$

$\dfrac{1}{180}\left(\dfrac{t^2}{36} - \dfrac{40t}{3} + 1600\right)$ μJ,

$60 \le t \le 240$ s;

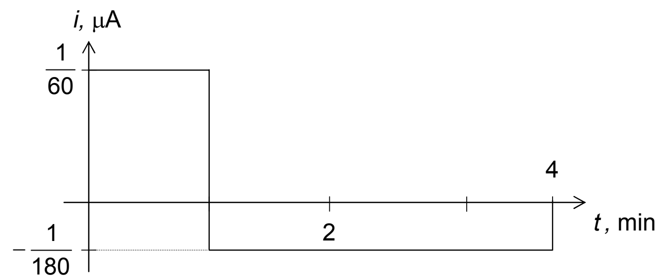
$w = 0$, $t \ge 240$ s.



(c) $i = \dfrac{1}{60}$ μA, $0 \le t \le 60$ s;

$i = -\dfrac{1}{180}$ μA, $60 \le t \le 240$ s;

$i = 0$, $t \ge 240$ s.

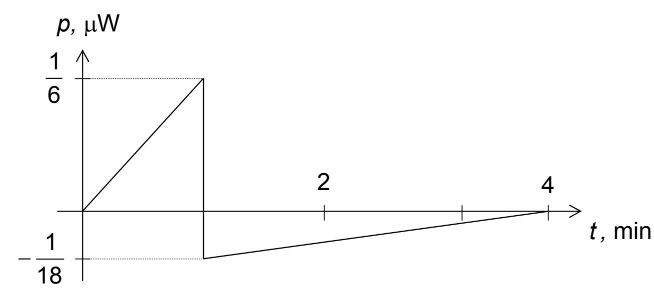


(d) $p = \dfrac{t}{360}$ μW, $0 \le t \le 60$ s;

$p = \dfrac{1}{180}\left(\dfrac{t}{18} - \dfrac{40}{3}\right)$ μW,

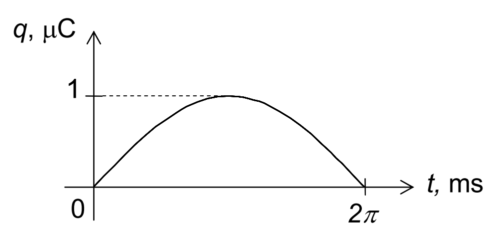
$60 \le t \le 240$ s;

$p = 0$, $t \ge 240$ s.



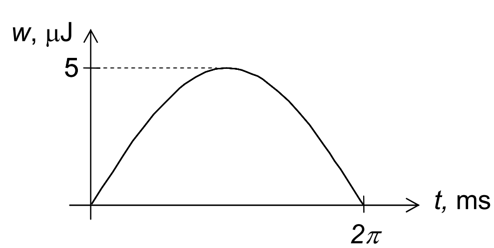
P1.4.13 (a) $q = Cv = \sin(500t)$ μC, $0 \le t \le 2\pi$ ms,

and $q = 0$ elsewhere.



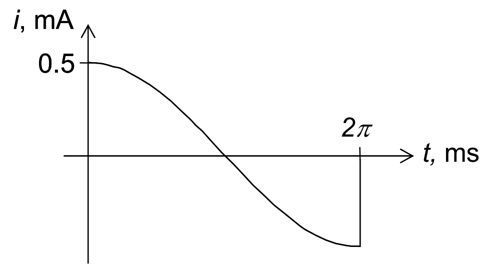
(b) $w = 5\sin^2(500t)$ μJ, $0 \le t \le 2\pi$ ms,

and $w = 0$ elsewhere.



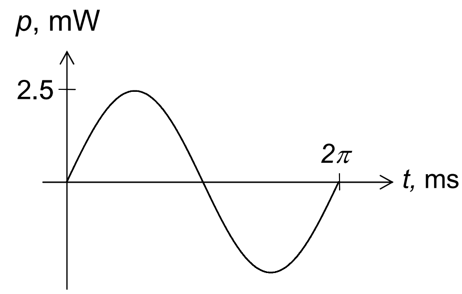
(c) $i = 500\cos(500t)$ μA, $0 \le t \le 2\pi$ ms,

and $i = 0$ elsewhere.

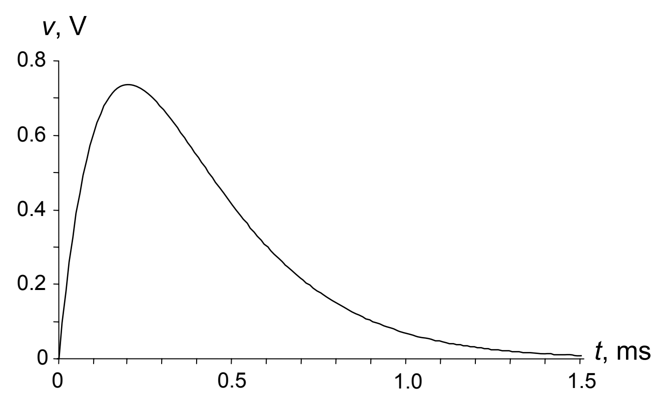


(d) $p = 2.5\sin(1000t)$ mW,

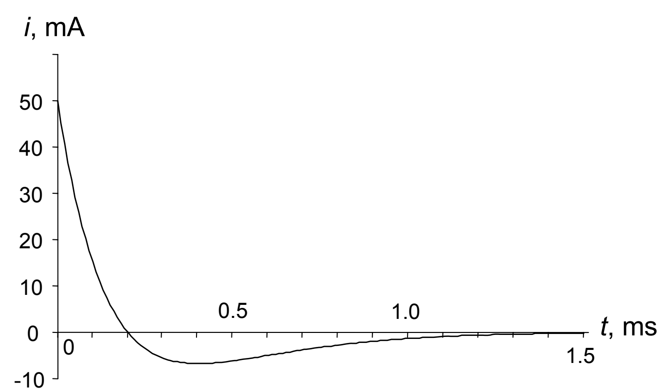
$0 \le t \le 2\pi$ ms, and p =0, elsewhere.



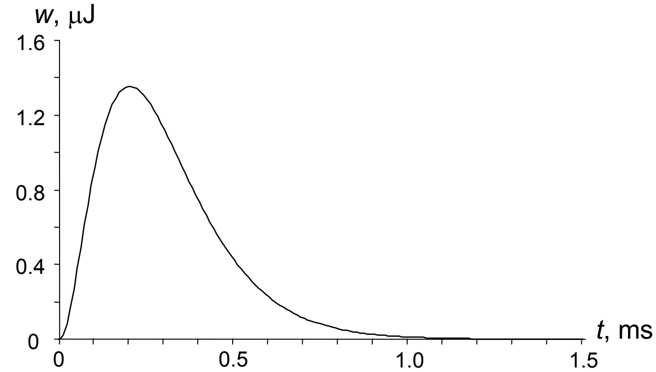
P1.4.14 $v = 10te^{-5t}$ V ;



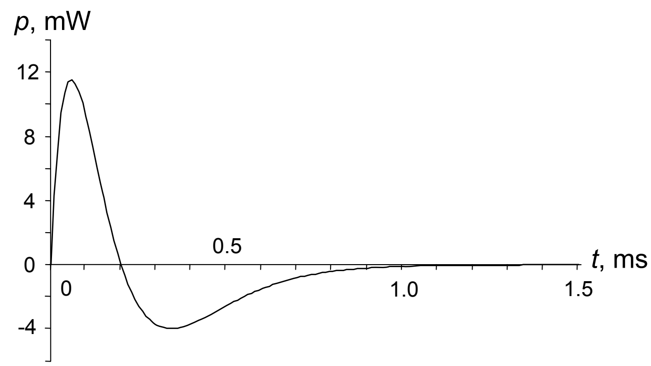
$i = 50\left(e^{-5t} - 5te^{-5t}\right)$ mA;



$w = 250t^2e^{-10t}$ μJ;



$p = 500\left(te^{-10t} - 5t^2e^{-10t}\right)$ mW.



P1.4.15 (a) $v_C = -\frac{2}{5}te^{-5t} - \frac{2}{25}e^{-5t} + \frac{2}{25}$ V.

(b) v_C = 21.1 mV.

P1.4.16 w = 21 J.

P1.5.1 L = 0.01 H.

P1.5.2 A = 200 A/s, B = 10 A.

P1.5.3 $L_0I_0\left(2t - 2te^{-\alpha t} + \alpha t^2e^{-\alpha t}\right)$ V.

P1.5.4 5 pulses.

P1.5.5 $i = 50t$ A, $0 \leq t \leq 200$ ms; i = 10 A for $t \geq 200$ ms.

P1.5.6 i = 50 A for $0 < t < 200$ ms and $i = 0$, $t > 200$ ms.

P1.5.7 Voltage Pulse: $i = 50t - 10$ A, $0 \leq t \leq 200$ ms; i = 0 A, $t \geq 200$ ms.

Voltage impulses: i = 50 A, $0 < t < 200$ ms and i = -10 A, $t > 200$ ms.

P1.5.8 (a) $0 \leq t \leq 10$ μs: $i = 1.5t^2$ mA where t is in μs. At t =10 μs, i = 150 mA.

$10 \leq t \leq 40$ μs: $i = -t^2 + 50t - 250$ mA. At t = 40 μs, i = 150 mA.

$40 \leq t \leq 60$ μs: $i = -30t + 1350$ mA. At t = 60 μs, i = -450 mA.

$60 \leq t \leq 80$ μs: $i = 0.75t^2 - 120t + 4050$ mA. At t = 80 μs, i = -750 mA.

$t \geq 80$ μs: i = -750 mA.

(b) At t = 10 µs, λ = 75 nWb-turns; at t = 50 µs, λ = -75 nWb-turns.

(c) At t = 80 µs, w = 0.14 µJ.

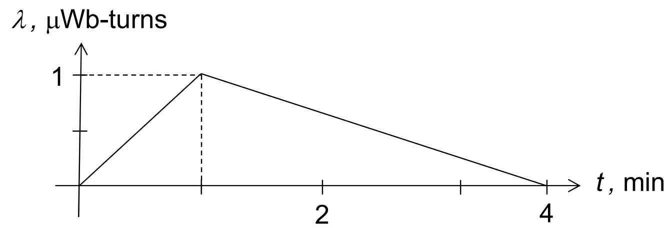
(d) All the expressions derived above for the current are increased by 0.5 V.

P1.5.9 (a) $\lambda = \dfrac{t}{60}$ µ Wb-turns,

$0 \le t \le 60$ s;

$\lambda = \dfrac{-t}{180} + \dfrac{4}{3}$ µ Wb-turns, $60 \le t \le 240$ s;

$\lambda = 0$, $t \ge 240$ s.



(b) $w = \dfrac{t^2}{720}$ µJ,

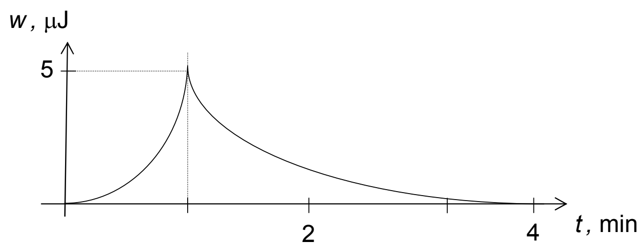
$0 \le t \le 60$ s;

$w =$

$$\frac{1}{180}\left(\frac{t^2}{36} - \frac{40t}{3} + 1600\right)$$

µJ, $60 \le t \le 240$ s;

$w = 0$, $t \ge 240$ s.

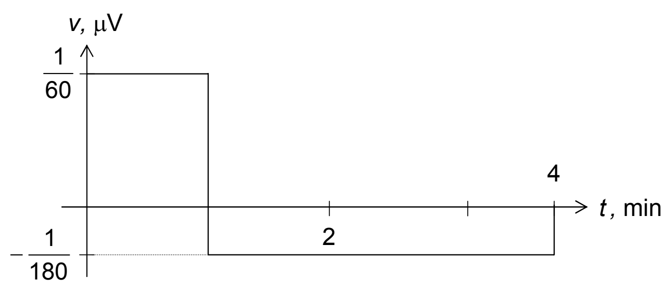


(c) $v = \dfrac{1}{60}$ µV, $0 \le t \le 60$ s;

$v = -\dfrac{1}{180}$ µV,

$60 \le t \le 240$ s;

$v = 0$, $t \ge 240$ s.



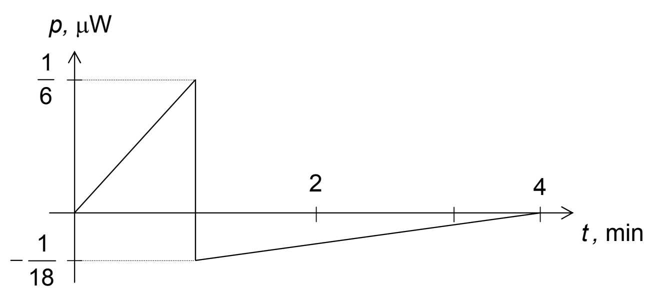
(d) $p = \dfrac{t}{360}$ µW,

$0 \le t \le 60$ s;

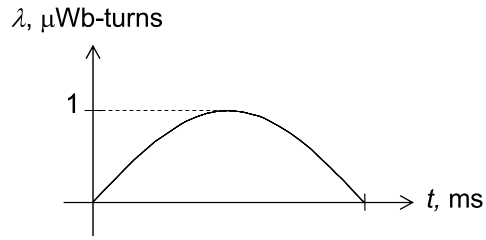
$p = \dfrac{1}{180}\left(\dfrac{t}{18} - \dfrac{40}{3}\right)$ µW,

$60 \le t \le 240$ s;

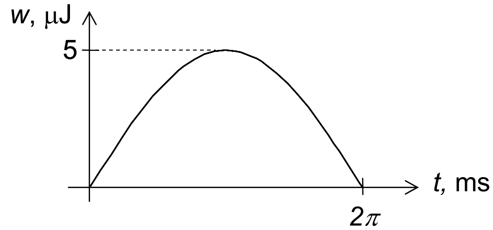
$p = 0$, $t \ge 240$ s.



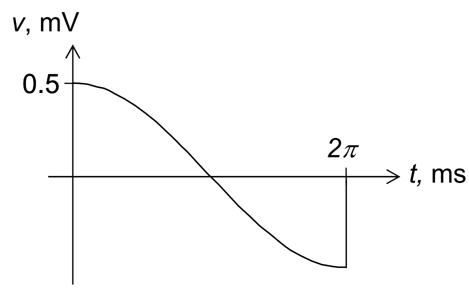
P1.5.10 (a) $\lambda = \sin(500t)$ μWb-turns, $0 \le t \le 2\pi$ ms, and $\lambda = 0$ elsewhere.



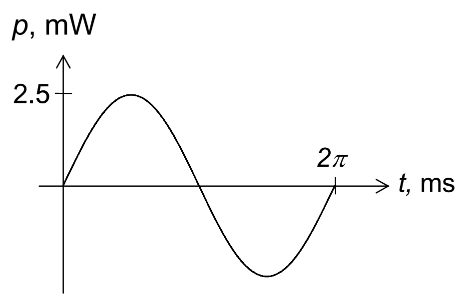
(b) $w = 5\sin^2(500t)$ μJ, $0 \le t \le 2\pi$ ms, and $w = 0$ elsewhere.



(c) $v = 500\cos(500t)$ μV, $0 \le t \le 2\pi$ ms, and $v = 0$ elsewhere.

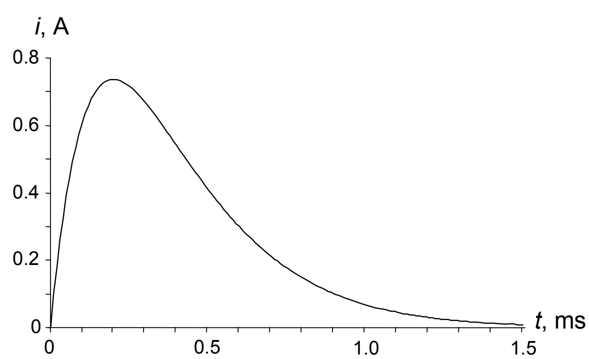


(d) $p = 2.5\sin(1000t)$ mW, $0 \le t \le 2\pi$ ms, and $p = 0$ elsewhere.

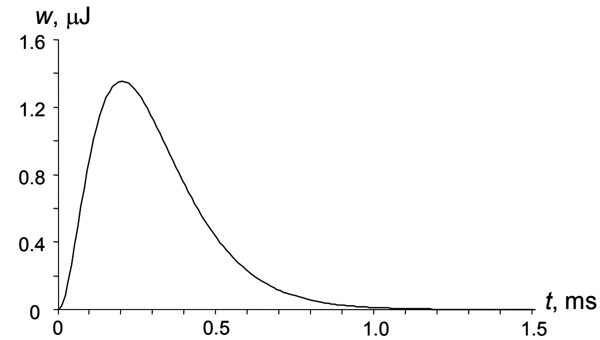


P1.5.11 $i = 10te^{-5t}$ A.

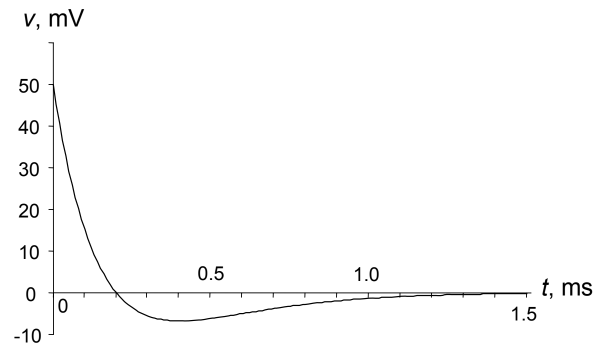
$\lambda = \; = 50te^{-5t}$ μWb-turns.



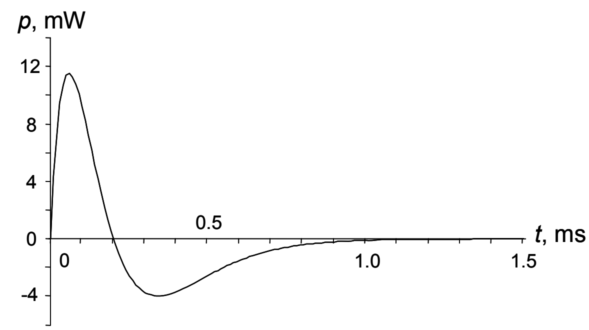
$w = \; = 250t^2e^{-10t}$ μJ.



$v = \; = 50\left(e^{-5t} - 5te^{-5t}\right)$ mV.



$p = 500\left(te^{-10t} - 5t^2e^{-10t}\right)$ mW.



P1.5.12 (a) $i_L = -\frac{2}{5}te^{-5t} - \frac{2}{25}e^{-5t} + \frac{2}{25}$ A.

(b) i_L = 21.1 mA.

P1.5.13 w = 21 J.

P1.6.1 i = 0.19 A.

Chapter 2 Basic Circuit Connections and Laws

P2.1.1 P1.2.1 I_A = 2 A; I_{SRC} = 3 A.

P1.2.2 V_A = -40 V ; V_{SRC} = -10 V.

P1.2.3 I_{SRC} = -15 A.

P1.2.4 V_{SRC} = 80 V.

P1.2.5 V_B = -5 V.

P1.2.6 I_B = -6 A.

P2.1.2 I_{SRC} = 5 A; power delivered by 10 A is 100 W; power absorbed by dependent current source is 50 W; power delivered by 10 V is 50 W; power absorbed by 20 V source is 100 W.

P2.1.3 I_Δ = -5 A; V_{SRC} = 50 V; V_x = 45 V; V_y = 60 V.

P2.1.4 I_Δ = 5 A; I_ϕ = 13 A; V_{bc} = 10 V; V_{da} = 10 V; V_{dc} = 20 V.

P2.1.5 I_{SRC} = 5 A; V_x = 40 V; power delivered by 50 V source is 250 W; power absorbed by dependent source is 50 W; power absorbed by 5 A source is 200 W.

P2.1.6 I_x = 5 A; V_{SRC} = 15 V; the voltage across the 5 A current source is 40 V, and the current through the 25 V voltage source is 10 A.

P2.1.7 Positive charge accumulates at a rate *i* on the plate of the capacitor inside the surface, so charge is conserved, as it must be. A conduction current *i* enters the surface and a displacement current *i* leaves through the capacitor. However, KCL is expressed in terms of conduction currents, so it does not apply in this case.

P2.2.1 R_{eq} = 30 Ω.

P2.2.2 G_{eq} = 30.61 S.

P2.2.3 (a) R_{eq} = 80/9 Ω; (b) R_{eq} = 76/9 Ω.

P2.2.4 (a) G_{eq} = 8.55 S; (b) G_{eq} = 9 S.

P2.2.5 G_{ab} = (7/6)*G.*

P2.2.6 R_{eq} = 0.6 kΩ.

P2.3.1 V_O = 0; I_{src} = 1 A.

P2.3.2 R = 3.2 Ω; I_x = 5 A; V_O = 24 V; V_I = 40 V; V_O/V_I = 3/5; I_x/I_{SRC} = 1/3.

P2.3.3 V_x = 20 V; $I_{12\Omega}$ = 5/3 A; $I_{6\Omega}$ = 10/3 A.

