P 2.2 [a] 8 [b] 6 [c] 4 [d] $v_a - R_1$, $v_b - R_3$ [e] 6

[f] (1) $v_a - R_1 - R_4 - R_2$

(2) $v_b - R_2 - R_5 - R_3$

(3) $R_4 - R_6 - R_5$

(4) $v_a - R_1 - R_6 - R_3 - v_b$

(5) $v_a - R_1 - R_4 - R_5 - R_3 - v_b$

(6) $v_a - R_1 - R_6 - R_5 - R_2$

(7) $v_b - R_2 - R_4 - R_6 - R_3$

P 2.3 [a] $i_o = \frac{v_o}{20} = \frac{100}{20} = 5\,\text{A}$

$v_a = 5(24) = 120\,\text{V}$

$i_a = \frac{120}{40} = 3\,\text{A}$

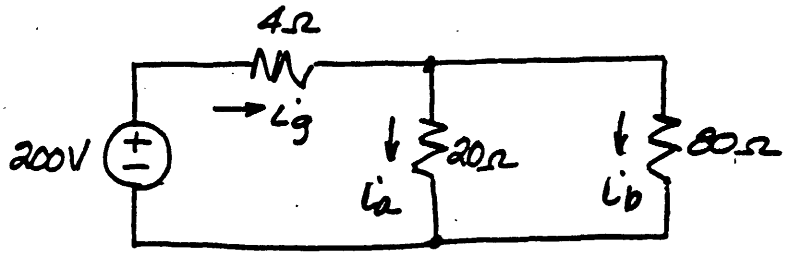
[b] $i_g = i_a + i_o = 3 + 5 = 8\,\text{A}$

[c] $p_g(\text{delivered}) = 8v_a = 960\,\text{W}$

P 2.7 The interconnection is not valid because it violates Kirchhoff's current law. Summing the currents at the lower node yields

$$5 - 20 + 10 \neq 0$$

P 2.8 [a]



$20i_a = 80i_b \qquad i_g = i_a + i_b = 5i_b$

$i_a = 4i_b$

$200 = 4i_g + 80i_b = 20i_b + 80i_b = 100i_b$

$i_b = 2\text{A}, \qquad \therefore\ i_a = 8\text{ A}$

[b] $i_b = 2\text{ A}$

[c] $v_o = 80i_b = 160\text{ V}$

[d] $p_{4\Omega} = i_g^2 4 = 100(4) = 400\text{ W}$

$p_{20\Omega} = i_a^2 20 = (64)(20) = 1280\text{ W}$

$p_{80\Omega} = i_b^2 80 = 4(80) = 320\text{ W}$

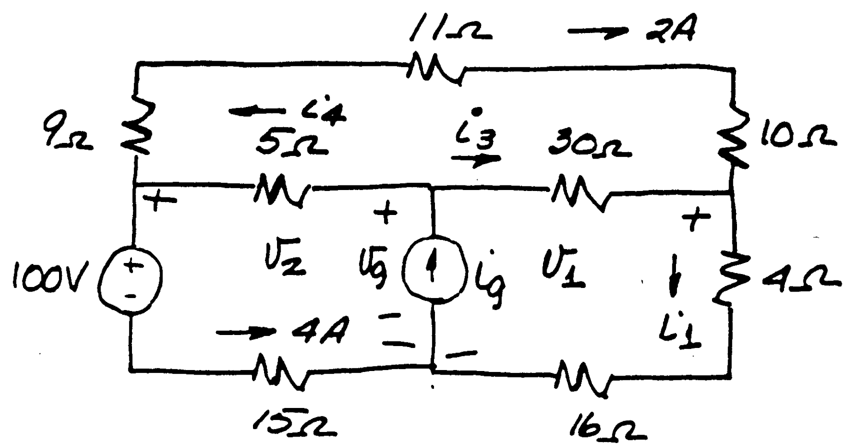
[e] $p_{200\text{V}}(\text{delivered}) = 200i_g = 2000\text{ W}$

Check:

$$\sum P_{\text{diss}} = 400 + 1280 + 320 = 2000\text{ W}$$

$$\sum P_{\text{del}} = 2000\text{ W}$$

P 2.10 [a]