P2.3.4 V_O = 24 V.

P2.3.5 V_O = 16 V.

P2.3.6 I_O = 25/3 A.

P2.3.7 $V_x = 8$ V; $I_y = 0.375$ A.

P2.4.1 $V_O = 6$ V.

P2.4.2 $V_O = 40$ V.

P2.4.3 $I_{src} = -1$ mA.

P2.4.4 $V_O = 12$ V.

P2.4.5 $V_O = 12$ V.

P2.4.6 $I_x = 7$ A.

P2.4.7 $I_x = 75.33$ A; $V_A = -20$ V; $V_B = 20$ V.

P2.4.8 $V_x = 490/3$ V.

P2.4.9 $V_x = 50$ V; $V_y = 46.67$ V.

P2.4.10 $I_x = -1$ A.

P2.4.11 $I_x = 1.2$ A.

P2.4.12 $V_{SRC} = 120$ V; $V_x = 48$ V; $V_y = 72$ V; $I_{src} = 12$ A; $I_{6\Omega} = 8$ A; $I_{12\Omega} = 4$ A; $I_{24\Omega} = 3$ A; $I_{8\Omega} = 9$ A.

P2.4.13 $V_x / I_x = -100/49$ kΩ.

P2.4.14 $R_0 = 3$ kΩ; $R_x = 27$ kΩ.

P2.4.15 $R_0 = 30$ kΩ; $R_x = 3.75$ kΩ.

P2.4.16 $V_O = 3$ V.

P2.4.17 $V_x = 30$ V; $V_{SRC} = 195$ V.

P2.4.18 $R = 3.2$ Ω; $I_x = 2$ A.

P2.4.19 $I_x = 1.19$ A.

P2.4.20 $I_x = 0.75$ A.

P2.4.21 $V_x = 1.71$ V.

Chapter 3 Basic Analysis of Resistive Circuits

P3.1.1 $\frac{10 - V_{ab}}{4} + \frac{20 - V_{ab}}{6} = \frac{V_{ab}}{6}$; $V_{ab} = 10$ V; $I_1 = 0$; $I_2 = -5/3$ A. Since $V_{ab} = 10$ V, the two terminals of the 4 Ω resistor are at the same voltage, so that $I_1 = 0$ and V_{ab} can be found by voltage division.

P3.1.2 $I_{SRC1} = -1.3$ A; $I_{SRC2} = 2.2$ A.

P3.1.3 $I_{SRC1} = -1.3$ A; $I_{SRC2} = 2.2$ A.

P3.1.4 $V_{ac} = 0$ V; $V_{bc} = -5/3$ V. Since $V_{ac} = 0$, node a is at the same voltage as node c, so that V_{bc} can be found by current division.

P3.1.5 $V_{SRC1} = -1.3$ V; $V_{SRC2} = 2.2$ V.

P3.1.6 V_{SRC1} = -1.3 V; V_{SRC2} = 2.2 V.

P3.1.7 V_O = 20 V. The 20 Ω and 40 Ω resistances are in the same ratio as the voltage sources, so the voltages across the resistors are the same as those of the corresponding sources.

P3.1.8 V_O = 20 V.

P3.1.9 I_O = 20 A. The 20 S and 40 S conductances are in the same ratio as the current sources, so that the current in each resistor is equal to that of the source in series with it.

P3.1.10 I_O = 20 A.

P3.1.11 V_O = 15.5 V.

P3.1.12 V_O = 15.5 V.

P3.1.13 I_O = 15.5 A.

P3.1.14 I_O = 15.5 A.

P3.1.15 V_O = -10/3 V.

P3.1.16 V_O = -10/3 V.

P3.1.17 I_O = -10/3 A.

P3.1.18 I_O = -10/3 A.

P3.1.19 V_O = 30 V.

P3.1.20 V_O = 30 V.

P3.1.21 I_O = 30 A.

P3.1.22 I_O = 30 A; I_{SRC1} = 1 A; I_{SRC2} = 95 A.

P3.1.23 I_O = -22 A.

P3.1.24 I_O = -22 A.

P3.1.25 V_O = 0 V.

P3.1.26 V_O = 0 V.

P3.1.27 V_O = 1.82 V.

P3.2.1 V_{ab} = 10 V.

P3.2.2 V_O = 10 V.

P3.2.3 V_{ab} = 18 V; I_{SRC1} = -1.3 A; I_{SRC2} = 2.2 A.

P3.2.4 V_{ac} = 0 V; V_{bc} = -5/3 V.

P3.2.5 V_{SRC1} = -1.3 V; V_{SRC2} = 2.2 V.

P3.2.6 V_O = 20 V.

P3.2.7 I_O = 20 A.

P3.2.8 V_O = 15.5 V.

P3.2.9 V_a = 10/49 V; I_x = 5/49 A; V_O = 15.51 V.

P3.2.10 I_O = 15.5 A; power dissipated = 30.03 W.

P3.2.11 I_x = 10/49 A; V_x = 5/49 V; I_O = 15.510 A.

P3.2.12 V_O = 30V; power dissipated = 180 W.

P3.2.13 I_O = 30 A; power dissipated = 180 W.

P3.2.14 I_O = -22 A; power dissipated = 121 W.

P3.2.15 V_O = 0V.

P3.2.16 I_x = -10 A; V_O = 0V.

P3.2.17 I_O = 10/13 A.

P3.2.18 V_{SRC} = 8 V.

Chapter 4 Circuit Simplification

P4.1.1 V_{Th} = 4 V; R_{Th} = 4 Ω.

P4.1.2 I_N = 0.3 A; G_N = 0.025 S.

P4.1.3 V_{Th} = 0; R_{Th} = 10 Ω.

P4.1.4 V_{Th} = 0; R_{Th} = -10 Ω.

P4.1.5 (a) V_{Th} = 0; R_{Th} = 1 Ω.

(b) V_{Th} = -V_{SRC}; R_{Th} =0.

P4.1.6 V_{Th} = 16 V; R_{Th} = 8 Ω.

P4.1.7 I_N = 4.4 A; G_N = 0.04 S.

P4.1.8 V_{Th} = 10 V; R_{Th} = 10 Ω.

P4.1.9 V_{Th} = 40 V; R_{Th} = 0.

P4.1.10 I_N = 8 A; G_N = 0.

P4.1.11 V_{Th} = 70/3 V; R_{Th} = 20/3 Ω; V_O = 20V.

P4.1.12 I_O = 20 A.

P4.1.13 V_O = 15.5 V.

P4.1.14 I_O = 15.5 A.

P4.1.15 V_O = -10/3 V.

P4.1.16 I_O = -10/3 A.

P4.1.17 V_O = 30 V.

P4.1.18 I_O = 30 A.

P4.1.19 I_O = -22 A.

P4.1.20 V_O = 0.

P4.2.1 I_x = 0.9 A.

P4.2.2 V_{cd} = -1 V.

P4.2.3 V_O = -10/3 V.

P4.2.4 I_O = -10/3 A.

P4.2.5 I_O = -22 A.

P4.2.6 V_O = 0.

P4.3.7 V_{ab} = 12 V.

P4.3.8 $\mathrm{V_{ab}}$ = 15 V.

P4.3.9 V_{ab} = 5 V.

P4.3.10 R_{ab} = 0.5 Ω.

P4.3.11 V_{Th} = 0; R_{Th} = 14 Ω; I_{SRC2} = 0.5 A. $\mathrm{V_{SRC1}}$ = 5 V. I_{SRC1} = 31 A.

Chapter 5 Sinusoidal Steady State

P5.1.1 (a) 3.19 + *j*16.37; 16.68∠78.96°.

(b) 23.19 – *j*18.27; 29.52∠-38.22°.

(c) -3.88 + *j*23.44; 23.76∠99.39°.

(d) 16.12 – *j*11.20; 19.63∠-34.78°.

P5.1.2 (a) -312 + *j*840; 896.1∠110.4°.

(b) 2.1667 – *j*5.8333; 6.223∠-69.62°.

(c) -5.4146 – *j*0.7317; 6.223∠-172.3°.

(d) 0.0376 + *j*0.0051; 0.0379∠7.69°.

P5.1.3 -4375 – *j*15000; 15,625∠-106.3°.

P5.1.4 3.42∠17.71°; 3.42∠137.71°; 3.42∠257.71°.

P5.1.5 *y* = 0.472cos(4t – 146.2°).

P5.1.6 v = 10cos(200πt + 72.54°) **V** = 10∠72.54°.

P5.2.1 (a) **V** = 145.02∠-57.87° ≡ 145.02cos(2500πt – 57.87°) V; $\mathbf{I_2}$ = -1.015 – *j*2.716 ≡ 2.9cos(2500πt – 110.49°) A.

(b) *Z* = 15.43 – *j*5.88 Ω (i) *R* = 15.43 Ω, *C* = 21.65 μF; (ii) *Y* = 0.0566 + *j*0.0216 S, where G = 0.0566 S and C = 2.75 μF.

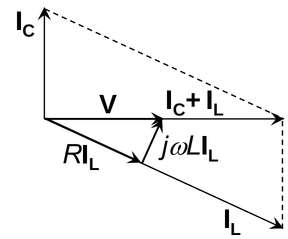
P5.2.2 Y_i = 0.478 – *j*0.0614 S.

P5.2.3 Z_i = 2(1 + *j*) Ω.

P5.2.4 Y_i =2.49 + *j*0.15 S.

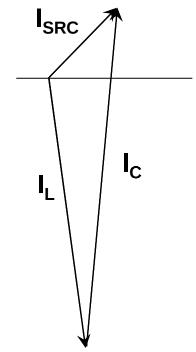
P5.2.5 Z_i = -10 + *j*5 Ω.

P5.2.6 C = 1.55 μF.



P5.2.7 $R = 1\ \Omega$; $C = 1$ F.

P5.2.8 $\mathbf{I_L} = 4.03\angle{-82.9°}$ A; $\mathbf{V_C} = 201\angle{-5.7°}$ V.



P5.3.1 $\mathbf{V_L} = \dfrac{8}{3\sqrt{2}}\angle 90° \equiv -\dfrac{8}{3\sqrt{2}}\sin(t)$ V.

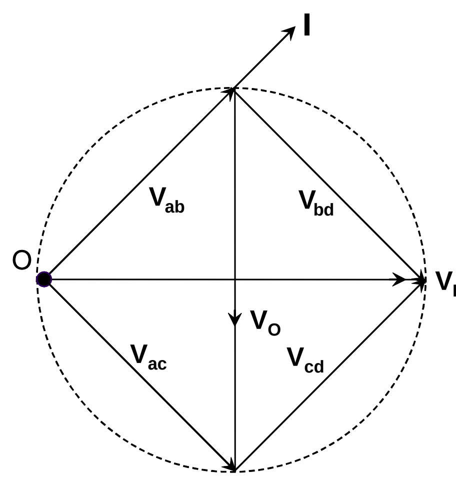
P5.3.2 $\mathbf{V_O} = 10.54\angle{-63.43°} \equiv 10.54\cos(\omega t - 63.43°)$ V.

P5.3.3 $\mathbf{I_1} = -0.0517 - j0.621$ A; $\mathbf{I_2} = -0.466 + j1.91$ A.

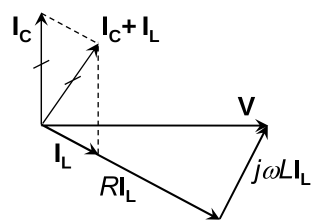
P5.3.4 $\mathbf{I_x} = -4.38 - j5.41 \equiv -6.96\cos(10^4 t + 51.1°)$ A;

$\mathbf{I_y} = -5.41 + j4.38 \equiv 6.96\cos(10^4 t + 141.1°)$A.

P5.3.5 $C = 5$ μF.



P5.3.6



P5.3.8 $\mathbf{I_O} = 2 + j4$ A.

P5.3.9 $\mathbf{V_O} = -9 + j10$ V.

P5.3.10 $\mathbf{I_{SRC}} = 0.5$ A.

P5.3.11 (a) Series branch is 75 nF. Shunt branch is 0.42 μH.

(b) Impedances of the T-circuit are all infinite.

P5.3.12 $\mathbf{V_c} = -30 - j90$ V; $\mathbf{I_L} = 8 - j6$ A.

P5.3.13 $\mathbf{I_x} = -j$ A.

P5.3.15 $\mathbf{V_O} = 0.544 - j0.543 \equiv 0.769\cos(\omega t - 44.95^\circ)$ V.

P5.3.16 $\mathbf{I_O} = -0.0868 + j0.101 \equiv 0.133\cos(\omega t + 130.1^\circ)$ A.

P5.3.17 $\mathbf{I_O} = 0.71 - j0.45$ A.

P5.3.18 $\mathbf{V_x} = 20\angle 0$ V.

P5.3.19 $\mathbf{V_O} = 13.98 - j2.851$ V.

P5.3.20 $2\sqrt{5}\cos(\omega t - 26.6^\circ)$ A.

P5.3.21 $\mathbf{V_O} = -j20\sqrt{2}$ V.

P5.3.22 $\mathbf{I_{SRC}} = 0.469 + j0.164 = 0.5\angle 19.3^\circ$ A; $\mathbf{V_L} = 13.4 + j11.7 = 17.8\angle 41.1^\circ$ V.

P5.3.23 $\mathbf{I_{SRC}} = 0.469 + j0.164 = 0.5\angle 19.3^\circ$ A; $\mathbf{V_L} = 13.4 + j11.7 = 17.8\angle 41.1^\circ$ V.

P5.3.24 $\mathbf{V_O} = 4.88 - j20.0$ V.

P5.3.25 $\mathbf{V_O} = 12.1 + j3.52 \equiv 12.60\cos(\omega t + 16.2^\circ)$ V.

P5.3.26 $\mathbf{I_O} = 5 + j5$ A.

P5.3.27 $\mathbf{I_O} = 5 + j5$ A.

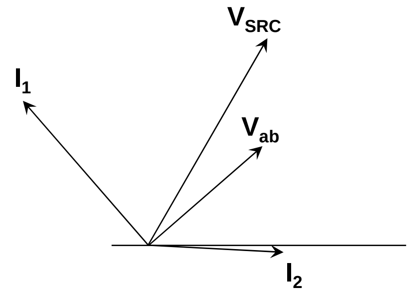
P5.3.28 $\mathbf{V_O} = 10 - j20$ V.

P5.3.29 $\mathbf{V_O} = 10 - j20$ V.

P5.3.30 $\mathbf{I_O} = 5 - j9$ A.

P5.3.31 $\mathbf{I_O} = 5 - j9$ A.

P5.3.32 $\mathbf{V_{ab}} = 31.63\angle 41.6^\circ$ V; $\mathbf{I_1} = 3.16\angle 131.6^\circ$ A; $\mathbf{I_2} = 2.24\angle -3.43^\circ$ A.



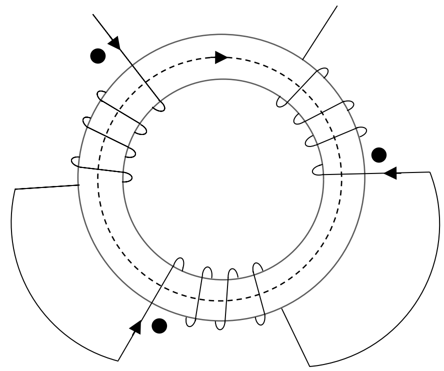
P5.3.33 $\mathbf{V_O} = 1.818$ V.

P5.3.37 $\mathbf{I_N} = -0.1$ A; $Y_N = \frac{1}{250}(4 - j3) = \frac{1}{50}\angle -36.9^\circ$ S.

P5.3.38 $\mathbf{V_{Th}} = \frac{15}{17}\left[\left(4\sqrt{3} - 1\right) + j\left(4 + \sqrt{3}\right)\right] = 7.277\angle 44.0^\circ$ V; $Z_{Th} = -20/17 - j5/17\ \Omega$.

Chapter 6 Linear and Ideal Transformers

P6.1.1



P6.1.2 3.5 J. The same sign of ϕ_{21} and ϕ_{12} implies that i_1 and i_2 both enter the dotted terminals.

P6.1.3 (a) $\phi_{12} = 500$ μWb.

(b) $k = 0.342$.

(c) M == 20 mH.

(d) $L_1 = 72$ mH; $L_2 = 47.50$ mH.

P6.1.4 $L_2 = 6.4$ H; $k = 2/3$.

P6.1.5 $\omega = \dfrac{\sqrt{10}}{3}$ krad/s.

For the maximum inductance connection: $I_{peak} = \dfrac{\sqrt{10}}{3}$ A, $W_{peak} = \dfrac{2}{15}$ J.

For the maximum inductance connection: $I_{peak} = \dfrac{\sqrt{10}}{3}$ A, $W_{peak} = \dfrac{1}{30}$ J.

P6.1.6 (a) L_{eqs} = 320 mH.

(b) L_{eqs} = 120 mH.

(c) L_{eqs} = 80 mH.

P6.1.7 $I_2 = \dfrac{2}{3}$ A.

P6.1.8 (a) The fluxes due to each coil alone are $\dfrac{L_1 I}{N_1}$ and $\dfrac{L_2 I}{N_2}$. The total flux is

$$\frac{N_2L_1 + N_1L_2}{N_1N_2} I .$$

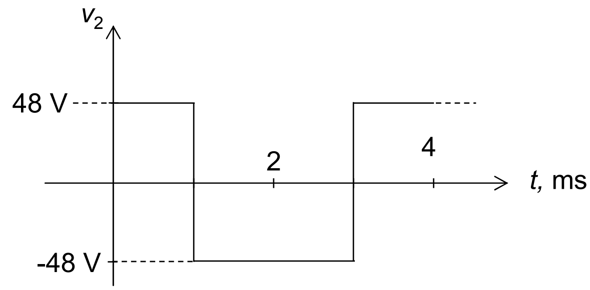
(b) $\dfrac{(N_2L_1 + N_1L_2)(N_1 + N_2)}{N_1N_2} I$.

(c) $L_1 + L_2 + \frac{N_2 L_1}{N_1} + \frac{N_1 L_2}{N_2} = L_1 + L_2 + 2M$.

P6.2.1 4 H, 16 H, 0.5.

P6.2.2 Reflected impedance = 8.82 + *j*13.22 Ω. Input impedance = 8.82 + *j*58.22 Ω. reflected impedance and input impedance of ideal transformer = 45 – *j*112.5 Ω.

P6.2.3 v_1 and v_2 have the square waveform shown. The amplitudes of v_1 and v_2 are 90 V and 48 V, respectively.



P6.2.4 18 μJ.

P6.2.5 $-j162\ \Omega$.

P6.2.6 (a) $k = 1$.

(b) $k = 0$.

P6.2.7 At 50 Hz, $\mathbf{V_{L1}} = 19.58\angle -13.4^\circ$ V; at 1 kHz, $\mathbf{V_{L2}} = 4.13\angle -78.17^\circ$ V. Attenuation is due to the shunt inductance at low frequencies and due to series inductance at high frequencies.

P6.2.10 $\mathbf{I_2} = 0.25\sqrt{2}\angle 135^\circ$ A $\equiv 0.25\sqrt{2}\cos(500t + 135^\circ)$ A;

$\mathbf{V_2} = 0.25\sqrt{2}\angle 135^\circ (10 - j40) = 14.58\angle 59^\circ$ V $\equiv 14.58\cos(500t + 59^\circ)$ V;

$\mathbf{V_1} = 2.5 + j12.5 = 12.75\angle 78.7^\circ$ V $\equiv 12.75\cos(500t + 78.7^\circ)$ V;

power dissipated in the 10 Ω resistor = 1.25 W.

P6.3.1 $k = 0.4$.

P6.3.2 $\mathbf{I_1} = 0.873 - j1.61$ A, $\mathbf{I_2} = 0.0895 - j0.604$ A.

P6.3.3 $\mathbf{I_o} = -0.0105 \equiv -0.0105\cos 1{,}000t$ A.

P6.3.4 $Z_x = -j\omega La$.

P6.3.5 $\mathbf{I_1} = 1.851 - j0.584$ A, $\mathbf{I_2} = -1.481 + j0.467$ A. $\mathbf{I_o} = 0.37 - j0.117$ A, $\mathbf{V_1} = 0.772 - j0.651$ V, $\mathbf{V_2} = 3.86 - j3.25$ V.

Power delivered to the 12 Ω resistor = $(0.388)^2 \times 12 = 1.81$ W;

$Z_i = 3.48 + j3.8\ \Omega$.

P6.3.6 $\mathbf{I_o} = -0.207 + j9.57$ A.

P6.3.7 $\mathbf{V_x} = 41.3 + j18.6 = 45.3\angle 25.3^\circ$ V;

$\mathbf{V_y}$ = -13.6 – j10.03 = 16.89∠-143.6° V.

P6.3.8 $\mathbf{I_x}$ = -0.0158 – j0.0123 A.

P6.3.9 $\mathbf{V_O}$ = 20$\mathbf{I_2}$ = 17.94 – j15.53 V.

P6.3.10 i_O = 1.96cos(100πt +86.6°) A.

P6.3.11 v_O = 19.71sin(ωt – 9.8°) V.

P6.3.12 $\mathbf{V_O}$ = 14.33 + j20.07 V.

P6.3.13 i_O = 3.33cos(500t – 7.87°) A.

P6.3.14 v_O = 16.72cos(500t + 35.4°) V.

P6.3.15 $\mathbf{V_{Th}} = \frac{28}{37}(6+j) = 4.6\angle 9.46$ V; $Z_{Th} = \frac{751+j304}{185} = 4.060 + j1.643 =$ 4.38∠22.04° Ω.

P6.3.16 $\mathbf{V_{Th}} = \frac{10}{41}(11-j17)$ V; Z_{Th} = 2 + j6 Ω.

P6.3.17 $\mathbf{V_{Th}}$ = -26.1 + j9.65 V; Z_{Th} = 26.1 – j9.65 A.

P6.3.18 $\mathbf{V_{TH}} = -10$ V; R_{Th} = 2.5 Ω.

P6.3.19 $\mathbf{V_{Th}}$ = 60(1 + j) V; $Z_{Th} = 3(3+j17)\,\Omega$.

P6.3.20 $\mathbf{V_{Th}} = -\frac{160}{197}(14+j)$ V; $Z_{Th} = \frac{20}{197}(183-j)\,\Omega$.

P6.3.21 Z_{in} = j20 Ω.

P6.4.1 $\phi_m = 1.5$ mWb; maximum rate of change = $120\pi \times 1.5 \cong 0.566$ Wb/s.

At 50 Hz, $\phi_m = 1.8$ mWb; core loss increases by a factor of $(60/50)^2 \cong 1.44$, or about 45%; copper loss in the primary winding also increases by about 45%.

Primary voltage must be reduced to 200 V rms.

P6.4.2 Changing the relative dot markings gives a different output voltage, current, and input impedance.

P6.4.3 current rating of the 10 kV winding = 6.6 A, that of the 2.2.kV winding = 30 A.

(a) $\mathbf{V_O}$ = 2.2 kV, $\mathbf{I_O}$ = 36.6 A, rating = 80.52 kVA.

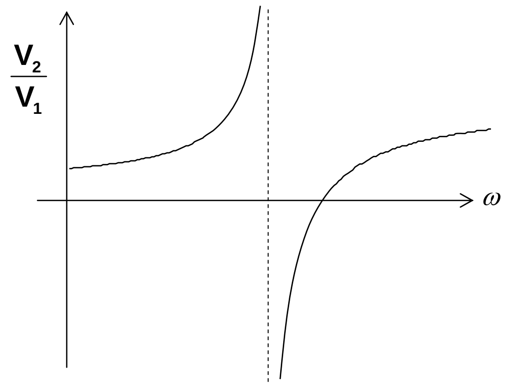
(b) $\mathbf{V_O}$ = -2.2 kV, $\mathbf{I_O}$ = 23.4 A, rating = 50.48 kVA.

(c) $\mathbf{V_O}$ = 12.2 kV, $\mathbf{I_O}$ = 30 A, rating = 366 kVA.

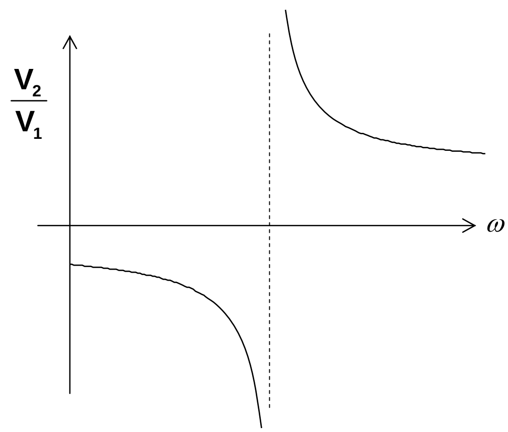
(d) $\mathbf{V_O}$ = 7.8 kV, $\mathbf{I_O}$ = 30 A, rating = 234 kVA.

The insulation level of the 2.2 kV winding in (c) should be at least 12.2 kV with respect to ground.

P6.4.4 The function has a pole at $\omega = \dfrac{1}{\sqrt{L_{lk}(C_2 + C_i}}$ and a zero at a higher frequency $\omega = \sqrt{\dfrac{a}{L_{lk}C_i}}$, The sketch is as shown, assuming a >1.



P6.4.5 The pole is unchanged; there is no zero at any real frequency. The sketch is as shown.



<u>Chapter 7 Power Relations and Circuit Measurements</u>

P7.1.1 **V** = $40\sqrt{2}\angle 90^\circ$ V.

P7.1.2 (a) S = 2.2 + j2.42 kVA, **I** = 10 – j11 A.

(b) 159 μF.

P7.1.3 -7.5 + j10 VA.

P7.1.4 2348 W.

P7.1.5 49.1 μF.

P7.1.6 R = 25 Ω; $\mathbf{V}_{\mathbf{SRC}}$ = 15 + j5 = $5\sqrt{10}\angle 18.4^\circ$ V.

P7.1.7 (a) $\mathbf{V}_{\mathbf{SRC}}$ = 570 – j20 = 570.3∠-2° V.

(b) p.f.= = 0.962.

(c) 86.85% .

P7.1.8 C = 0.2 F, or C = 0.8 F.

P7.1.9 S_{SRC1} = 12.5 + j1.83 kVA, S_{SRC2} = 6.5 + j4.5 kVA.

P7.1.11 Instantaneous power = 103.1[cos(76°) + cos(2×10^6t) VA; S = 25 + j100 VA in terms of rms values.

P7.1.12 $-j\frac{10}{9}$ Ω.

P7.1.13 S = 2.93 + j1.46 VA.

P7.2.1 R_{Lm} = 10 Ω, power absorbed = 62.5 W.

P7.2.2 G_{Lm} = 10 S, power absorbed = 62.5 W.

P7.2.3 R_{Lm} = 10/3 Ω, power absorbed = 40.83 W.

P7.2.4 R_{Lm} = 50 Ω, power absorbed = 0.139 W.

P7.2.5 R_{Lm} = 5/17Ω, power absorbed = 90 W.

P7.2.6 $\omega M = 20\sqrt{2}$ Ω, power absorbed = 478 W.

P7.2.7 R_{Lm} = 160/7Ω, power absorbed = 20/7 W.

P7.2.8 R_{Lm} = 10 Ω, power absorbed = 20 W.

P7.2.9 Z_{Lm} = 8(1 + j2) Ω, power absorbed = 78.125 W.

P7.2.10 R_{Lm} = 4.38 Ω, power absorbed = 1.25 W.

P7.2.11 (a) Z_{Lm} = 3.6 + j1.8 Ω; power absorbed = 1.25 W.

(b) X_{Lm} = 0, $R_{Lm} = \frac{9}{\sqrt{5}}$ Ω, power absorbed = 11.8 W.

P7.2.12 (a) Y_{Lm} = 3.6 + j1.8 S; power absorbed = 12.5 W.

(b) B_{Lm} = 0, $G_{Lm} = \frac{9}{\sqrt{5}}$ S; power absorbed = 11.8 W.

P7.2.13 Z_{Lm} = 8.123 – j3.785 Ω, power absorbed = 549.2 W.

P7.2.14 a = 2.54, power absorbed = 86.21 W.

P7.2.15 $\mathbf{V}_{oc}$ = 10 V, $\mathbf{I}_{sc}$ = -j2.5 A.

P7.2.16 R_{Lm} = 8 Ω. power absorbed = 50 W.

P7.2.17 a = 2, power absorbed = 2 W.

P7.2.18 (a) N_2 = 4,000 turns.

(b) N_2 = 6,000 turns.

P7.2.19 (a) a = 2.34, power absorbed = 1.18 W.

(b) $X = \frac{80}{29}$ Ω, power absorbed = 3.19 W.

(c) R_x = 25.96 Ω; power absorbed = 3.53 W.

(d) $R_x = \frac{664}{29}$ Ω and $X = \frac{80}{29}$ = 2.76 Ω, power absorbed = 3.77 W.

P7.2.20 (a) $a = 2.34$, power absorbed = 1.18 W.

(b) $B = \frac{80}{29}$ S, power absorbed = 3.19 W.

(c) G_x = 25.96 S; power absorbed = 3.53 W.

(d) $G_x = \frac{664}{29}$ S and $B = \frac{80}{29} = 2.76$ S; power absorbed = 3.77 W.

P7.3.1 $R_{sh} = \frac{5}{0.95} = 5.26\ \Omega$.

P7.3.2 $R_v = \frac{10\text{ V}}{50\ \mu\text{A}} = 200\ \text{k}\Omega$.

P7.3.3 -20%.

P7.3.4 9.0%.

P7.3.5 6,666,433 Ω.

P7.3.6 499,990 Ω.

P7.3.7 (a) $R_V = \frac{20\text{ V}}{50\ \mu\text{A}} - 100 = 399{,}900\ \Omega$.

(b) 40 V.

(c) $R_1 = \frac{400}{3}$ kΩ, $R_2 = 0.4$ MΩ.

Chapter 8 Balanced Three-Phase Systems

P8.1.1 $2.591\angle 37.2^\circ\ \Omega$.

P8.1.2 $16.43\angle -11.5$ A.

P8.1.3 $379.77\angle -0.19^\circ$ V.

P8.1.4 $\mathbf{I}_{aA} = 59\angle 75^\circ$ A, $\mathbf{I}_{AB} = 34\angle 45^\circ$ A.

P8.1.5 $\mathbf{I}_{nN} = 2.233\angle 29.4^\circ$ A.

P8.1.6 $\mathbf{I}_{aA} = 5.82\angle 40^\circ$ A, $\mathbf{I}_{bB} = 3\angle 142.5^\circ$ A, $\mathbf{I}_{cC} = 6\angle\text{-}110^\circ$ A.

P8.1.7 $|Z_\phi| = \frac{8}{50} = 0.16\ \Omega$. Since a percentage voltage drop is involved, the impedance per phase is independent of whether the generators are connected in Y or in Δ. $|Z_\phi| = \frac{8}{50} = 0.16\ \Omega$. Magnitude of circulating = 10.42 A.

P8.1.8 $\frac{10}{\sqrt{3}}\angle 30^\circ$ A.

P8.2.3 4.3A.

P8.2.4 12.06 A.

P8.2.5 $\mathbf{I_N} = 204.0\angle\text{-}162.7°$ A before the phase is open circuited and $\mathbf{I_N}$ = $176.8\angle 111.6°$ A after the phase is open circuited.

P8.2.6 $|\mathbf{V_{6\Omega}}| = 130.8$ V, $|\mathbf{V_{10\Omega}}| = 187.4$ V, $|\mathbf{V_{15\Omega}}| = 210$ V.

P8.2.7 $\mathbf{I_{aA}} = -20\sqrt{3} + j20$ A; $\mathbf{I_{bB}} = -20 - j20(2+\sqrt{3})$ A, $\mathbf{I_{cC}} = 20(\sqrt{3}+1)(1+j)$ A.

P8.2.8 $\mathbf{I_{aA}} = -20\sqrt{3} + j20$ A.

P8.2.9 13.13 kV.

P8.2.10 $\mathbf{I_{aA}} = 26.17\angle 64.5°$ A.

P8.2.11 $\mathbf{I_{nN}} = 12.2\angle\text{-}150°$ A.

P8.2.12 $\mathbf{V_1} = 181.5\angle\text{-}30°$ V.

P8.2.13 $\mathbf{V_{AB}} = 75.2\angle 39.4°$ V.

P8.2.14 $\mathbf{I_C} = 1.36\angle 8.61°$A.

P8.2.15 $j\dfrac{13\pi}{\sqrt{3}}$ Ω.

P8.2.16 The single-phase equivalent circuit is $25\left(2-\sqrt{3}\right) - j25$ V with respect to n, in series with 5 Ω.

P8.2.17 Equivalent phase impedance is $-j5$ Ω.

P8.3.1 30 + j23.49 Ω.

P8.3.2 C = 5.55 mF.

P8.3.3 Total real power = 5.73 Kw, total reactive power = 1.27 kVAR.

P8.3.4 35.7%.

P8.3.5 Total real power absorbed = 18.392 kW; total reactive power absorbed = 7744 – 5808 = 1.936 kVAR; total apparent power absorbed = 18.49 kVA.

P8.3.6 C = 1.78 mF.

P8.3.7 (a) $\mathbf{I_C} = 25.58\angle 180°$ A.

(b) R_C = 4.29 Ω; X_C = -7.43 Ω.

(c) Q_B = 1900 VAR, Q_C = -4860 VAR.

P8.3.8 Total real power = 1731 W, total reactive power -1729 VAR; apparent power = 2446 W.

P8.3.9 577 V.

P8.3.10 363 V.

P8.3.11 9584 W; p.f. = 0.73.

P8.3.12 (a) 128.3 A.

(b) 491 V.

(c) 109.1 kVA.

P8.3.15 57.74 kW and 28.87 kW.

P8.3.16 W_1 = 6.38 kW and W_2 = 19.62 kW.

P8.3.17 0.87.

P8.3.18 $W_2 = 39.6$ W.

P8.3.19 W_1 = 8848 W; W_2 = 5572 W.

P8.3.20 -j125.1 Ω.

Chapter 9 Responses to Periodic Inputs

P9.1.1 (a) 20 ms;

(b) Function is not periodic.

P9.1.2 (a) period = 0.02 s; $f(t)$ = 0.5sin(100πt) + 0.5sin(300πt).

(b) period = 0.02 s; $f(t)$ = 0.25 – 0.25[0.5cos(200πt) + sin(200πt)] + 0.25sin(400πt) + 0.125cos(600πt)].

P9.1.3 1/π.

P9.1.5 $f(t) = 1.5 + \frac{4}{\pi^2}\sum_{\substack{n=-\infty \\ n\neq 0}}^{\infty}\frac{1}{n^2}\left(\cos\left(\frac{n\pi}{2}\right) - 1 - j\sin\left(\frac{n\pi}{2}\right)\right)$; in trigonometric form: a_0 = 1.5, $a_n = \frac{8}{\pi^2 n^2}\left(\cos\left(\frac{n\pi}{2}\right) - 1\right) = -\frac{8}{\pi^2 n^2}$, n = 1, 3, 5, 7, etc., $a_n = -\frac{16}{\pi^2 n^2}$, n = 2, 6, 10, 14, etc., and a_n = 0, n = 4, 8, 12, 16, etc. $b_n = \frac{8}{n^2\pi^2}\sin\left(\frac{n\pi}{2}\right)$ = 0 for even n, $b_n = \frac{8}{\pi^2 n^2}1$, n = 1, 5, 9, 13, etc. and $b_n = -\frac{8}{\pi^2 n^2}$, n = 3, 7, 11, 15, etc.

P9.1.6 $f(t) = \sum_{n=1}^{\infty}\frac{16}{\pi^2 n^2}\cos\frac{n\pi}{4}(t-1)$.

P9.1.7 $f(t) = 6 - \sum_{n=1,3,5,\ldots}^{\infty}\frac{16}{\pi^2 n^2}\cos n\pi t - \sum_{n=1,,3,5\ldots}^{\infty}\frac{8}{\pi n}\sin n\pi t.$

P9.1.8 a_n = 0 for even n, and $a_n = \frac{-2}{n^2\pi^2}$ for odd n; $b_n = \frac{-1}{n\pi}$ for even n, and

$b_n = \frac{5}{n\pi}$ for odd n.

P9.1.9 $\frac{A_1 + A_2}{\pi} + \frac{A_1 - A_2}{2}\cos\omega_0 t + \frac{2}{\pi}(\frac{A_1 + A_2}{3}\cos 2\omega_0 t - \frac{A_1 + A_2}{15}\cos 4\omega_0 t +$

$\frac{A_1 + A_2}{35}\cos 6\omega_0 t + \ldots + \frac{(-1)^{n+1}}{4n^2 - 1}(A_1 + A_2)\cos 6\omega_0 t + \ldots$

P9.1.10 $a_n = -\frac{4A_m}{n^2\pi^2}$, and $b_n = \frac{2A_m}{n\pi}$.

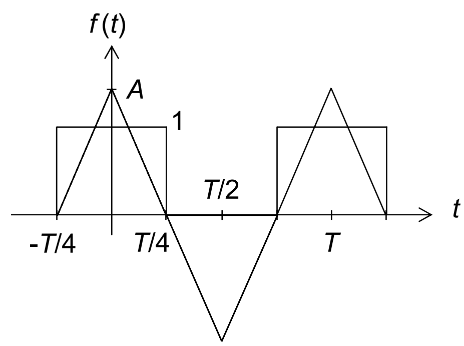
P9.1.11 (a) $a_n = \frac{2(e\cos n\pi - 1)}{1 + n^2\pi^2}$; $a_n = \frac{2(e-1)}{1 + n^2\pi^2}$ for even n, and $a_n = -\frac{2(e+1)}{1 + n^2\pi^2}$ for odd n.

(b) $b_n = -\frac{2n\pi(e\cos n\pi - 1)}{1 + n^2\pi^2}$; $b_n = -\frac{2n\pi(e-1)}{1 + n^2\pi^2}$ for even n, and

$b_n = \frac{2n\pi(e+1)}{1 + n^2\pi^2}$ for odd n.

P9.1.12 (a) $f(t) = \frac{A}{4} + \frac{4A}{\pi^2}\left(\cos\omega_0 t + \frac{1}{2}\cos 2\omega_0 t + \frac{1}{9}\cos 3\omega_0 t + \frac{1}{25}\cos 5\omega_0 t + \ldots\right)$.

(c) the FSE of the required function could be obtained as the product of $-f_{tr}(t)$ of Eq. (9.3.12) and the FSE of the rectangular pulse train shown.

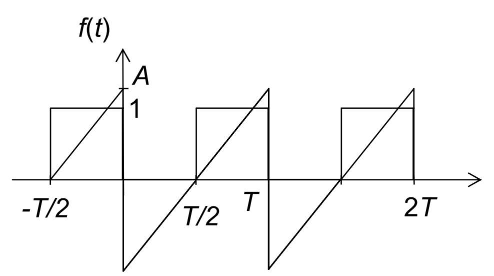


P9.1.13 (a) $f(t) = \frac{A}{4} - (\frac{2A}{\pi^2}\cos\omega_0 t + \frac{A}{\pi}\sin\omega_0 t) - \frac{A}{2\pi}\sin 2\omega_0 t -$

$(\frac{2A}{9\pi^2}\cos 3\omega_0 t + \frac{A}{3\pi}\sin 3\omega_0 t) -$

$\frac{A}{4\pi}\sin 4\omega_0 t - \ldots.$

(b) The FSE can be obtained as the product of the two functions shown.



P9.1.14 $f(t)=\frac{A}{4}-(\frac{2A}{\pi^2}\cos\omega_0 t-\frac{A}{\pi}\sin\omega_0 t)+\frac{A}{2\pi}\sin 2\omega_0 t-$

$(\frac{2A}{9\pi^2}\cos 3\omega_0 t-\frac{A}{3\pi}\sin 3\omega_0 t)+\frac{A}{4\pi}\sin 4\omega_0 t-....$

P9.1.16 $C_n=\frac{1}{n^2\omega_0^2}\left(1-e^{jn\pi/2}\right).$

P9.1.18 $f(t)=\frac{1}{4}+\frac{1}{\pi}\left[\cos\frac{\pi}{2}t+9\sin\frac{\pi}{2}t\right]+\sin\pi t+\frac{1}{3}\left(-\cos\frac{3\pi}{2}t+9\sin\frac{3\pi}{2}t\right)+$

$\frac{1}{5}\left(\cos\frac{5\pi}{2}t+9\sin\frac{5\pi}{2}t\right)+...\Big].$

P9.1.19 The harmonics vary with n as $1/n^3$.

P9.1.20 a_1 = -1.1024, a_3 = 0.6460, a_5 = 0.4564, b_1 = 3.4065, b_3 = 0.2, b_5 = 0.0935.

P9.2.1 $v_O=\frac{8A_m}{\pi^2}\left[\frac{\omega_0 CR}{\sqrt{1+\omega^2C^2R^2}}\sin(\omega_0 t-\alpha)+\frac{\omega_0 CR}{3\sqrt{1+9\omega_0^2C^2R^2}}\sin(3\omega_0 t-\alpha)+\right.$

$\frac{\omega_0 CR}{5\sqrt{1+25\omega_0^2C^2R^2}}\sin(5\omega_0 t-\alpha)+...$

P9.2.2 4.37cos(ωt + 158.5°) + 0.34cos(ωt + 130.2°) + 0.085cos(ωt + 116.9°) V.

P9.2.3 $v_O(t)$ = 31.83 + 3.00cos(200πt + 12.8°) + 0.138cos(400πt -174.1°) + 0.026cos(600πt +3.85°) V; rms of AC components of output = 2.12 V.

P9.2.4 $v_O(t)$ =25 + 25.44cos(200πt + 38.9°) + 0.63cos(400πt -172°) + 0.13cos(600πt +4.64°) V; rms of AC components of output = 18 V.

P9.2.5 $v_O(t)$ = -0.0106cos(10^6t – 90.38°) -0.0018cos(2×10^6t – 90.13°) - 0.00074cos(3×10^6t – 90.08°) -0.00041cos(4×10^6t – 90.06°) - 0.00026cos(5×10^6t – 90.05°) V. The second harmonic is attenuated by a factor of 0.013. The capacitor blocks the DC component from the output without affecting the AC component.