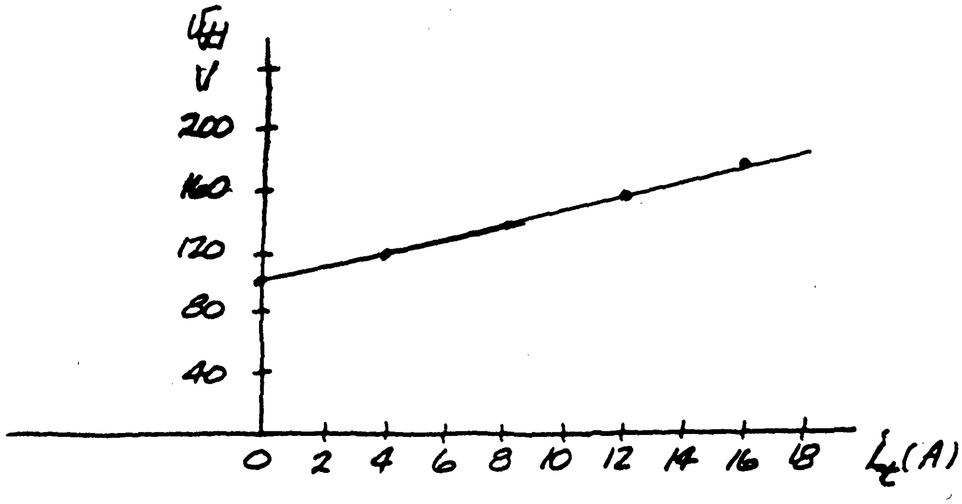


$$v_2 = 100 + 4(15) = 160\text{ V}$$
$$v_1 = 160 - 30(2) = 100\text{ V}$$
$$i_1 = \frac{v_1}{20} = \frac{100}{20} = 5\text{ A}$$
$$i_3 = i_1 - 2 = 5 - 2 = 3\text{ A}$$
$$v_g = v_1 + 30i_3 = 100 + 90 = 190\text{ V}$$
$$v_g - 5i_4 = v_2$$
$$5i_4 = v_g - v_2 = 190 - 160 = 30\text{ V}$$
$$i_4 = \frac{30}{5} = 6\text{ A}$$
$$i_g = i_3 + i_4 = 3 + 6 = 9\text{ A}$$

[b]

$$p_{9\Omega} = (2)^2(9) = 36\text{ W}$$
$$p_{11\Omega} = (2)^2(11) = 44\text{ W}$$
$$p_{10\Omega} = (2)^2(10) = 40\text{ W}$$
$$p_{30\Omega} = (3)^2(30) = 270\text{ W}$$
$$p_{5\Omega} = (6)^2(5) = 180\text{ W}$$
$$p_{4\Omega} = (5)^2(4) = 100\text{ W}$$

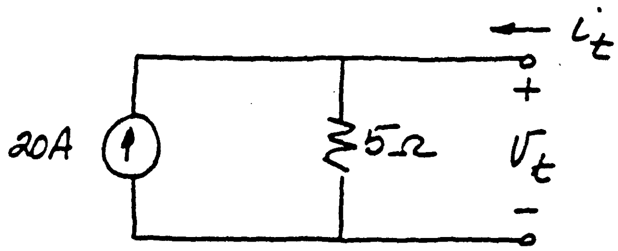
P 2.14 [a] Plot the $v - i$ characteristic



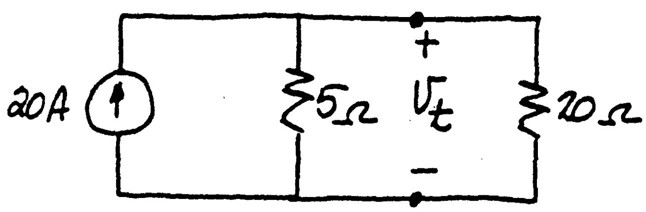
From the plot: $R = \frac{\Delta v}{\Delta i} = \frac{180 - 100}{16 - 0} = \frac{80}{16} = 5\Omega$