P9.2.6 $v_O(t)$ = 85.1cos($\omega_0 t$ – 85.8°) + 3.03cos($3\omega_0 t$ – 89.7°) + 0.651cos($5\omega_0 t$ – 89.8°) V.

P9.2.7 10 V.

P9.2.8 0, ωt, $2\omega t$, $2\omega t$, $3\omega t$, and $4\omega t$.

P9.2.9 $v_O=\frac{5}{2}+\sqrt{5}\cos(\omega_o t-63.4°)+2.06\cos(2\omega_o t-76.0°)+2\sin 3\omega_o t-$

$2\cos 4\omega_o t$ V.

P9.2.10 $v_o(t) = 4 + 24.8\sin 2{,}000\pi t - 4\cos 4{,}000\pi t - 1.6\sin 6{,}000\pi t$ V. The output does not possess half-wave symmetry because of the DC and the cosine terms due to v_i^2.

P9.3.1 rms value = 9.46 V; % error $= 0.56\%$.

P9.3.2 11.87 A.

P9.3.3 5 A.

P9.3.4 4.44 W.

P9.3.5 $I_1 = 2.5\sqrt{11/3}$ A, $I_3 = 2.5/\sqrt{3}$ A, $V_1 = 2.5\sqrt{110/3}$ V, and $V_3 = 2.5\sqrt{82/3}$ V.

P9.3.6 $2\sqrt{55/3}$ V.

P9.3.8 (a) rms value = 14.44;

(b) $f(t) = -20\sin 10^3t + 4\sin 3\times10^3t - \sin 5\times10^3t + 0.2\sin 7\times10^3t$.

(c) The function is odd and half-wave symmetric.

If the function is negated, $f(t) = 20\sin 10^3t - 4\sin 3\times10^3t + \sin 5\times10^3t - 0.2\sin 7\times10^3t$. the rms value is the same and the function is still odd and half-wave symmetric.

P9.3.9 (a) 9.54 V.

(b) 13.11 A.

(c) 12 W.

Chapter 10 Frequency Responses

P10.1.1 (a) $0.958\sin(0.3\times10^6t - 16.7°)$ V.

(b) $0.707\sin(10^6t - 45°)$ V.

(c) $0.316\sin(3\times10^6t - 71.6°)$ V.

P10.1.2 $H(j\omega) = \dfrac{V_O(j\omega)}{I_{SRC}(j\omega)} == \dfrac{5\times10^3}{1+j\omega}$ V/A; response is lowpass; passband gain = 5×10^3; corner frequency = 1 krad/s.

P10.1.3 $H(j\omega) = \dfrac{V_O(j\omega)}{I_{SRC}(j\omega)} = \dfrac{2.5\times10^3\,j\omega}{1+j\omega}$ V/A; response is highpass; passband gain = 2.5×10^3; corner frequency = 1 krad/s,

P10.1.4 $\dfrac{V_O}{V_I} = \dfrac{R_2}{R_1+R_2} \times \dfrac{1}{1+sC(R_1 \,||\, R_2)}$; the effect of R_2 is to reduce the magnitude by $R_2/(R_1 + R_2)$ and to increase the cutoff frequency from $1/CR_1$ to $1/C(R_1||R_2)$.

P10.1.5 $H(j\omega) = \frac{0.5}{1 + j40\omega}$; $|H(j\omega)| = \frac{0.5}{\sqrt{1 + (40\omega)^2}}$, $\angle H(j\omega) = -\tan^{-1}(40\omega)$; response is lowpass; passband gain = 0.5; corner frequency = 25 krad/s.

P10.1.6 $H(j\omega) = \frac{40j\omega}{1 + j40\omega}$; $|H(j\omega)| = \frac{40\omega}{\sqrt{1 + (40\omega)^2}}$, $\angle H(j\omega) = 90^\circ - \tan^{-1}(40\omega)$; response is highpass; passband gain = 1; corner frequency = 25 krad/s.

P10.1.7 $H(j\omega) = \frac{2 \times 10^3}{1 + j0.09\omega}$ V/A; $|H(j\omega)| = \frac{2 \times 10^3}{\sqrt{1 + (0.09\omega)^2}}$ V/A,

$\angle H(j\omega) = -\tan^{-1}(0.09\omega)$; response is lowpass; passband gain = 2×10^3; corner frequency = 100/9 krad/s.

P10.1.8 $H(j\omega) = \frac{j5 \times 10^{-5}\omega}{1 + j3 \times 10^{-4}\omega}$; $|H(j\omega)| = \frac{5 \times 10^{-5}\omega}{\sqrt{1 + (3 \times 10^{-4}\omega)^2}}$,

$\angle H(j\omega) = 90^\circ - \tan^{-1}(3 \times 10^{-4}\omega)$; response is highpass; passband gain = 1/6; corner frequency = 10/3 krad/s.

P10.1.9 $H(j\omega) = \frac{1/6}{1 + j\omega 25/3}$, where ω is in Mrad/s. It follows that

$|H(j\omega)| = \frac{1/6}{\sqrt{1 + (25\omega/3)^2}}$. $\angle H(j\omega) = -\tan^{-1}(25\omega/3)$; response is lowpass; passband gain = 1/6; corner frequency = 120 krad/s.

P10.1.10 $H(j\omega) = \frac{0.8}{1 + 0.04j\omega}$. It follows that $|H(j\omega)| = \frac{0.8}{\sqrt{1 + (0.04\omega)^2}}$.

$\angle H(j\omega) = -\tan^{-1}(0.04\omega)$; response is lowpass; passband gain = 0.8; corner frequency = 25 krad/s.

P10.1.11 $H(j\omega) = \frac{j0.05\omega}{1 + j\omega/16}$. It follows that $|H(j\omega)| = \frac{0.05\omega}{\sqrt{1 + (\omega/16)^2}}$,

$\angle H(j\omega) = 90^\circ - \tan^{-1}(\omega/16)$; response is highpass; passband gain = 0.8; corner frequency = 16 krad/s.

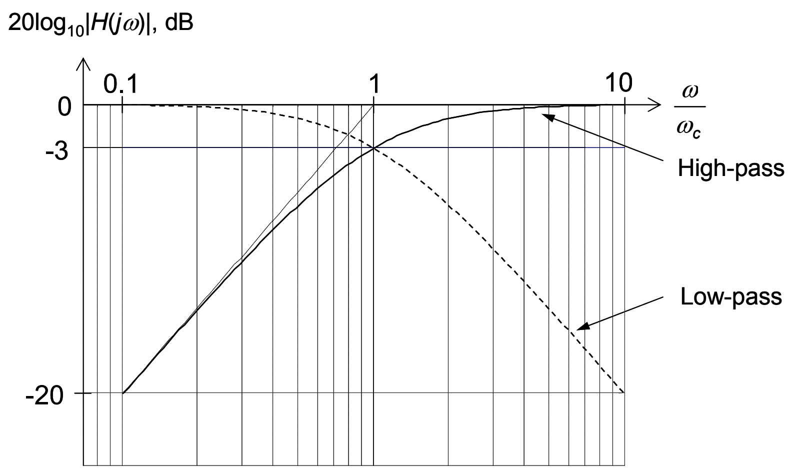
P10.1.12 $H(j\omega) = \frac{2j\omega}{1 + j1.8\omega}$. It follows that $|H(j\omega)| = \frac{2\omega}{\sqrt{1 + (1.8\omega)^2}}$,

$\angle H(j\omega) = 90^\circ - \tan^{-1}(1.8\omega)$; response is highpass; passband gain = 10/9; corner frequency is ω_{cl} = 5/9 krad/s.

P10.1.13 $H(j\omega) = \dfrac{10/9}{1 + j\omega/180}$. It follows that $|H(j\omega)| = \dfrac{10/9}{\sqrt{1 + (\omega/180)^2}}$,

$\angle H(j\omega) = -\tan^{-1}(\omega/180)$; response is lowpass; passband gain = 10/9; corner frequency = 180 krad/s.

P10.1.14



P10.2.1 No, the lowest-order bandpass and bandstop filters are second order.

P10.2.2 R = 10 kΩ, $C = 25$ nF, and L = 4 mH.

P10.2.3 $20\log_{10}2$ = 6 dB.

P10.2.4 $L_1 = 0.1$ mH, $L_2 = 0.3$ mH.

P10.2.5 $\theta \cong \dfrac{2\omega'}{\omega_0}$.

P10.2.6 10^4 rad/s.

P10.2.7 (a) $H(s) = \dfrac{4s}{s^2 + 5s + 625}$, where s is in krad/s.

(b) 25 krad/s.

(c) $Q = 5$.

(d) BW = 5 krad/s.

P10.2.8 Q is reduced from 200 to 500/3.

P10.2.9 (a) $Q = 1/3$.

(b) $Q = 1/2$.

The interpretation is that when k is large, the circuit composed of kR and C/k has a negligible loading effect on the first circuit. The two circuits, of identical time constant RC, are cascaded but effectively isolated.

P10.2.10 (a) $\omega_{ch} = 5$ krad/s, $R = 200\ \Omega$.

(b) the response is -20.04 dB when the switch is open and -46 dB when the switch is closed.

P10.2.11 (a) $H(j\omega) = 1$ at all frequencies.

(b) Phase angle varies between 0 and 360°.

P10.2.17 0.56.

P10.2.18 (a) Response is highpass with peaking.

(b) 40 dB.

(c) $0.9951\omega_0$ and $1.0051\omega_0$. For a bandpass response having Q = 100, the half-power frequencies are at $0.9950\omega_0$ and $1.0050\omega_0$.

P10.3.1 $R = 1000\sqrt{2}\ \Omega$ and $L' = 0.1$ H.

P10.3.2 $R = 1000\sqrt{2}\ \Omega$ and $L' = 0.1$ H.

P10.3.3 $\dfrac{V_O}{V_{SRC}} = \dfrac{R_2}{LCR_1}\dfrac{1}{s^2 + s\left(\dfrac{1}{CR_1} + \dfrac{R_2}{L}\right) + \dfrac{1}{LC}\dfrac{R_1 + R_2}{R_1}}$; $C = \dfrac{5\sqrt{6}}{4\pi}\left(\sqrt{3} \pm 1\right)$ nF,

$L' = \dfrac{\sqrt{6}}{4\pi}\left(\sqrt{3} \mp 1\right)$.

P10.3.4 $\dfrac{V_O}{V_{SRC}} = \dfrac{R_2}{R_1 + R_2}\dfrac{s^2}{s^2 + \dfrac{s}{(R_1 + R_2)}\left(\dfrac{1}{C} + \dfrac{R_1R_2}{L}\right) + \dfrac{1}{LC}\dfrac{R_1}{R_1 + R_2}}$;

C = $\dfrac{5}{\pi\sqrt{6}}\left(\sqrt{3} \pm 1\right)$ nF, $L = \dfrac{1}{\pi\sqrt{6}}\left(\sqrt{3} \mp 1\right)$ H.

P10.3.5 $\dfrac{V_O(s)}{V_{SRC}(s)} = \dfrac{s^3CL}{2s^3C^2L + s^2\left(2LC + C^2\right) + 2sC + 1}$; $L = 15.9$ mH, $C = 7.96$ nF.

P10.4.3 (a) $\dfrac{V_O}{V_{SRC}} =$

$$\frac{R_C}{\left(R_{src} + R_C\right)}\frac{s^2 + s\left(\dfrac{1}{CR_C} + \dfrac{R_L}{L}\right) + \dfrac{1}{LC}}{s^2 + \dfrac{s}{R_{src} + R_C}\left[\dfrac{1}{C} + \dfrac{1}{L}\left(R_{src}R_L + R_LR_C + R_CR_{src}\right)\right] + \dfrac{\left(R_{src} + R_L\right)}{LC\left(R_{src} + R_C\right)}};$$

(c) $\omega_0 = 10.01$ krad/s, $Q = 6.27$.

P10.4.4 (a) 0 dB.

(b) $H(s) = \dfrac{s(s+10^5)\times 10^6}{(s+100)(s+10^4)(s+10^6)}$.

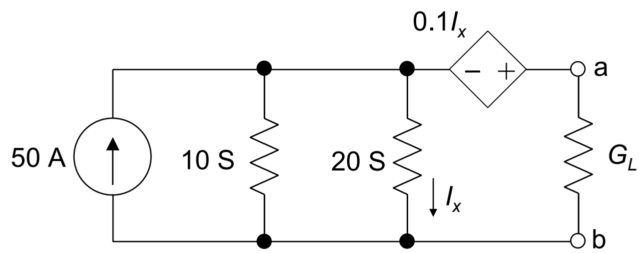
Chapter 11 Duality and Energy-Storage Elements

P11.1.1 The circuit of Fig. P1.2.10 is the dual of the circuit of Fig. P1.2.7, and the circuit of Fig. P1.2.9 is the dual of the circuit of Fig. P1.2.8.

P11.1.2 It is the same transformer with the input and output interchanged.

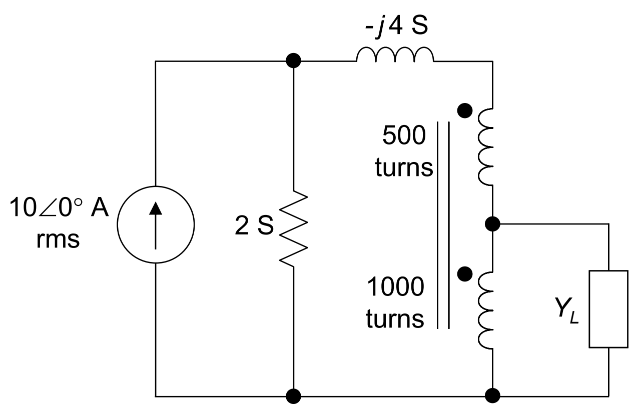
P11.1.3 The series impedance is a resistance of 1/20 Ω in series with a capacitive reactance of $-j/30\Omega$. The shunt impedances consist of a resistance of 1/8 Ω in parallel with an inductive reactance $j/12$ Ω.

P11.1.6 R_{Lm} = 0.1 Ω, power absorbed = 62.5 W.

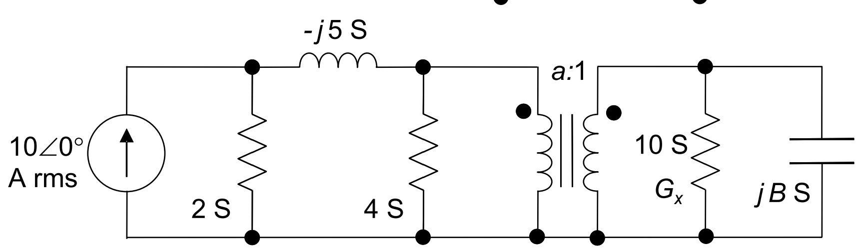


P11.1.7 (a) Y_{Lm} = 3.6 + j1.8 S; maximum power absorbed $=12.5$ W.

(b) B_{Lm} = 0, G_{Lm} = $\dfrac{9}{\sqrt{5}}$ S; power absorbed = 11.8 W.



P11.1.8



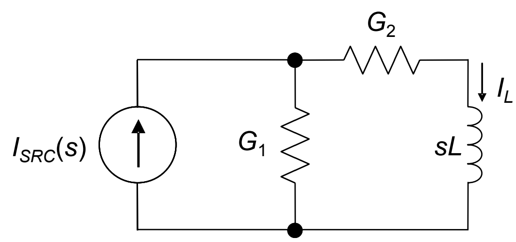
(a) $a = \sqrt{\dfrac{10\sqrt{10}}{5.766}} = 2.34$; power absorbed $=$ 1.18 W.

(b) $B = \frac{80}{29}$; power absorbed = 3.19 W.

(c) G_x = 25.96 S; power absorbed = 3.53 W.

(d) $G_x = \frac{664}{29}$ S, $B = \frac{80}{29}$ = 2.76 S, power absorbed = 3.77 W

P11.1.9 $\frac{I_L}{I_{SRC}} = \frac{10}{s + 21/2}$, where s is in krad/s; response is lowpass.



P11.2.1 $p = \delta(t)$ Ws; $w = 1$ J.

P11.2.2 $p = 10\delta(t-2)$ Ws; $w = 10$ J.

P11.2.3 $p = 10\left(1-e^{0.5}\right)\delta(t-1)$ Ws; $w =$ -6.49J.

P11.2.4 (a) -21.17.

(b) 13.

P11.2.6 1.

P11.2.8 For the train of positive-going impulses, $C_0 = \frac{2A_m}{T} = C_n$; the amplitude spectrum is a series of lines of height $2A_m/T$ and the phase spectrum has zero angles.

For the train of negative-going impulses, $C_0 = -\frac{2A_m}{T}$, $C_n = (-1)^{n+1}\frac{2A_m}{T}$; the amplitude spectrum is the same as before, whereas the phase spectrum is 180° for even n, including zero, and is zero for odd n.

For the delayed square wave, $C_n = -j\frac{2A_m}{n\pi}$; the amplitude spectrum is a series of lines of amplitude $\frac{2A_m}{n\pi}$; The phase spectrum is -90° for positive n and 90° for negative n.

P11.3.1 $\frac{2}{3}$ F.

P11.3.2 18 mH.

P11.3.3 $= \frac{1}{5}$ H.

P11.3.4 15/41 F.

P11.3.5 5/8 F.

P11.3.6 2.2 H.

P11.3.8 (a) 2.35 V; charges on capacitors are: 47/5 C, 141/10 C, and 47/2 C.

(b) Initial energy $= 56.75$ J; final energy $= 55.225$ J.

P11.3.9 (a) q_{1f} = –78/31 C, q_{2f} = 15/31 C, q_{3f} = 170/31 C; $v_{1f} = 39/62$ V,

$v_{2f} = 5/62$ V, and $v_{3f} = 17/31$ V.

(b) Initial energy = 56.75 J; final energy = 2.31 J.

P11.3.10 (a) $\lambda_{1f} = -2$ Wb-turns, $\lambda_{2f} = -6$ Wb-turns, $\lambda_{3f} = 18$ Wb-turns; $i_{1f} = -0.5$ A,

$i_{2f} = -1$ A, and $i_{3f} = 1.5$ A.

(b) Initial energy = 98 J; final energy = 17 J.

P11.3.11 (a) final current: $20/11$ A; final flux linkage are: $80/11$ Wb-turns, $120/11$ Wb-turns, and $240/11$ Wb-turns.

(b) Initial energy = 98 J; final energy = 400/11 J.

P11.3.13 q_{1f} = 2 – 0.4 = 1.6 C, q_{2f} = –3 – 0.4 = –3.4 C, q_{34f} = 3 – 0.4 = 2.6 C.

$v_{1f} = 4/15$ V, $v_{2f} = -17/15$ V, $v_{3f} = 13/15$ V. The charges on C_3 and C_4 are:

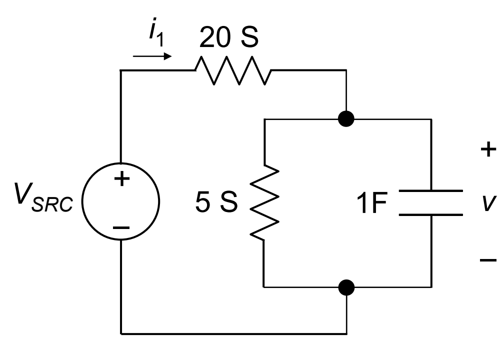
$q_{3f} = 13/15$ C and $q_{4f} = 26/15$ C.

P11.3.15 $v_O = 20e^{-1.25t}$ V, where t is in s.

Chapter 12 Natural Responses and Convolution

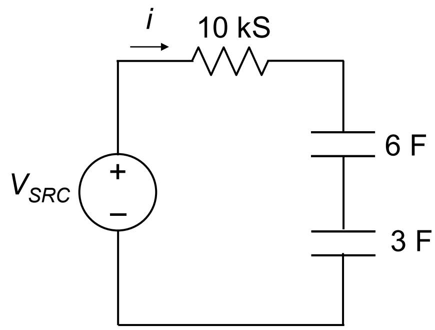
P12.1.1 $i_L = 2e^{-t/40}$ A, $v_1 = -40e^{-t/40}$ V, where t is in ms.

P12.1.2 $v = 2e^{-t/40}$ V and $i_1 = -40e^{-t/40}$ A, where t is in ms.



P12.1.3 $v = -50e^{-5t}$ V, where t is in ms.

P12.1.4 $i = -50e^{-5t}$ A, where t is in ms.



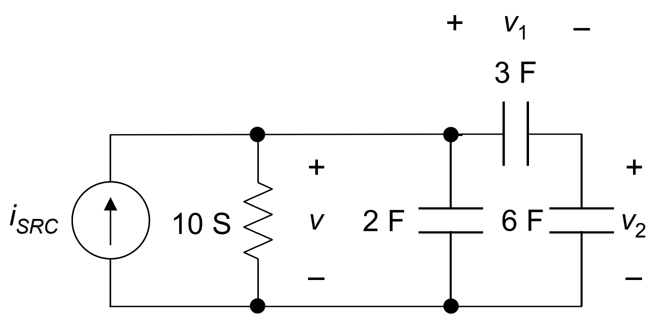
P12.1.5 $v = -90e^{-5t}$ V, where t is in ms.

P12.1.6 $i = -90e^{-5t}$ A, where t is in ms.

P12.1.7 $i_1 = \frac{5}{3}e^{-2.5t}$ A, $i_2 = \frac{4}{3}e^{-2.5t}$ A.

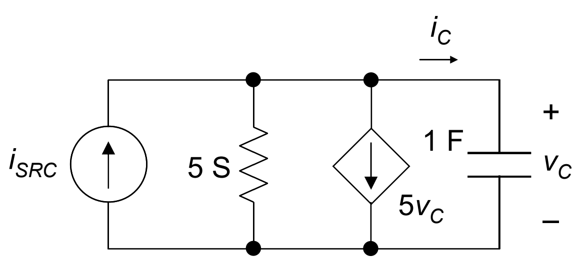
P12.1.8 $v_1 = \frac{5}{3}e^{-2.5t}$ V,

$v_2 = \frac{4}{3}e^{-2.5t}$ V.



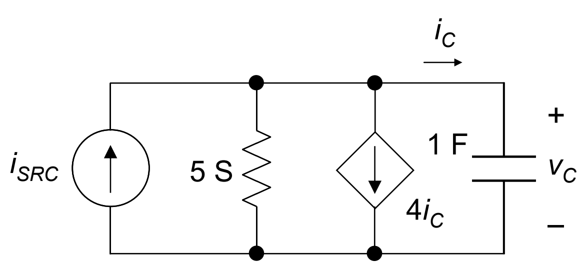
P12.1.9 $v_L = -100e^{-10t}$ V.

P12.1.10 $i_C = -100e^{-10t}$ A.



P12.1.11 $v_L = -2e^{-t}$ V.

P12.1.12 $i_C = -10e^{-t}$ A.



P12.2.1 (a) $R = 2\omega_o L = 1000\ \Omega$.

(d) $v_C = 10e^{-t}(t+1)$V, $v_L = 10e^{-t}(1-t)$ V, where t is in ms.

P12.2.2 (b) $R_p = 0.001\,\Omega$; $v_{Cp} = 20te^{-t}$ mV, $i_{Lp} = 10e^{-t}(t+1)$A, $i_{Cp} = 10e^{-t}(1-t)$ A, where *t* is in ms.

P12.2.3 (c) $v_C = 10e^{-t}(1-t)$V, $v_L = 10e^{-t}(t-3)$, where *t* is in ms.

P12.2.4 (a) $s_1 = -1000\left(2-\sqrt{3}\right) = -267.95$ rad/s, $s_2 = -1000\left(2+\sqrt{3}\right) = -3732.1$ rad/s;

$Q = 0.25$; $v_C(0^+)$ = 10 V; $i_L(0^+)$ = 80 mA; $A = 0.04 - \dfrac{0.07}{\sqrt{3}}$ A;

$B = 0.04 + \dfrac{0.07}{\sqrt{3}}$ A.

(c) $v_C = 10e^{-2t}\left(\cosh\sqrt{3}t - \dfrac{2}{\sqrt{3}}\sinh\sqrt{3}t\right)$,

$v_L = 10e^{-2t}\left(-15\cosh\sqrt{3}t + \dfrac{26}{\sqrt{3}}\sinh\sqrt{3}t\right)$V, where *t* is in ms.

P12.2.5 (a) $s_1 = -200\left(1 - j2\sqrt{6}\right)$ rad/s, $s_2 = -200\left(1 + j2\sqrt{6}\right)$ rad/s; $Q = 2.5$; $v_C(0^+)$ = 10 V; $i_L(0^+)$ = 8 mA; $A = 0.004 - j\dfrac{0.023}{\sqrt{6}}$ A, $B = 0.004 + j\dfrac{0.023}{\sqrt{6}}$ A.

(b) $i_L = e^{-t/5}\left(8\cos 0.4\sqrt{6}t + \dfrac{46}{\sqrt{6}}\sin 0.4\sqrt{6}t\right)$ mA, where *t* is in ms;

$v_L = e^{-t/5}\left(8.4\cos 0.4\sqrt{6}t - \dfrac{14.2}{\sqrt{6}}\sin 0.4\sqrt{6}t\right)$V, where *t* is in ms;

$v_C = e^{-t/5}\left(10\cos 0.4\sqrt{6}t - \dfrac{5}{\sqrt{6}}\sin 0.4\sqrt{6}t\right)$V, V, where *t* is in ms.

P12.2.6 (a) $R = 250\,\Omega$.

(d) $i_L = 5e^{-t/2}(2-t)$ mA, $i_C = 30e^{-t/2} - 5te^{-t/2}$ mA, where *t* is in μs.

P12.2.7 (a) $s_1 = -10^5$ rad/s, $s_2 = -2.5\times10^6$ rad/s; $Q = 0.19$; $i_L(0^+)$ = 10 mA;

$v_C(0^+) = -26$ V; $A = 1/24$ V and $B = -626/24$ V.

(b) $v_L = \dfrac{e^{-t/10}}{24} - \dfrac{625e^{-2.5t}}{24}$V, $i_L \equiv -\dfrac{5}{12}e^{-t/10} + \dfrac{125}{12}e^{-2.5t}$ mA,

$i_C = -\dfrac{e^{-t/10}}{60} + \dfrac{6250}{24}e^{-2.5t}$ mA, $v_C = -\dfrac{e^{-10^5 t}}{24} + \dfrac{625e^{-2.5\times10^6 t}}{24}$, where *t* is in μs.

P12.2.8 (a) $s_1 = -0.4\times10^6 + j0.3\times10^6$ rad/s, $s_2 = -0.4\times10^6 - j0.3\times10^6$ rad/s;

$Q = 0.625$; $i_L(0^+)$ = 10 mA; $v_C(0^+) = -\dfrac{32}{4} = -8$ V; $A = -4 - j\dfrac{7}{6}$ V,

$B = -4 + j\dfrac{7}{6}$ V.

(b) $v_L = -e^{-0.4t}\left(8\cos 0.3t - \dfrac{7}{3}\sin 0.3t\right)$, $i_L = 10e^{-0.4t}\left(\cos 0.3t - \dfrac{4}{3}\sin 0.3t\right)$ mA,

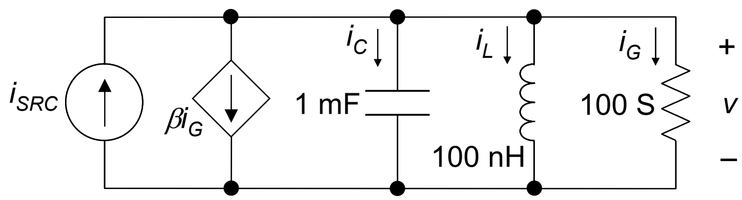
$i_C = 0.4e^{-0.4t}\left(39\cos 0.3t + \dfrac{44}{3}\sin 0.3t\right)$mA, where t is in μs.

P12.2.9 (a) $\beta = 1$.

(b) $\beta = \sqrt{2} - 1$.

P12.2.10 (a) $\beta = 1$.

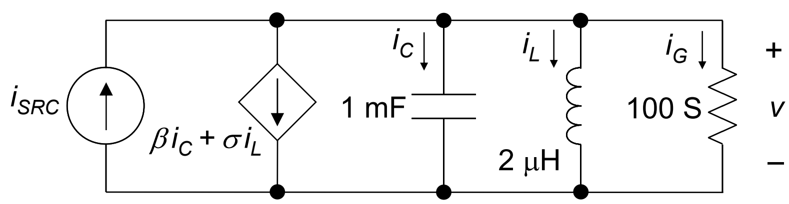
(b) $\beta = \sqrt{2} - 1$.



P12.2.11 $\beta = 5\sqrt{2} - 1$, $\sigma = \sqrt{2} - 1$.

P12.2.12 $\beta = 5\sqrt{2} - 1$,

$\sigma = \sqrt{2} - 1$.



P12.2.13 $L = 6.25$ H, R = 5 KΩ, $v_C = 2\times10^4 te^{-400t}$ V.

P12.2.16 $= 4\cos 2t + 6$ J.

P12.3.1 $1 + e^{-2t} - 2e^{-t}$.

P12.3.2 (a) $\dfrac{t}{2}\sin\omega t$.

(b) $\dfrac{t}{2}\cos\omega t + \dfrac{\sin\omega t}{2\omega}$.

(c) $\dfrac{\omega\sinh at - a\sin\omega t}{\omega^2 + a^2}$.

P12.3.3 $y = -\dfrac{t^2}{2}$, $0 \le t \le 1$; $y = \dfrac{t^2}{2} - 2t + 1$, $1 \le t \le 3$; $y = \dfrac{t^2}{2} - 2t + 1$, $3 \le t \le 4$;

$y = -\dfrac{3t^2}{2} + 14t - 31$, $4 \le t \le 5$; $y = -\dfrac{t^2}{2} + 4t - 6$, $5 \le t \le 6$;

$y = \frac{t^2}{2} - 8t + 30$, $6 \le t \le 7$; $y = \frac{3t^2}{2} - 22t + 79$, $7 \le t \le 8$;

$y = -\frac{t^2}{2} + 10t - 49$, $9 \le t \le 11$; $y = \frac{t^2}{2} - 12t + 72$, $11 \le t \le 12$;

$y(t) = 0$, $t \ge 12$. At $t = 5$, $y = 3/2$.

P12.3.4 The functions to be convolved are:

$$f^{(-1)}(t) = -\frac{t^2}{2}u(t) + \left[t^2 - 2t + 1\right]u(t-1) + \left[-t^2 + 6t - 9\right]u(t-3)$$

$$+\left[t^2 - 10t + 25\right]u(t-5) + \left[-\frac{t^2}{2} + 6t - 18\right]u(t-6)\text{, and:}$$

$$g^{(1)}(t) = \delta(t) - 2\delta(t-3) + \delta(t-6).$$

P12.3.5 $y = -\frac{t^3}{6} + t$, $0 \le t \le 1$; $y = \frac{t^3}{2} - 2t^2 + 3t - \frac{2}{3}$, $1 \le t \le 2$;

$-\frac{t^3}{2} + 4t^2 - 11t + \frac{34}{3}$, $2 \le t \le 3$; $\frac{t^3}{6} - 2t^2 + 7t - \frac{20}{3}$, $3 \le t \le 4$;

$y(t) = 0$, $t \ge 4$.

P12.3.6 The functions to be convolved are:

$$f^{(-1)}(t) = \left(\frac{t^2}{2} + t\right)u(t) + \left(-t^2 + 2t - 1\right)u(t-1) + \left(\frac{t^2}{2} - 3t + 4\right)u(t-2)\text{, and:}$$

$$g^{(1)}(t) = \delta(t) - u(t) + 2u(t-1) - u(t-2) - \delta(t-2).$$

P12.3.7 $y = 9t$, $0 \le t \le 1$; $y = 18 - 9t$, $1 \le t \le 2$; $y = 2t - 4$, $2 \le t \le 3$; $y = 8 - 2t$, $3 \le t \le 4$;

$y = t - 4$, $4 \le t \le 5$; $y = 6 - t$, $5 \le t \le 6$; $y = 0$, $t \ge 6$.

P12.3.8 $y = t$, $0 \le t \le 1$; $y = 2 - t$, $1 \le t \le 2$; $y = 2t - 4$, $2 \le t \le 3$; $y = 8 - 2t$, $3 \le t \le 4$;

$y = 9t - 36$, $4 \le t \le 5$; $y = 9(6 - t)$, $5 \le t \le 6$; $y = 0$, $t \ge 6$.

P12.3.9 $y(0) = \frac{1}{CR}\left[\frac{e^{(-a+1/CR)\lambda}}{-a+1/CR}\right]_{-\infty}^{0}$.

P12.3.11 $8u(t-1) - 12u(t-3) - 4u(t-6) + 6u(t-8)$.

P12.3.12 $y = t + 1$ V, $t \le 0$; $= 2te^{-t} - t + 1$V, $t \ge 0$.

P12.3.13 (a) $y = \frac{t^2}{2} + t + \frac{1}{2}$, $-1 \le t \le 0$; $y = -\frac{3}{2}t^2 + t + \frac{1}{2}$, $0 \le t \le 1$;

$y = \frac{3}{2}t^2 - 5t + \frac{7}{2}$, $1 \le t \le 2$; $y = -\frac{t^2}{2} + 3t - \frac{9}{2}$, $2 \le t \le 3$; $y = 0$, $t \ge 6$.

(b) The functions to be convolved are:

$$g^{(-1)}(t) = \left(\frac{t^2}{2} + t + \frac{1}{2}\right)u(t+1) - t^2u(t) + \left(\frac{t^2}{2} - t + \frac{1}{2}\right)u(t-1)\text{, and:}$$

$$f^{(1)}(t) = \delta(t) - 2\delta(t-1) + \delta(t-2)\,.$$

P12.3.14 The two functions are expressed in terms of step functions as:

$$f(t) = 2u(t) - 3u(t-1) + u(t-2)\,;$$

$$g(t) = 2u(t) + u(t-1) - 2u(t-2) - u(t-3)\,.$$

Chapter 13 Switched Circuits

P13.1.1 $v_O = -80e^{-5t}$ V.

P13.1.2 $v_C = -50 + 95e^{-t/30}$ V, where t is in ms; v_C =0 at t = 19.3 ms.

P13.1.3 $i_x = -\frac{4}{6}i_c = -\frac{1}{6}e^{-\frac{t}{0.72}}$ mA.

P13.1.4 5 J.

P13.1.5 1.44 kHz.

P13.1.6 $v_C = 30\left(1 - e^{-0.3t}\right)$V, $i_x = 3 + 6e^{-0.3t}$ mA.

P13.1.7 $v_O = 24 + 48e^{-t/0.12}$ V.

P13.1.8 $v_C = -12.8\left(1 - e^{-t/0.48}\right)$ V, $0 \le t \le 1$ s; $v_C = 8 + (-19.21)e^{-35(t-1)/12}$ V, $t \ge 1$ s.

P13.1.9 $v_x(t) = \frac{500}{7}e^{-17t/1400}$ V, $0 \le t \le 50$ μs; $v_x(t) = 38.9e^{-(t-50)/200}$ V, $50 \le t \le 100$ μs;

$v_x(t) = 30.3e^{-17(t-100)/1400}$ V, $t \ge 100$ μs.

P13.1.10 $v_C = 10e^{-t/10}$ V, where t is in ms.

P13.1.11 $i_x = \frac{1}{3}e^{-t/1.2}$ mA, where t is in ms.

P13.1.12 $v_C = \frac{160}{7}\left(1 - 2e^{-7t}\right)$ V.

P13.1.13 Switch in position b: $v_C = 14.86\left(1 - e^{-t/0.74}\right)$V, where t is in ms;

switch in position c: $v_C = 0.94 + 9.06e^{(t-0.83)/4.76}$ V, $t \ge 0.83$ ms,

P13.1.14 $v_x = 12 - 8e^{-27t/29}$ V, $t \ge 0$ s.

P13.1.15 (a) $v_C = 6\left(1-e^{-t}\right)$ V, $i_C = 6e^{-t}$ mA, $t \geq 0$ ms.

(b) energy delivered by supply = $72\left(1-e^{-t}\right)$ mJ; energy absorbed by battery $= 36\left(1-e^{-t}\right)$ mJ.

(c) 18 J.

(d) $v_C = -6 + 12e^{-t'}$ V, $i_C = -12e^{-t'}$; as $t' \to \infty$, energy delivered by battery = 72 J, net energy lost by the capacitor = 0, energy dissipated in resistor = 72 J.

P13.1.16 $i_1 = \dfrac{16}{3}(1\text{-}\ e^{-2.5t})$, $0 \leq t \leq 1$ ms; $i_1 = 4.9e^{-t/2}$ mA, $t \geq 1$ ms.

P13.1.17 $v_\phi = 75e^{-t}$ V, $R = 1250/3$ kΩ.

P13.1.18 $i_\phi = e^{-2.5t}$ A, R = 50 Ω.

P13.1.19 $v_O = 12e^{-21t/80}$ V, $t \geq 0$ ms; final current is 8/7 A in the 0.8 H inductor, 3/35 A in the 0.4 H inductor, and 43/35 in the 0.2.H inductor.

P13.1.20 $v_L = 10e^{40t/11}$ V, $t \geq 0$ μs.

P13.1.21 $v_O = \dfrac{1680}{101} + \dfrac{168}{1010}e^{-101t/16}$ V, $t \geq 0$.

P13.1.22 $i_1 = 4\left(1+e^{-15t/4}\right)$ V, $t \geq 0$.

P13.1.23 $v_1 = 1.35e^{-5(t-3)/8}$, $t \geq 3$ ms.

P13.2.1 (a) 311.88 Ω.

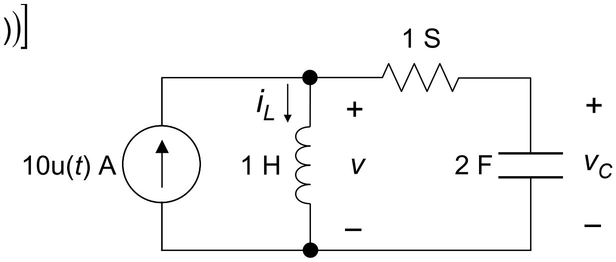
(b) 289.48 Ω.

P13.2.2 (a) $v_C(0^+) = 0$, $i_L(0^+) = 0$, $v_L(0^+) = 10$ V, and $i(0^+) = 10$ A.

(b) underdamped.

(c) $i_L = 10e^{-t/2}\sin(t/2)$ A; $v_L = 10e^{-t/2}[\cos(t/2) - \sin(t/2)]$ V;

$v_C =$
$10\left[1 - e^{-t/2}\left((\cos(t/2) - \sin(t/2)\right)\right]$
V; $i = 10e^{-t/2}\cos(t/2)$ A.



P13.2.3 (a) $v_C(0^+) = 0$, $i_L(0^+) = 0$,

$i_C(0^+) = 10$ A, and

$v(0^+) = 10$ V.

(b) underdamped.

(c) $v_C = 10e^{-t/2}\sin(t/2)$ A; $i_C = 10e^{-t/2}[\cos(t/2) - \sin(t/2)]$ V;

$i_L = 10[1 - e^{-t/2}((\cos(t/2) - \sin(t/2))]$ A; $v = 10e^{-t/2}\cos(t/2)$ A.

P13.2.4 (a) 500 Ω.

(b) $i_L(0^+)$ = 100 μA, $v_C(0^+)$ = 50 mV, and $v_L(0^+)$ = -50 mV.

(c) i_L = $100e^{-0.2t}$ μA, $v_C = 50e^{-0.2t}$ mV, where t is in μs.

P13.2.5 (a) 500 S.

(b) $v_C(0^+)$ = 100 μV, $i_L(0^+)$ = 50 mA, and $i_C(0^+)$ = -50 mA.

(c) v_C = $100e^{-0.2t}$ μV and i_L = $50e^{-0.2t}$ mA, where t is in μs.

P13.2.6 (a) $\rho = 0$.

(b) $v = 100te^{-10t}$ V, $i_C = 100(e^{-10t} - 10te^{-10t})$ mA, and

$i_L = 100 - 100(e^{-10t} + 10te^{-10t})$ mA, t being in ms.

P13.2.7 (a) $\rho = 0$.

(b) $i = 10te^{-10t}$ mA, $v_L = 0.1e^{-10t} - te^{-t}$ V, and $i_L = 100 - 100(e^{-10t} + 10te^{-10t})$ mA, t being in ms.

P13.2.8 Response is underdamped; $i = \frac{5}{4}e^{-6t}\sin 8t$ mA,

$v_L = 25e^{-6t}[4\cos 8t - 3\sin 8t]$ mV, and

$v_C = 100 - 25e^{-6t}[4\cos 8t + 3\sin 8t]$ mV, where t is in ms.

P13.2.9 $i = 20e^{-t}\sin t$ mA and $v_0 = 10e^{-t}(\cos t - \sin t)$ V, where t is in ms.

P13.2.10 $v_O = \frac{5e^{-0.5t}}{1+\sqrt{3}}\left[\left(4+\sqrt{3}\right)e^{\sqrt{3}t/2} - \left(5+2\sqrt{3}\right)e^{-\sqrt{3}t/2}\right]$ V, where t is in ms.

P13.2.11 $v_O = e^{-t}\left[\left(160 + 280/\sqrt{3}\right)e^{\sqrt{3}t/2} + \left(160 - 280/\sqrt{3}\right)e^{-\sqrt{3}t/2}\right]$ V, where t is in ms.

P13.2.12 v_O = 0.

P13.2.13 $v_O = e^{2t}$ V,

Chapter 14 Two-Port Circuits

P14.1.1 $z_{11} = \frac{V_1}{I_1} = \frac{1}{51}\Omega$, $z_{12} = \frac{1}{51}\Omega$; $z_{21} = -\frac{99}{51}\Omega$, $z_{22} = \frac{1}{17}\Omega$;

y_{11} = 1.5 S, y_{12} = -0.5 S, y_{21} = 49.5 S, and y_{22} = 0.5 S.

P14.1.2 $h_{11} = \frac{2}{3}\,\Omega$, $h_{12} = \frac{1}{3}$, $h_{21} = 33$, h_{22} = 17 S;

$g_{11} = 51$S, g_{21} = -1, $g_{21} = -99$, $g_{22} = 2\,\Omega$.