When $i_t = 0$, $v_t = 100\,\text{V}$

$\therefore\ i_s 5 = 100$; $i_s = 20\,\text{A}$



[b]



$$-20 + \frac{v_t}{5} + \frac{v_t}{20} = 0$$

$\therefore\ 5v_t = 400$; $v_t = 80\,\text{V}$

$$p_{20\Omega} = \frac{(80)^2}{20} = 320\,\text{W}$$

P 2.22 $40i_2 + \frac{v_o}{40} + \frac{v_o}{10} = 0$

$$1600i_2 + 5v_o = 0$$

$$i_2 = \frac{-5v_o}{1600} = \frac{-25}{1600} = -15.625\,\text{mA}$$

$$v_1 = 80i_2 = -1.25\,\text{V}$$

$$25i_1 + \frac{v_1}{20} + \frac{v_1}{80} = 0$$

$$2000i_1 + 5v_1 = 0$$

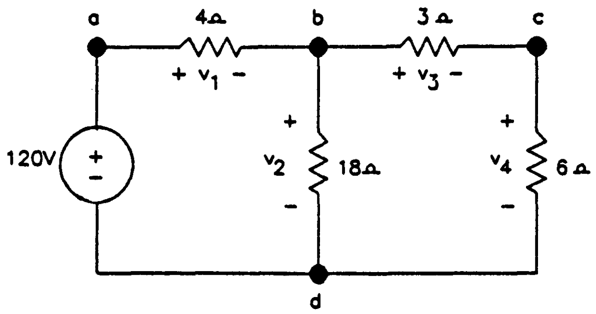
$$i_1 = \frac{-5v_1}{2000} = \frac{6.25}{2000} = 3.125\,\text{mA}$$

$$v_g = 320i_1 = 1000\,\text{mV} = 1\,\text{V}$$

P3.1 [a] From Ex. 3-1: $i_1 = 4\,\text{A}$, $i_2 = 8\,\text{A}$, $i_s = 12\,\text{A}$

at node x: $-12 + 4 + 8 = 0$, at node y: $12 - 4 - 8 = 0$

[b]



$v_1 = 4i_s = 48\,\text{V}$ $v_3 = 3i_2 = 24\,\text{V}$

$v_2 = 18i_1 = 72\,\text{V}$ $v_4 = 6i_2 = 48\,\text{V}$

loop abda: $-120 + 48 + 72 = 0$,

loop bcdb: $-72 + 24 + 48 = 0$,

loop abcda: $-120 + 48 + 24 + 48 = 0$

P3.2 [a] $p_{4\Omega} = i_s^2 4 = (12)^2 4 = 576\,\text{W}$ $p_{18\Omega} = (4)^2 18 = 288\,\text{W}$,

$p_{3\Omega} = (8)^2 3 = 192\,\text{W}$ $p_{6\Omega} = (8)^2 6 = 384\,\text{W}$

[b] $p_{120\text{V}}(\text{delivered}) = 120i_s = 120(12) = 1440\,\text{W}$

[c] $p_{\text{diss}} = 576 + 288 + 192 + 384 = 1440\,\text{W}$

P3.3 [a] $5\,\Omega // 20\,\Omega = 4\,\Omega$ $\therefore\ R_{ab} = 10 + 4 + 6 = 20\,\Omega$

[b] $200\,\Omega // 50\,\Omega = 40\,\Omega$

$20\,\Omega + 40\,\Omega = 60\,\Omega$

$$\frac{1}{R_{ab}} = \frac{1}{30} + \frac{1}{60} + \frac{1}{60} = \frac{4}{60} = \frac{1}{15}\,\mho$$

$\therefore\ R_{ab} = 15\,\Omega$

P 3.4 [a] $R_{ab_a} = 4\,\Omega // 12\,\Omega = 3\,\Omega$

$R_{ab_b} = [2.5//7.5//5//15//5 + 7]//8 + 8 = 4 + 8 = 12\,\Omega$

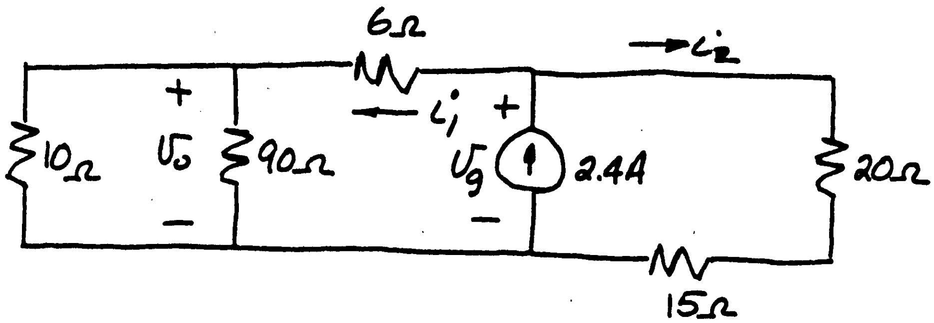
$R_{ab_c} = [6//3 + 3]//20 + 7 = 11\,\Omega$