P14.1.3 $a_{11} = -\frac{1}{99}$, $a_{12} = -\frac{1}{49.5}\,\Omega$, $a_{21} = -\frac{17}{33}$S. $a_{22} = -\frac{1}{33}$;

$b_{11} = 3$, $b_{12} = 2\,\Omega$, $b_{21} = \frac{I_2}{V_1} = 51$S; $b_{22} = 1$.

P14.1.4 z_{11}=1 Ω, z_{12}= 1 Ω, z_{21}= -0.5 Ω, z_{22}= 0.5 Ω;

y_{11}= 0.5 S, y_{12} = -1S, y_{21}= 0.5 S, $y_{22} = \frac{\mathbf{I_2}}{\mathbf{V_2}}\Big|_{\mathbf{V_1=0}}$ = 1S.

P14.1.5 h_{11}= 2 Ω, h_{12}= 2 , h_{21}= 1, h_{22}= 2 S;

g_{11}= 1S, g_{12}= -1, g_{21}= -0.5; g_{22}= 1Ω.

P14.1.6 a_{11}= -2, a_{12}= -2 Ω, a_{21}= -2 S, a_{22}= -1;

b_{11}= 0.5; b_{12}= 1 Ω, b_{21}= 1 S; b_{22}= 1.

P14.1.7 $z_{11} = j\,\Omega$; z_{12} = j2 Ω, $z_{21} = j2\,\Omega$, z_{22} = 0;

y_{11} = 0, $y_{21} = -\frac{j}{2}$S, $y_{21} = -\frac{j}{2}$S. $y_{22} = -\frac{j}{4}$S.

P14.1.8 $h_{11} = \infty$, $h_{12} = \infty$, $h_{21} = \infty$ $h_{22} = \infty$;

g_{11} = j S, g_{12} = 2, g_{21} = -2, g_{22} = j4 Ω.

P14.1.9 $a_{11} = -\frac{1}{2}$, a_{12} = -j2 Ω, $a_{21} = -\frac{j}{2}$S; a_{22} = 0;

b_{11} = 0, b_{12} = -j2Ω, b_{21} = $= -\frac{j}{2}$S, $b_{22} = -\frac{1}{2}$.

P14.1.10 $z_{11} = \frac{-2\omega^2 + j3\omega}{1 + j6\omega}\;\Omega$, $z_{12} = \frac{j4\omega}{1 + 6j\omega} = z_{21}\;\Omega$, $z_{21} = \frac{j4\omega}{1 + j6\omega}\;\Omega$, $z_{22} = \frac{j6\omega}{1 + j6\omega}\,\Omega$;

$y_{11} = \frac{3}{j\omega}$; $y_{12} = -\frac{2}{j\omega}$S = y_{21}, $y_{22} = 1 + \frac{3}{j2\omega}$ S.

P14.1.11 $h_{11} = \frac{j\omega}{3}\;\Omega$, $h_{12} = \frac{2}{3}$, $h_{21} = -\frac{2}{3}$; $h_{22} = 1 + \frac{1}{j6\omega}$ S;

$g_{11} = \frac{1 + j6\omega}{-\omega^2 + j3\omega}$S, $g_{12} = \frac{-4}{3 + j2\omega}$, $g_{21} = \frac{4}{3 + j2\omega}$, $g_{22} = \frac{j2\omega}{3 + j2\omega}\,\Omega$.

P14.1.12 $a_{11} = \frac{3 + j2\omega}{4}$, $a_{12} = \frac{j\omega}{2}\,\Omega$, $a_{21} = \frac{1 + j6\omega}{j4\omega}$ S; $a_{22} = -\frac{\mathbf{I_1}}{\mathbf{I_2}}\Big|_{\mathbf{V_2=0}} = \frac{3}{2}$;

$b_{11} = \dfrac{3}{2}$; $b_{12} = \dfrac{j\omega}{2}\,\Omega$, $b_{21} = \dfrac{1+j6\omega}{j4\omega}$ S, $b_{22} = \dfrac{3+j2\omega}{4}$.

P14.1.13 z_{11}= 2(s + 1/s) Ω = z_{22}, z_{21}= (s + 1 /s) = z_{12} Ω.

P14.1.14 y_{11} = 1 S = y_{22}, $\boldsymbol{y_{12}} = -\dfrac{1}{1+j\omega}$ = y_{22}.

P14.1.15 $z_{11} = \dfrac{2-\omega^2+j2\omega}{1+j3\omega-2\omega^2-j\omega^3}$, $z_{12} = \dfrac{1}{1+j3\omega-2\omega^2-j\omega^3} = z_{21}$,

$z_{22} = \dfrac{1-\omega^2+j\omega}{1+j3\omega-2\omega^2-j\omega^3}$.

P14.1.16 $z_{11} = 2 + j10\,\Omega$, z_{12}= (1 – $j\omega$) Ω, z_{21}= (1 – $j\omega$) Ω, $z_{22} = 2 + j2\omega\,\Omega$.

P14.1.17 $z_{11} = \dfrac{s^3+5s^2+6s+1}{s(s^2+4s+3)}\,\Omega$, $z_{12} = \dfrac{1}{s(s^2+4s+3)}\,\Omega$, $z_{21} = \dfrac{1}{s(s^2+4s+3)}\,\Omega$,

$z_{22} = \, = \dfrac{s+2}{s(s+3)}\,\Omega$,

P14.1.18 $y_{11} = \left(\dfrac{j\omega}{4+j\omega} + \dfrac{1-\omega^2}{1-\omega^2+j\omega}\right)$S, $y_{12} = -\left(\dfrac{j2\omega}{4+j\omega} + \dfrac{1}{1-\omega^2+j\omega}\right) = y_{21}$,

$y_{22} = \dfrac{j4\omega}{4+j\omega} + \dfrac{1+j\omega}{1-\omega^2+j\omega}$.

P14.1.19 $h_{11} = r_x + \dfrac{1}{1/r_\pi + s(C_\pi + C_\mu)}$, $h_{12} = \dfrac{\mathbf{V_1}}{\mathbf{V_2}} = \dfrac{sC_\mu}{1/r_\pi + s(C_\pi + C_\mu)}$,

$h_{21} = \dfrac{\mathbf{I_2}}{\mathbf{I_1}} = \dfrac{sC_\mu + g_m}{1/r_\pi + s(C_\pi + C_\mu)}$, $h_{22} = \dfrac{\mathbf{I_2}}{\mathbf{V_2}} = \dfrac{sC_\mu(sC_\pi + g_m + 1/r_\pi)}{1/r_\pi + s(C_\pi + C_\mu)}$.

P14.2.4 $\mathbf{V_{Th}} = \dfrac{10\angle 0^\circ}{3j/40} \equiv$ 9.97cos(1,000t + 4.29°) V, $Z_{Th} = \dfrac{110 + 2385j/4}{1 - 3j/40}$

$\equiv 605.0\angle 83.8^\circ\,\Omega$; v_2 = 1.6cos(1,000t – 70.4°) V.

P14.2.5 power input is = 197.8 W; power delivered to load = 27.3 W.

P14.2.6 Z_{Lm} = 4 – j4 Ω, maximum power delivered = 100 W.

P14.2.7 $R_{Lm} = 4.31\,\text{k}\Omega$, maximum power delivered $= 8.9\,\mu$W.

P14.2.8 a_{11} = a_{22} = 2, $a_{12} = 3$ Ω, and a_{21} = 1 S.

P14.2.9 Z_{in1} = 0.841 kΩ, $Z_{in2} = \dfrac{1}{5.1} = 0.196$ kΩ, overall gain = 8446.

P14.2.10 R_m = 10 kΩ.

P14.2.11 $\frac{\mathbf{V_2}}{\mathbf{V_1}} = \frac{10}{97}(-4 + 9j)$.

P14.2.14 $Z_{in} = 14.38 - 0.0156j\ \Omega$, $Z_{out} = 260\ \Omega$, v_2 = 12.9cos(1,000t + 0.24°) V.

P14.2.15 $\mathbf{V_{Th}}$ = 0, $Z_{Th} = \frac{b_{12} + b_{11}Z_{src}}{b_{22} + b_{21}Z_{src}} = 20 - j10\ \Omega$, $\boldsymbol{v_2}$ = 0.

P14.2.16 $\mathbf{V_{Th}}$ = -10.181 + j0.5325 V, Z_{Th} = 1.0432 – j0.0546 Ω,

v_2 = 9.23cos(1000t + 177.3°) V.

P14.2.17 $Z_{in} = \frac{46}{65} + \frac{21}{130}j\ \text{k}\Omega$, $Z_{out} = \frac{90}{137} + \frac{42}{137}j\ \text{k}\Omega$, $\frac{\mathbf{V_2}}{\mathbf{V_1}} = 0.46\angle -41.8^\circ$.

P14.2.18 $\mathbf{V_O}/\mathbf{V_{SRC}}$= 0.0068 - j0.0653.

P14.2.19 911 krad/s.

P14.2.20 *2* krad/s.

P14.2.21 $Z_{in} = 5.2035 + j1.9469\ \Omega$, Z_{Th} = -0.3529 - j0.5882 Ω,

$\mathbf{V_O}/\mathbf{V_{SRC}}$ = -0.4795 - j0.4452.

P14.2.22 Z_{in} = 0.3904 - j0.4589 Ω, Z_{Th} = 2.6154 + j2.9231 Ω,

$\mathbf{V_O}/\mathbf{V_{SRC}}$ = 0.1308 + j0.1462.

Chapter 15 Laplace Transform

P15.1.3 (a) $\frac{s}{s^2 - a^2}$.

(b) $\frac{a}{s^2 - a^2}$.

(c) $\frac{s^2 + 2s + 17}{\left(s^2 + 2s - 15\right)^2}$.

P15.1.4 (a) $2\frac{e^{-(s+2)}}{s+2}$.

(b) $\frac{s\cos(1) + 4\sin(1)}{s^2 + 16}$.

P15.1.9 $\frac{A}{\alpha T}\frac{1}{s^2} - \frac{A}{\alpha(1-\alpha)T}\frac{e^{-\alpha Ts}}{s^2} + \frac{A}{(1-\alpha)T}\frac{e^{-Ts}}{s^2}$.

P15.1.10 (a) $\frac{A}{(1 - e^{-sT})}$.

(b) $-\dfrac{Ae^{-sT/2}}{(1-e^{-sT})}$.

P15.1.11 $24-47e^{-t}+23e^{-2t}$.

P15.1.12 (a) $F(s) = 0.1-\dfrac{3.4643}{s+16.7154}+\dfrac{1.4857}{s+8.8198}-\dfrac{0.0107+j0.1226}{s-2.7676-j5.1240}-$

$\dfrac{0.0107-j0.1226}{s-2.7676+j5.1240}$, $f(t) = 0.1\delta(t) - 3.4643\,e^{-16.7154t} - 1.4857\,e^{-8.8198t}$ +

$0.2462e^{2.7676t}\cos(5.1240t-95^{\circ})$.

(b) $F(s) = 0.5-\dfrac{3.3733}{s+4.0567}-\dfrac{0.1727+j0.0224}{s-1.1176-j2.1732}+\dfrac{0.1727-j0.0224}{s-1.1176+j2.1732}+$

$\dfrac{0.5140-j0.7716}{s+1.0893-j1.1750}$ + $\dfrac{0.5140+j0.7716}{s+1.0893+j1.1750}$, $f(t) = 0.5\delta(t)$ –

$3.3733\,e^{-4.0567t}$ + $0.1741e^{1.1176t}\cos(2.1732t+7.4^{\circ})$ +

$0.9271e^{1.1176t}\cos(1.1750t-56.3^{\circ})$.

P15.1.13 $x(t)=\left[-\dfrac{3+j4}{25}e^{+j2t}-\dfrac{1-j2}{5}te^{-t}+\dfrac{3+j4}{25}e^{-t}\right]u(t)$; because of the differences in the values at $t=0^{-}$.

P15.1.14 $h(t)=4e^{-t}\cos 2t-2e^{-t}\sin 2t$.

P15.1.15 $H(s)=\dfrac{2(7s^2+8s+3)}{(s+1)^3(s^2+1)}$, $h(t)=e^{-t}\left(2-4t+t^2\right)-2\cos t+6\sin t$.

P15.1.16 (a) $e^{-2s}\left(\dfrac{1}{s^2}+\dfrac{1}{s}\right)$.

(b) $e^{-s}\left(\dfrac{1}{s^2}-\dfrac{1}{s}\right)$.

P15.1.18 $f(t) = \delta^{(1)}(t)+\cos t$.

P15.2.1 $v_o(t)=5e^{-t}$ where t is ms; the pole of $V_O(s)$ is located at $s =$ -1 krad/s.

P15.2.2 $v_O(t) = \dfrac{10}{3}$ V; The pole of $V_O(s)$ is at the origin.

P15.2.3 $i_O(t)=\dfrac{10}{3}e^{-t/90}$ mA, where t is in μs; the pole of I_O(s) is at $-\dfrac{1}{90}$ Mrad/s.

P15.2.4 $v_o(t)=\dfrac{900}{19}-\dfrac{710}{19}e^{-38t/3}$, where t is in ms; the poles of $V_O(s)$ are at zero and

$\frac{38}{3}$ krad/s.

P15.2.5 $v_O(t) = 0.5e^{-t/3}$ V, where t is in ms; the pole of $V_O(s)$ is at -1000/3 rad/s.

P15.2.6 $v_O(t) = 10$ V, the pole of V_O is at the origin.

P15.2.7 $H(s) = \frac{1}{s+1}$, $V_{SRC} = \frac{2}{s} - \frac{e^{-4s}}{s^2} + \frac{e^{-6s}}{s^2}$.

P15.3.1 $C_2R_2 = C_1R_1$.

P15.3.2 $v_O(t) = 0.5\delta(t) - 12.5e^{-57t}$, $t \geq 0$, $\frac{1}{3}\sqrt{\frac{1+(0.02\omega)^2}{1+\left(\frac{0.04\omega}{3}\right)^2}}$

$\tan\phi = \frac{0.02\omega - 0.04\omega/3}{1+(0.02\omega)(0.04\omega/3)}$,

P15.3.3 $h(t) = \frac{1}{\sqrt{5}}\left[e^{-\left(\frac{3-\sqrt{5}}{2}\right)t} - e^{-\left(\frac{3+\sqrt{5}}{2}\right)t}\right]$.

P15.3.4 $H(j\omega) = \frac{10^{10}}{10^{10} - \omega^2 + 3\times 10^5 j\omega}$; at $\omega = 10^5$ rad/s, $|H(j\omega)| = 1/3$, and

$\angle H(j\omega) = -90°$.

P15.3.5 1.265×10^5 rad/s.

P15.3.6 $V_O(s) = \frac{s}{s^2 + s + 1/2}$, $v_O(t) = \sqrt{2}\, e^{-t/2}(\cos t/2 + 45°)$ V.

P15.3.7 $L = 2.5$ H, $C = 400\sqrt{2}$ μF.

P15.3.8 $\frac{V_O}{V_I} = \frac{2s(s+1)}{2s^2 + 2s + 1}$.

P15.3.9 $\frac{V_o}{I_I} = \frac{1}{6s+7}$.

P15.3.10 $v_O(t) = \frac{2e^{-t}}{3}\left(\frac{1}{3} - t\right)$, $|H(j\omega)| = \frac{2\omega^2}{\sqrt{(5-3\omega^2)^2 + 121\omega^2}}$, $\phi = \tan^{-1}\left(\frac{11\omega}{5-3\omega^2}\right)$.

P15.3.11 $v_O(t) = v_{O1}(t)u(t) - v_{O1}(t-1)u(t-1)$ V, where v_{O1} =

$\left(\frac{1}{3} + \frac{11\sqrt{61}}{183}\right)e^{-\left(\frac{\sqrt{61}+11}{6}\right)t} - \left(\frac{1}{2} - \frac{11\sqrt{61}}{183}\right)e^{\left(\frac{\sqrt{61}-11}{6}\right)t}$ V.

P15.3.12 $v_O(t) = v_{O1}(t)u(t) - v_{O1}(t-\pi)u(t-\pi)$ V, where v_{O1} =

$$\frac{22}{125}\cos t - \frac{4}{125}\sin t + \frac{2e^{-11t/6}}{125}\left[-11\cosh\left(\frac{\sqrt{61}\,t}{6}\right) + \frac{141}{\sqrt{61}}\sinh\left(\frac{\sqrt{61}\,t}{6}\right)\right] \text{ V.}$$

P15.3.13 $v_O(t) = v_{O1}(t)u(t) - v_{O1}(t-2\pi)u(t-2\pi)$ V where v_{O1} =

$$\frac{22}{125}\cos t - \frac{4}{125}\sin t + \frac{2e^{-11t/6}}{125}\left[-11\cosh\left(\frac{\sqrt{61}\,t}{6}\right) + \frac{141}{\sqrt{61}}\sinh\left(\frac{\sqrt{61}\,t}{6}\right)\right] \text{ V.}$$

P15.3.14 $v_O = -v_{O1}(t-1)u(t-1) + v_{O2} + v_{O3}$, where v_{O1} is as derived in P15.3.11; v_{O2} =

$$\frac{2}{\sqrt{61}}\left(e^{-\left(\frac{\sqrt{61}+11}{6}\right)t} + e^{\left(\frac{\sqrt{61}-11}{6}\right)t}\right)\text{V, and } v_{O3} = -v_{O2}u(t-1) \text{ V.}$$

P15.3.15 $v_O = v_{O1} + v_{O2} + v_{O3}$, where v_{O1} is as derived in P15.3.11, $v_{O2} + v_{O3}$ are the negations of those derived in P15.3.14.

P15.3.16 $v_O = (1.3 + 4.5e^{-2t})u(t)$; $|H(j\omega)| = \dfrac{\omega}{\sqrt{4+\omega^2}}$, $\angle H(j\omega) = 90° - \tan^{-1}\dfrac{\omega}{2} = \phi$.

P15.3.17 $v_O = \left(t - \dfrac{1}{3}\right)e^{-t} + \dfrac{e^{-t/2}}{3}\left[\cos\dfrac{\sqrt{5}}{2}t - \dfrac{1}{\sqrt{5}}\sin\dfrac{\sqrt{5}}{2}t\right]$V; $|H(j\omega)| = \dfrac{\omega}{\sqrt{1+4\omega^2}}$,

$\angle H(j\omega) = 90° - \tan^{-1}(2\omega)$.

P15.3.18 $v_O = \dfrac{1}{2}\left(1 - e^{-t}(\cos t + \sin t)\right)u(t) - \dfrac{1}{2}\left(1 - e^{-(t-1)}(\cos(t-1) + \sin(t-1))\right)u(t-1)$;

$|H(j\omega)| = \dfrac{1}{2\sqrt{1+\omega^4}}$, $\angle H(j\omega) = -\tan^{-1}\dfrac{2\omega}{2-\omega^2}$.

P15.3.19 $v_x = \dfrac{1}{5}\left(\sin t + 2t\sin t - 2\cos t + t\cos t\right) + \dfrac{2e^{-t/2}}{5}\left(\cosh\dfrac{\sqrt{5}}{2}t - \dfrac{1}{\sqrt{5}}\sinh\dfrac{\sqrt{5}}{2}t\right)$;

$|H(j\omega)| = \dfrac{\omega^2}{\sqrt{(\omega^2+1)^2 + 4\omega^2}}$, $\angle H(j\omega) = \tan^{-1}\dfrac{2\omega}{\omega^2+1}$.

P15.3.20 $v_O = 20 - \dfrac{262}{59}e^{-40t} - \dfrac{40}{177}e^{-2t/3}$ V.

P15.3.21 $v_O = 2 - \dfrac{518}{59}e^{-40t} + \dfrac{20}{177}e^{-2t/3}$ V.

P15.3.22 $v_O = 10 + \dfrac{248}{5}e^{t/2}\cos\dfrac{\sqrt{11}}{2}t + \dfrac{32\sqrt{11}}{5}e^{t/2}\sin\dfrac{\sqrt{11}}{2}t$ V.

P15.3.23 $v_O = \frac{10}{3} + \frac{110}{3}e^{t/2}\cos\frac{\sqrt{11}}{2}t + \frac{910\sqrt{11}}{33}e^{t/2}\sin\frac{\sqrt{11}}{2}t$ V.

P15.3.24 $v_O = 10 - \frac{97}{10}e^{-170t/3}\cosh\frac{\sqrt{28390}}{3}t -$

$\frac{1634}{\sqrt{28390}}e^{-170t/3}\sinh\frac{\sqrt{28390}}{3}t + \frac{97}{10}\cosh\left(\frac{\sqrt{28390}}{3} - 170\right)t$ V.

P15.3.25 $v_O = 10 - 10e^{-170t/3}\cosh\frac{\sqrt{28390}}{3}t - \frac{337\sqrt{28390}}{5678}e^{-170t/3}\sinh\frac{\sqrt{28390}}{3}t -$

$\left[\frac{513\sqrt{28390}}{5678} + 15\right]\frac{416}{\sqrt{28390}}\sinh\left(\frac{\sqrt{28390}}{3} - 170\right)t$ V.

P15.3.26 $v_O = 20 - 20\cos 5\sqrt{2}t + \frac{39\sqrt{2}}{10}\sin 5\sqrt{2}t$ V.

P15.3.27 $v_O = 20 - 17\cos 5\sqrt{2}t + 4\sqrt{2}\sin 5\sqrt{2}t$ V.

P15.3.28 $v_O = 100 - e^{-3750t}\left[100\cosh 20\sqrt{35155}t + \frac{149997\sqrt{35155}}{281240}\sinh 20\sqrt{35155}t\right]$ V.

P15.3.29 $v_O = 100 - e^{-3750t}\left[95\cosh 20\sqrt{35155}t + \frac{17812}{\sqrt{35155}}\sinh 20\sqrt{35155}t\right]$ V.

P15.3.30 $i_2 = -0.6e^{-1.5t}$ A.

P15.3.31 $i_2 = -\frac{9}{22}e^{-.5t/44}$ A,

P15.4.1 $f(t) = e^{-t}$.

P15.4.2 (a) $\frac{t}{2}\sin\omega t$.

(b) $\frac{t}{2}\cos\omega t + \frac{\sin\omega t}{2\omega}$.

(c) $\frac{\omega\sinh at - a\sin\omega t}{\omega^2 + a^2}$.

P15.4.3 $v_O = 8u(t-1) - 12u(t-3) - 4u(t-6) + 6u(t-8)$ V.

P15.4.4 $i_{SRC} = 2.5\delta(t) - 5e^{-4t}$, $v_{SRC} = 2.5\delta(t)$.

P15.4.5 $i_C = 2\sqrt{2}\sin t/\sqrt{2} - \cos t/\sqrt{2}$.

Chapter 16 Fourier Transform

P16.1.1 (a) $\frac{1}{j\omega}\left(1-e^{-j4\omega}\right)$.

(b) $\frac{2}{(3+j\omega)^3}$.

(c) $-\frac{2}{\omega^2}$.

(d) $\frac{j2a\omega}{a^2+\omega^2}$.

(e) $\pi(e^{-|\omega-a|}+e^{-|\omega+a|})$.

P16.1.2 (a) $\frac{1}{2}\operatorname{sgn}(t) - e^{-5t}u(t)$.

(b) $(4e^{-2t}-5e^{-3t})u(t)$.

(c) $\frac{1}{4}(t+1)e^{-t}u(t)+\frac{1}{4}(t-1)e^{t}u(t)$.

(d) $\frac{4}{\pi}\operatorname{sinc}(2t)$.

(e) $1-e^{-2t}$.

P16.1.3 $f(t) = \left(\frac{A}{j\pi t}\right)\left(1-\cos\frac{\pi t}{2}\right)$.

P16.1.4 $F(j\omega) = \frac{2}{\omega}\left(2\sin 2\omega+\sin\omega\right)$

P16.1.5 $f(t) = -j\frac{A}{\pi t}\cos \pi t/2 + j\frac{2A}{\pi\pi t^2}\sin \pi t/2$.

P16.1.6 $f(t) = \frac{\tau}{j2t}e^{-j\pi t/2}+\frac{1}{t^2}\left[1-e^{-j\pi t/2}\right]$.

P16.1.7 (a) $F(j\omega)=\frac{2A}{\omega}\sin\left(\frac{\tau\omega}{2}\right)-\frac{8A}{\tau\omega^2}\sin^2\left(\frac{\tau\omega}{4}\right)$.

(b) $F(j\omega) = j2A\sin\left(\frac{\tau\omega}{2}\right)+\frac{j4A}{\tau\omega}\left(\cos\left(\frac{\tau\omega}{2}\right)-1\right)$.

P16.1.8 $f(t) = \frac{\tau}{t}\sin\left(\frac{\pi t}{2}\right)-\frac{4}{t^2}\sin^2\left(\frac{\pi t}{4}\right)$.

P16.1.9 $f(t)=\frac{A}{\pi}\frac{\cos(\pi t/2)}{1-t^2}$.

P16.1.10 $F(j\omega) = \dfrac{A\tau}{2}\left(\text{sinc}\dfrac{\omega\tau}{4}\right)^2$.

P16.1.11 $F(j\omega) = \dfrac{j2A}{\omega^2 - 1}\sin\pi\omega$.

P16.1.13 $F(j\omega) = \dfrac{j30}{\omega^2}\sin 2\omega - \dfrac{j20}{\omega^2}\sin 3\omega$.

P16.1.14 $F(j\omega) = \sum_{n=-\infty}^{\infty}\dfrac{jA}{n}\delta(\omega - n\omega_0)$, where $n \neq 0$ and $F(j\omega) = 2\pi \times \dfrac{A}{2}\delta(\omega) = \pi A\delta(\omega)$ for $n = 0$.

P16.1.15 $F(j\omega) = -\sum_{n=-\infty}^{\infty}\dfrac{jA}{n}\delta(\omega - n\omega_0)$, where $n \neq 0$ and $F(j\omega) = 2\pi \times \dfrac{A}{2}\delta(\omega) = \pi A\delta(\omega)$ for $n = 0$.

P16.1.16 $F(j\omega) = \sum_{n=-\infty}^{\infty} -\dfrac{8A_m}{\pi n^2}\delta(\omega - n\omega_0)$, n odd.

P16.1.17 $F_{hw}(j\omega) = \dfrac{A\pi}{2}\sum_{-\infty}^{\infty}\text{sinc}(n\pi/2)\left[\delta(\omega - \omega_0 - n\omega_0) + \delta(\omega + \omega_0 - n\omega_0)\right]$.

P16.1.18 $F_{hw}(j\omega) = 4A\delta(\omega) + 2A\sum_{-\infty}^{\infty}\dfrac{1}{n}\left[\delta(\omega - \omega_0 - n\omega_0) + \delta(\omega + \omega_0 - n\omega_0)\right]$, n odd.

P16.1.19 $\delta(\omega - (a+b))$.

P16.1.20 $F(j\omega) = \dfrac{1}{1 - re^{-j\omega}}$.

P16.1.21 $F(j\omega) = -\dfrac{2}{j\omega^3} + \dfrac{4e^{-j\omega}}{\omega^2} + \dfrac{2e^{-j2\omega}}{j\omega^3} = \dfrac{4e^{-j\omega}}{\omega^2}(1 - \text{sinc}\omega)$.

P16.1.22 $F(j\omega) = \dfrac{2}{\omega^2}\left[3\cos\omega - \cos 2\omega - 2\text{sinc}\omega\right]$.

P16.1.23 $F(j\omega) = \dfrac{j4}{\omega^3}(\cos\omega + \omega\sin\omega - 1)$.

P16.1.24 $f(t) = 2(t\cosh t + \sinh t)u(t)$.

P16.1.25 $H(j\omega) = \pi\delta(\omega) - \dfrac{j}{\omega} = \pi\delta(\omega) + \dfrac{1}{j\omega}$; $h(t) = u(t)$.

P16.2.1 $v_O = \dfrac{2}{3}\delta(t) - \dfrac{4}{9}e^{2t/3}u(t)$.

P16.2.2 $v_O = \frac{2}{3}e^{-2t/3}u(t)$.

P16.2.3 $v_O = \frac{2}{3}e^{-2t/3}u(t)$.

P16.2.4 $v_O = 2\left(e^{-jt} - \frac{2}{3}e^{-2t/3}\right)u(t)$.

P16.2.5 $v_O = \frac{4}{\sqrt{10}}\cos(2t + 18.4^\circ)$ V.

P16.2.6 $v_O = \frac{25}{3}\left(1 - e^{-6t/25}\right)u(t)$, $i_O = 2\times 10^{-3}e^{-6t/25}u(t)$ A.

P16.2.7 $v_O = \frac{25}{6}\text{sgn}(t) - \frac{25}{3}e^{-6t/25}u(t)$, $i_O = 2e^{-6t/25}u(t)$ mA, where t is in ms.

P16.2.8 (a) $i_O = te^{-t}u(t)$ A, $v_O = u(t) - e^{-t}u(t) - te^{-t}u(t)$ V.

(b) $i_O = \frac{2}{3}\left(e^{-0.5t} - e^{-2t}\right)u(t)$ A, $v_O = u(t) - \frac{4}{3}e^{-0.5t}u(t) + \frac{1}{3}e^{-2t}u(t)$ V.

(c) $i_O = 1.25e^{-0.6t}(\sin 0.8t)\, u(t)$ A, $v_O = \left[1 - e^{-0.6t}\left(\cos 0.8t + 0.75\sin 0.8t\right)\right]u(t)$ V.

P16.2.9 (a) $i_O = te^{-t}u(t)$ A, $v_O = 0.5\,\text{sgn}(t) - e^{-t}u(t) - te^{-t}u(t)$ V.

(b) $i_O = \frac{2}{3}\left(e^{-0.5t} - e^{-2t}\right)u(t)$ A, $v_O = 0.5\,\text{sgn}(t) - \frac{4}{3}e^{-0.5t}u(t) + \frac{1}{3}e^{-2t}u(t)$ V.

(c) $i_O = 1.25e^{-0.6t}(\sin 0.8t)\, u(t)$ A, v_O = 0.5sgn(t) +

$\left[-e^{-0.6t}\left(\cos 0.8t + 0.75\sin 0.8t\right)\right]u(t)$ V.

P16.2.10 $i_O = -\frac{8}{9}e^{-2t}u(t) + \frac{16}{9}e^{-t}u(t) - \frac{8}{9}e^{-0.5t}u(t) + \frac{1}{9}e^{-|t|}$ A,

$v_O = \frac{4}{9}e^{-2t}u(t) - \frac{20}{9}e^{-t}u(t) + \frac{16}{9}e^{-0.5t}u(t) + \frac{1}{9}e^{-|t|}$ V.

P16.2.11 $i_O = \frac{25}{16}e^{-6t}\cos(0.8t)u(t) - \frac{25}{16}e^{-t}u(t) + \frac{5}{16}e^{-|t|}$ A,

$v_O = -\frac{15}{16}e^{-0.6t}\cos(0.8)tu(t) + \frac{5}{4}e^{-0.6t}\sin(0.8t)u(t) + \frac{15}{16}e^{-t}u(t) + \frac{5}{16}e^{-|t|}$ V.

P16.2.12 $v_O = 5\left[-\text{sgn}(t+1) + 2e^{-(t+1)}u(t+1) + 2\,\text{sgn}(t) - 4e^{-t}u(t) - \text{sgn}(t-1) + \right.$

$\left. 2e^{-(t-1)}u(t-1)\right]$ V.

$i_O = 10\left[-e^{-(t+1)}u(t+1) + 2e^{-t}u(t) - e^{-(t-1)}u(t-1)\right]$ mA, where t is in ms.

P16.2.13 $v_O = 5\big[-\operatorname{sgn}(t+1) + 2e^{-(t+1)}u(t+1) - \operatorname{sgn}(t-1) + 2e^{-(t-1)}u(t-1) + 2\,|\,t+1\,| -$

$\operatorname{sgn}(t+1) + 2e^{-(t+1)}u(t+1) - 2\,|\,t-1\,| + \operatorname{sgn}(t-1) - 2e^{-(t-1)}u(t-1)\big]$ V,

$i_O = 5\big[-2e^{-(t+1)}u(t+1) - 2e^{-(t-1)}u(t-1) + \operatorname{sgn}(t+1) - 2e^{-(t+1)}u(t+1) -$

$\operatorname{sgn}(t-1) + 2e^{-(t-1)}u(t-1)\big]$ mA, where t is in ms.

P16.2.14 $v_O = 5\big[2\,|\,t+1\,| - \operatorname{sgn}(t+1) + 2e^{-(t+1)}u(t+1) -$

$4\,|\,t\,| + 2\operatorname{sgn}(t) - 4e^{-t}u(t) + 2\,|\,t-1\,| - \operatorname{sgn}(t-1) + 2e^{-(t-1)}u(t-1)\big]$ V,

$i_O = 5\big[\operatorname{sgn}(t+1) - 2e^{-(t+1)}u(t+1) - 2\operatorname{sgn}(t) + 4e^{-t}u(t) + \operatorname{sgn}(t-1) -$

$2e^{-(t-1)}u(t-1)\big]$ mA, where t is in ms.

P16.2.15 $v_O = 5\big[e^{-(t+\pi/2)}u(t+\pi/2) -$

$\frac{1}{2}\sin(t+\pi/2) + \sin(t+\pi/2)u(t+\pi/2) + \frac{1}{2}\cos(t+\pi/2) -$

$\cos(t+\pi/2)u(t+\pi/2) + e^{-(t-\pi/2)}u(t-\pi/2) - \frac{1}{2}\sin(t-\pi/2) +$

$\sin(t-\pi/2)u(t-\pi/2) + \frac{1}{2}\cos(t-\pi/2) - \cos(t-\pi/2)u(t-\pi/2)\big]$ V,

$i_O = 5\big[-e^{-(t+\pi/2)}u(t+\pi/2) - \frac{1}{2}\sin(t+\pi/2) + \sin(t+\pi/2)u(t+\pi/2) -$

$\frac{1}{2}\cos(t+\pi/2) + -\frac{1}{2}\sin(t-\pi/2) + \cos(t+\pi/2)u(t+\pi/2) -$

$e^{-(t-\pi/2)}u(t-\pi/2) + \sin(t-\pi/2)u(t-\pi/2) - \frac{1}{2}\cos(t-\pi/2) +$

$\cos(t-\pi/2)u(t-\pi/2)\big]$ A, where t is in ms.

P16.2.16 $v_O = 5\big[-e^{-(t+\pi)}u(t+\pi) + \frac{1}{2}\sin(t+\pi) - \sin(t+\pi)u(t+\pi) - \frac{1}{2}\cos(t+\pi) +$

$\cos(t+\pi)u(t+\pi) + e^{-(t-\pi)}u(t-\pi) - \frac{1}{2}\sin(t-\pi) + \sin(t-\pi)u(t-\pi) +$

$\frac{1}{2}\cos(t-\pi) - \cos(t-\pi)u(t-\pi)\big]$ V,

$i_O = 5\big[e^{-(t+\pi)}u(t+\pi) - \frac{1}{2}\sin(t+\pi) + \sin(t+\pi)u(t+\pi) + \frac{1}{2}\cos(t+\pi)$

$-\cos(t+\pi)u(t+\pi) - e^{-(t-\pi)}u(t-\pi) - \frac{1}{2}\sin(t-\pi) +$

$\sin(t-\pi)u(t-\pi) + \frac{1}{2}\cos(t-\pi) - \cos(t-\pi)u(t-\pi)\big]$ A, where t is in ms.

P16.2.17 $v_O = 15\Big[-|t+2| + \frac{1}{2}\text{sgn}(t+2) - e^{-(t+2)}u(t+2) + |t-2| - \frac{1}{2}\text{sgn}(t-2) +$

$e^{-(t-2)}u(t-2)\Big] + 10\Big[|t+3| - \frac{1}{2}\text{sgn}(t+3) + e^{-(t+3)}u(t+3)$

$-|t-3| + \frac{1}{2}\text{sgn}(t-3) - e^{-(t-3)}u(t-3)\Big]$ V.

$i_O = 15\Big[-\frac{1}{2}\text{sgn}(t+2) + e^{-(t+2)}u(t+2) + \frac{1}{2}\text{sgn}(t-2) - e^{-(t-2)}u(t-2)\Big] +$

$10\Big[\frac{1}{2}\text{sgn}(t+3) - e^{-(t+3)}u(t+3) - \frac{1}{2}\text{sgn}(t-3) + e^{-(t-3)}u(t-3)\Big]$ A, where

t is in ms.

P16.2.18 $v_O = \left(\frac{4}{5}e^{-t} - \frac{1}{2}e^{-2t} - \frac{3}{10}e^{-6t}\right)u(t)$.

P16.3.2 $= \frac{1}{4}$ J.

P16.3.3 $\frac{1}{16}$ J.

P16.3.4 $\frac{1}{32}$ J.

P16.3.5 98.4% .

P16.3.6 (a) 38.5%.

(b) 44.0%.

P16.3.7 (a) 72.5%.

(b) 77.2%.

<u>Chapter 17 Basic Signal Processing Operations</u>

P17.1.1 0, ωt, $2\omega t$, $3\omega t$, and $4\omega t$, where $\omega = 4{,}000$ rad/s.

P17.1.2 The amplitude of the fundamental is multiplied by $\sqrt{5}$ and its phase is delayed by 63.4°. The amplitude of the second harmonic is multiplied by 1.03 and its phase is delayed by 76.0°.

P17.1.3 (a) Amplitude ratio = 0.415 and phase angle = -94.76°.

(b) Amplitude ratio = 0.0445 and phase angle = -32.27°.

P17.1.4 Not if the system is causal.

P17.1.5 No, unless $\theta = k\pi$, where *k* is a positive or negative integer.

P17.1.6 27.8 μs.

P17.2.1 $f_{AM}(t) = 10\cos(3\times10^6 \pi t) + \ 2.5\cos(3\times10^6 \pi + 10^4 \pi)t$

$+ 2.5\cos(3\times10^6 \pi - 10^4 \pi)t$ V.

$$F_{AM}(j\omega) = 10\pi\left[\delta(\omega - 3\times10^6\pi) + \delta(\omega + 3\times10^6\pi)\right] +$$

$$2.5\pi\left[\delta(\omega - 3\times10^6\pi - 10^4\pi) + \delta(\omega - 3\times10^6\pi + 10^4\pi)\right] +$$

$$2.5\pi\left[\delta(\omega + 3\times10^6\pi - 10^4\pi) + \delta(\omega + 3\times10^6\pi + 10^4\pi)\right].$$

50 W for the carrier and 3.125 W for each of the sidebands.

P17.2.2 Lower sideband extends from 0.97 MHz to 0.99999 MHz, upper sideband extends from 1.00001 MHz to 1.03 MHz.

P17.2.3 107.

P17.2.4 15, 30.

P17.2.5 Spectrum is from $f_{m\min}$ to $2f_c + f_{m\max}$ and contains the modulating frequencies, which can be recovered by lowpass filtering and removal of the DC component. The main difficulty is in having the local oscillator always synchronized with the carrier frequency of the received signal.

P17.2.6 C_{nF} in $F(j\omega)$ of the modulated signal is:

$$\frac{1}{\pi^2}\left\{\frac{\sin\left[(n+10^6)\tau\omega_0/2\right]}{(n+10^6)} + \frac{\sin\left[(n-10^6)\tau\omega_0/2\right]}{(n-10^6)}\right\}.$$

P17.3.1 $H_{inv}(j\omega) = \dfrac{j2\omega}{(2+j\omega)^2}$, $h_{inv}(t) = 2e^{-2t}(1-2t)u(t)$.

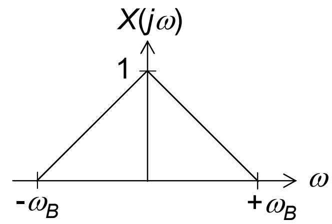
P17.3.2 $H_{inv}(j\omega) = \dfrac{e^{-1}e^{-j\omega}}{1+j\omega}$, $h_{inv}(t) = e^{-t}u(t-1)$.

P17.3.3 $H(j\omega) = 2\left[1 - \dfrac{1}{2+j\omega}\right]$, $h(t) = 2\delta(t) - 2e^{-2t}u(t)$.

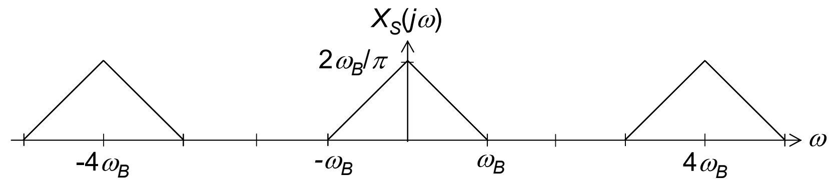
P17.4.1 (a) 800π rad/s.

(b) 800π rad/s.

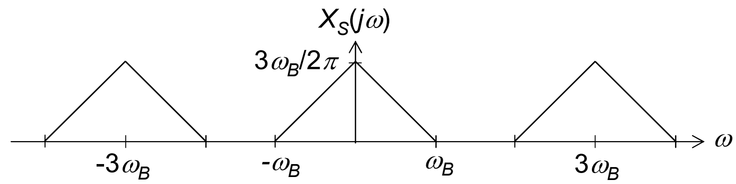
P17.4.2



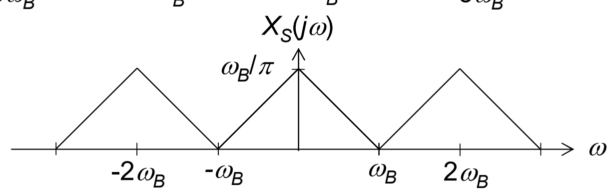
$T_S = \pi/2\omega_B$, or $\omega_S = 4\omega_B$:



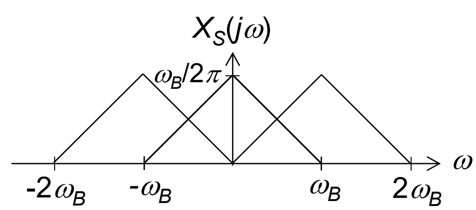
$T_S = 2\pi/3\omega_B$, or $\omega_S = 3\omega_B$:



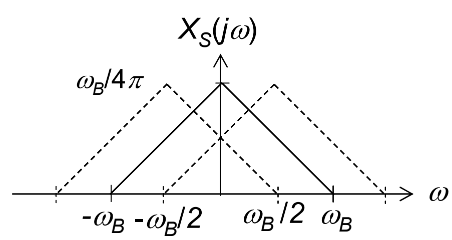
$T_S = \pi/\omega_B$, or $\omega_S = 2\omega_B$:



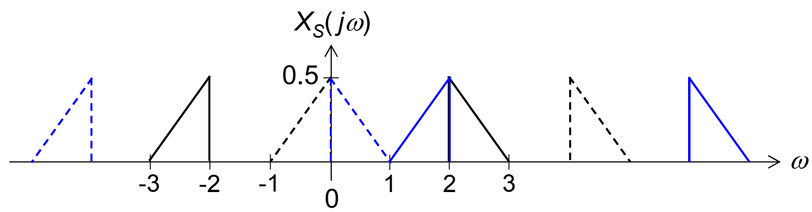
$T_S = 2\pi/\omega_B$, $\omega_S = \omega_B$:
Aliasing now occurs.

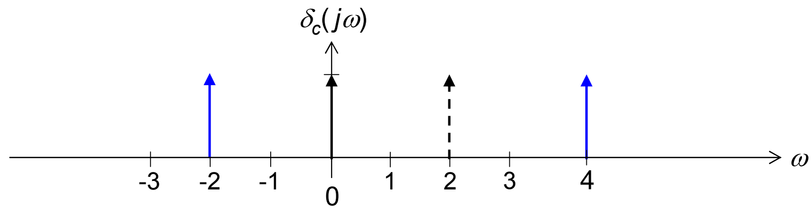


P17.4.3 The frequencies that are adequately sampled are those in the range 0 to $\omega_S/2 = \omega_B/4$. The frequencies are folded back around this frequency.



P17.4.4 The sampling rate must be equal to twice the 1 rad/s bandwidth of the signal, i.e., 2 rad/s.



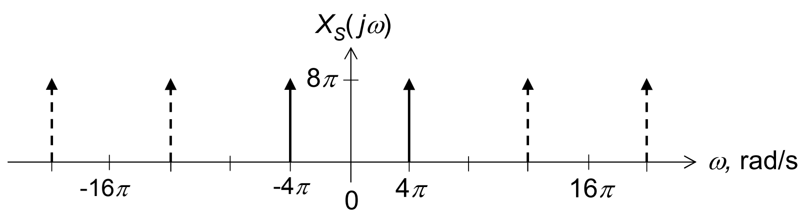


P17.4.5 $h(t) = \text{sinc}(\pi t)\cos(2.5t)$.

P17.4.6 T_S = 1/8 s, or

$$\omega_S = \frac{2\pi}{T_S} = 16\pi$$

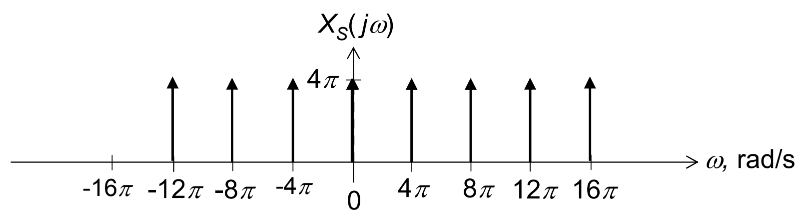
rad/s:



T_S = 1/2 s, or

$$\omega_S = \frac{2\pi}{T} = 4\pi$$

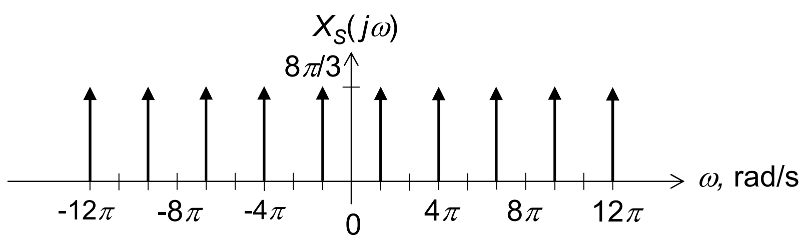
rad/s; aliasing occurs.



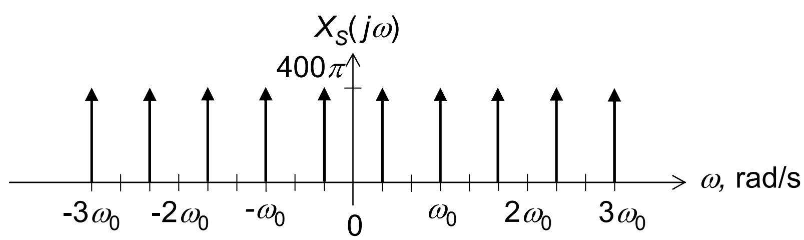
T_S = 3/4 s,

$$\omega_S = \frac{2\pi}{T} = \frac{8\pi}{3}$$

rad/s; aliasing occurs.



P17.4.7 $f(t) = 2\cos(200\pi t)$.



P17.5.1 $\omega_{cl} > 1/\tau$ $\omega_{cl} > 1/\tau$.

P17.5.2 $\omega_{cl} = 4\tan\left(\frac{9\pi}{20}\right) = 25.26$ rad/s.

P17.5.3 1200π rad/s.

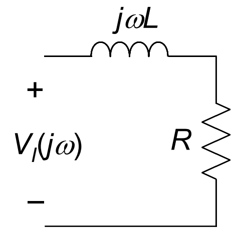
P17.5.4 (a) 0, 250 Hz, 500 Hz, 750 Hz, and 1000 Hz.

(b) 4500 Hz, 4750 Hz, 5000 Hz, etc.

(c) 2500 Hz, 2750 Hz, 3000 Hz, 3250 Hz, and 3500 Hz.

(d) 0, 250 Hz, 500 Hz, 750 Hz, 1000 Hz, 1250 Hz, 1500 Hz, 1750 Hz, 2000 Hz, 2250 Hz, 3750 Hz, 4000 Hz, etc.

P17.5.5 Series *RL* circuit to which a voltage is applied,



Chapter 18 Signal Processing Using Operational Amplifiers

P18.1.1 $R = 100$ kΩ, $R_L = 20$ kΩ.

P18.1.2 $C\left(R_1 + R_3 + \dfrac{R_1R_3}{R_2}\right)$.

P18.1.4 The purpose of the first op amp is to isolate the input while applying v_{in} to the second op amp.

P18.1.5 (a) $(1+k)R$.

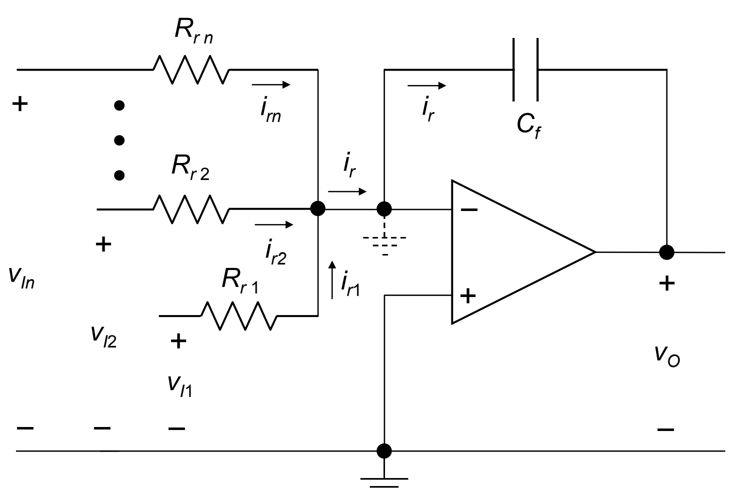
(b) $\dfrac{R}{1-\dfrac{k}{k+1}\cdot\dfrac{v_1}{v_2}}$.

(c) $2R$.

(d) $(1+k)R/2$.

P18.1.6 13/3 mA.

P18.1.7 An inverting, summing integrator is shown. Replacing the capacitor by a resistors, and the resistors by capacitors gives an inverting, summing differentiator.



P18.1.8 $R_{in} = 0$.

P18.1.13 (a) $R = 70\ \text{k}\Omega$.

(b) $V_{SRC} = \pm 1.5$ V.

P18.1.14 $\left(1 + \frac{R_2}{R_1} + \frac{R_4}{R_3}\right)$.

P18.1.15 $v_O = \frac{R_2 R_4}{R_1 R_3} v_1 - \frac{R_4}{R_3}\left(1 + \frac{R_2}{R_1}\right) v_2$.

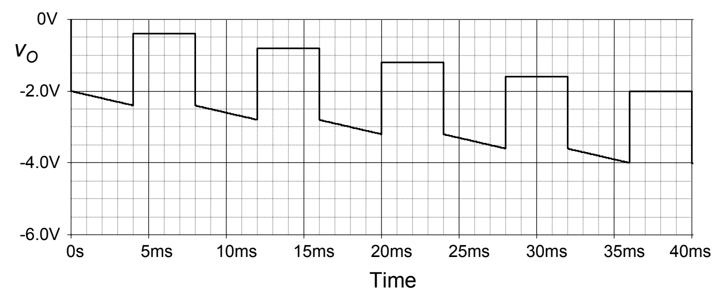
P18.1.16 $v_O = -\frac{40}{17}$ V.

P18.1.17 v_O = -5/2 – 0.005*exp(-10000*t) + 2.5*exp(-20*t) V.

P18.1.18 (a) $f = 11.2$ Hz; phase deviation $= 8.1°$.

(b) 2.01 ms.

P18.1.19 The simulation results are shown for R_r = 10 kΩ, R_f = 20 kΩ, and C_f = 1μF.



P18.1.20 12 mV.

P18.1.24 $C_o \cong 8\ \mu$F, $C_r \cong 0.8\ \mu$F.

P18.2.3 $\frac{v_O}{v_{SRC}} = -0.96 + j0.19$.

P18.2.4 $S_{A_v}^{A} = 1.26 \times 10^{-5}$.

P18.2.5 CMRR = 10,000.

P18.2.6 0.1%.

P18.2.7 $A_{vcm} = 10$, the output is 2 ± 1 V.

P18.2.8 (a) $f_{\max} = 318.3$ kHz.

(b) $f_{\max} = 63.7$ kHz.

P18.2.9 0.2 μs.

P18.2.10 (a) 5.03×10^{-16} VA.

(b) 0.71 μV.

(c) 7.1 μV.

P18.2.11 (a) $v_o = V_{io}$.

(b) $v_o = V_{io} + RI_{bP}$.

(c) $v_o = V_{io} - RI_{bN}$.

(d) $v_o = V_{io} + R(I_{bP} - I_{bN})$.

P18.2.12 R_2, = 100 Ω, R_1 = 9 kΩ, R_3 = 65 kΩ, R_p = 1 kΩ, R_a = 9.5 kΩ.

P18.3.6 $\omega_0 =$ rad/s, $Q = 0.5$; passband gain: $= \frac{1}{2}$; input impedance = 10(1 – j) kΩ.

P18.3.7 $R_{fl} \cong 160$ kΩ, R_{rl} = 16 kΩ, R_{rh} = 1.6 kΩ = R_{fh}.

P18.3.8

	$n = 1$	2	3	10	50	
(a)	-10	-20	-30	-100	-500	dB/decade
(b)	-10	-11.7	-12.4	-13.4	-13.8	

P18.3.9 $R =$ 31.8 kΩ, $2QR =$ 3.18 MΩ, $\frac{C}{2Q} = 1$ nF.

P18.3.10 Highpass filter. First-order section: $R_r = 160$ Ω, $R_f = 1.6$ kΩ; second-order section: R_1 =80 Ω and R_2 =320 Ω.

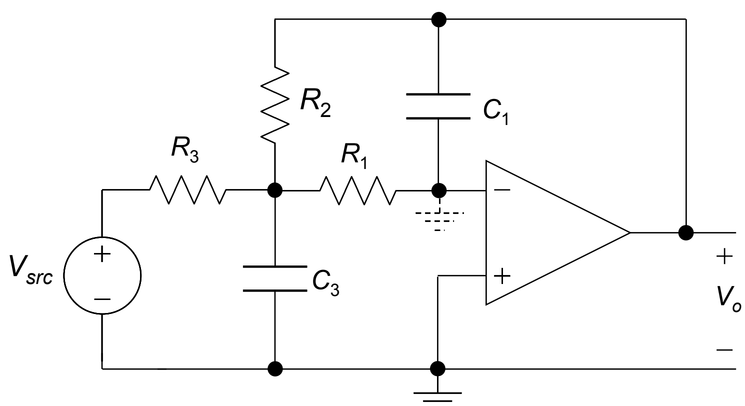
Lowpass filter. First-order section: $C_f = 0.2$ nF; second-order section: $C_1 = 0.4$ nF, $C_2 = 0.1$ nF.

Attenuation = -23.9 dB at 4 kHz and 200 kHz, with respect to the midband gain.

P18.3.11 Lowpass filter.

C_1 = 0.094 nF,

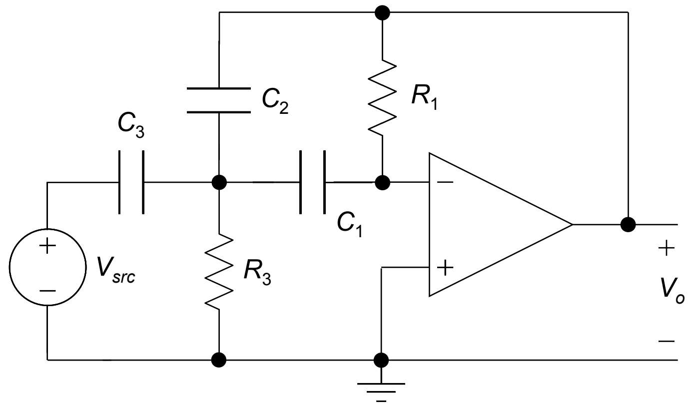
C_3 = 0.42 nF.



Highpass filter.

$R_1 \cong 340\ \Omega$,

$R_3 = 25.3\ \text{k}\Omega$.



Attenuation = 16 dB at 4 kHz and 200 kHz, with respect to midband gain.

P18.3.12 $C = 2.25\,\text{nF}$, A = 4.93, maximum gain = 37 dB.

P18.3.13 R_1 = 63.7 kΩ, $R \cong 80\ \Omega$, maximum gain = 52 dB.

P18.3.14 $R \cong 1.6\,\text{k}\Omega$, $R_2 \cong 256\,\Omega$; magnitude of the maximum gain = 39.

P18.3.15 $R \cong 1.6\,\text{k}\Omega$, $R_3 \cong 32\ \text{k}\Omega$; magnitude of the maximum gain is $= 3.2$.

P18.3.17 $R = 100\,\text{k}\Omega$, R_3 = 390 kΩ, we could choose R_f = 1kΩ, R_B = 19.5 kΩ, and R_L = 195 kΩ.

P18.3.18 $R = 100\,\text{k}\Omega$, $R_2 = 100\ \text{k}\Omega$, we can choose R_1 = 500 kΩ, R_a =10 kΩ, R_3 = 100 kΩ.

P18.3.19 $S_{R_1}^{Q} = -\frac{1}{2} + Q\sqrt{\frac{C_2R_2}{C_1R_1}} = -S_{R_2}^{Q}$, $S_{C1}^{Q} = -\frac{1}{2} + Q\left[\sqrt{\frac{C_2R_1}{C_1R_2}} + \sqrt{\frac{C_2R_2}{C_1R_1}}\right] = -S_{C_2}^{Q}$,

$S_{R_f}^{Q} = Q(1-A)\sqrt{\frac{C_1R_1}{C_2R_2}} = -S_{R_r}^{Q}$, $S_{A}^{Q} = QA\sqrt{\frac{C_1R_1}{C_2R_2}}$.

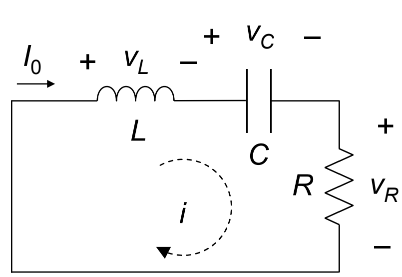
P18.3.20 $S_{R_3}^{Q} = \frac{1}{1+R_2/R_3}$, $S_{R_2}^{Q} - \frac{1}{1+R_2/R_3}$, $S_{R_2}^{K} = -\frac{R_2}{2R_3} = \frac{1}{2} - \frac{1}{K}$, $S_{R_3}^{K} = \frac{1}{K} - \frac{1}{2}$.

Chapter 19 Electric Circuit Analogs of Non-Electrical Systems

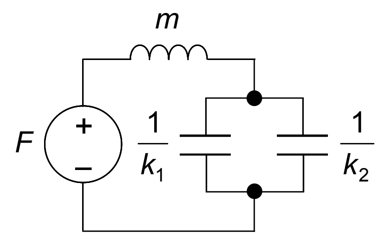
P19.1.1 Parallel LC circuit, $f = \frac{1}{2\pi}\sqrt{\frac{k}{J}}$.

P19.1.2 (a) $u = U_0 e^{-\omega_0 t}\left(1-\omega_0 t\right)$, where $\omega_0 = \sqrt{\frac{k}{m}}$,

(b) $\frac{U_0}{\omega_0 e}$.



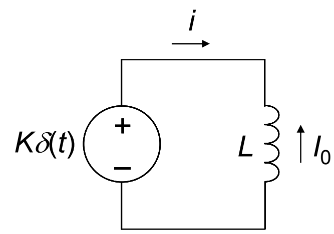
P19.1.3 $\dfrac{1}{2\pi\sqrt{\dfrac{m(k_1+k_2)}{k_1k_2}}}$.



P19.1.4 The equivalent electric circuit is a series combination of L, C_1, and C_2.

$f_0 = \dfrac{1}{2\pi}\sqrt{\dfrac{k_1+k_2}{m}}$.

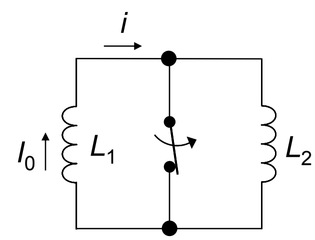
P19.1.5 In the horizontal direction, $K_x = 2.91$ Ns, in the vertical direction, $K_y = 1.41$ Ns, $K = 3.23$ Ns at an angle of 25.9° with respect to the horizontal.



P19.1.6 (a) 0.83 m/s.

(b) 8.3 Ns.

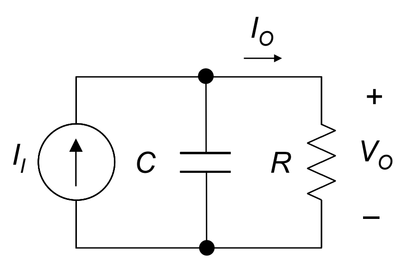
(c) 20.83 J.



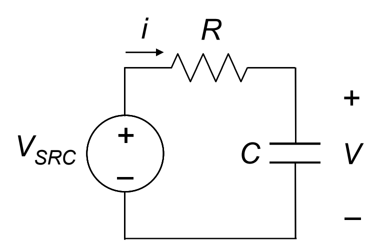
P19.2.1 $F_1 = F_2 + F_3$.

P19.2.2 (a) A transformer of turns ratio $\dfrac{x_2}{x_1}$.

P19.2.3 $R = \dfrac{V_O}{I_O} \equiv \dfrac{\rho g H}{F_O}$. $C = \dfrac{A}{\rho\, g}$.



P19.2.4 $H = H_I\left(1 - e^{-t/RC}\right)$, where $C = \dfrac{A}{\rho g}$.



P19.2.5 The equivalent circuit is an LC circuit with an initial charge on C, with LC = l/g; $f_0 = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$.

P19.3.1 (a) junction temperature = 164°C, temperature of the case = 155°C.

(b) junction temperature = 54°C, temperature of the case = 45°C.

P19.3.2 40 W.

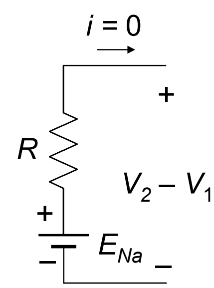
P19.3.3 $\theta_{JC} = 19$ °C/W, maximum power dissipation $= 2.11$W.

P19.3.4 3.27 W.

P19.3.5 3,626.0 W.

P19.3.6 The equivalent circuit is that of a capacitor having an initial voltage corresponding to 25°C and is being charged through a resistance R from a source of voltage corresponding to 200°C; temperature at any time t is: T = 200 + $(25 - 200)e^{-t/\tau}$, time t taken to reach a temperature of 195°C = 47.4 s.

P19.4.1 (a) $V_2 - V_1 = E_{Na} = \frac{kT}{q}\ln\frac{[\text{Na}^+]_1}{[\text{Na}^+]_2}$.



(b) $V_2 - V_1 = E_{Cl} = -\frac{kT}{q}\ln\frac{[\text{Cl}^-]_1}{[\text{Cl}^-]_2}$, so that E_{Cl} of opposite polarity to E_{Na}.

P19.4.2 (a) 10^{-7} C/cm^2.

(b) $\frac{10^{-7}}{1.6\times10^{-19}} \cong 6.3\times10^{11}$ monovalent ions/cm^3.

(c) $6\times10^{23}\times0.1\times10^{-3} = 6\times10^{19}$ monovalent ions/cm^3.

(d) $\frac{6.3\times10^{11}}{6\times10^{19}} \cong 10^{-8}$ cm.

P19.4.6 V_m = -70 mV; J_K = 120 nA/cm2 = -JK_P.