[b] $P_{15V} = \dfrac{15^2}{3} = 75\,\text{W}$

$P_{48V} = \dfrac{48^2}{12} = 192\,\text{W}$

$P_{22V} = \dfrac{22^2}{11} = 44\,\text{W}$

P 3.8 [a]



$10//90 = 9\,\Omega, \qquad 9 + 6 = 15\,\Omega, \qquad 15 + 20 = 35\,\Omega$

$i_1 = \dfrac{(2.4)(35)}{(35 + 15)} = \dfrac{35}{50}(2.4) = 1.68\,\text{A}$

$v_o = (9)(1.68) = 15.12\,\text{V}$

[b] $i_2 = 2.4 - 1.68 = 0.72\,\text{A}$

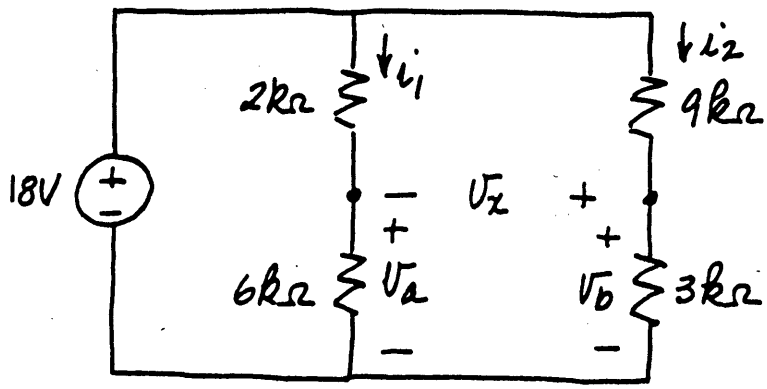
$p_{20\Omega} = i_2^2(20) = (0.72)^2(20) = 10.368\,\text{W}$

[c] $v_g = 35 i_2 = 35(0.72) = 25.20\,\text{V}$

$p_g(\text{dev}) = (25.2)(2.4) = 60.48\,\text{W}$

P 3.12 [a]

$$v_a = \frac{18}{8} \times 6 = 13.5\,\text{V}$$
$$v_b = \frac{18}{12}(3) = 4.5\,\text{V}$$
$$v_a + v_x = v_b$$
$$v_x = 4.5 - 13.5 = -9\,\text{V}$$



[b]

$$v_a = \frac{v_s}{8} \times 6 = 0.75v_s$$
$$v_b = \frac{v_s}{12}(3) = 0.25v_s$$
$$v_x = v_b - v_a = 0.25v_s - 0.75v_s = -0.5v_s$$

P 3.17 [a] $v_o = \dfrac{80R_2}{(R_1+R_2)} = 20$

$\therefore \quad \dfrac{R_2}{R_1+R_2} = \dfrac{20}{80} = \dfrac{1}{4}; \qquad \therefore\ 3R_2 = R_1$

Let $R_e = R_2//R_L = \dfrac{R_2R_L}{R_2+R_L}$

$v_o = \dfrac{80R_e}{R_1+R_e} = 18; \qquad \dfrac{R_e}{R_1+R_e} = \dfrac{18}{80} = \dfrac{9}{40}$

$40R_e = 9R_1 + 9R_e; \qquad 31R_e = 9R_1 = 27R_2; \qquad R_e = \dfrac{(37.8)R_2}{R_2+37.8}$

$\dfrac{31(37.8)R_2}{R_2+37.8} = 27R_2$

$\therefore \quad \dfrac{31(37.8)}{27} = R_2 + 37.8; \qquad R_2 = 5.6\,\text{k}\Omega; \qquad R_1 = 3(5.6) = 16.8\,\text{k}\Omega$

[b] Power dissipated in R_1 will be maximum when the voltage across R_1 is maximum. This will occur under load conditions.

$v_{R_1} = 80 - 18 = 62\,\text{V}$

$P_{R_1} = \dfrac{(62)^2}{16.8} \times 10^{-3} = 228.81\,\text{mW}$

P 3.18 Refer to the solution of Problem 3.17. The divider will reach its dissipation limit when the power dissipated in R_1 equals 0.25 W.

Notes:

The dissipation in R_2 will be equal to or less than $P_{R_2} \leq \dfrac{400}{5.6} = 71.43\,\text{mW}$

The dissipation in R_1 can reach a maximum of $P_{R_1} = \dfrac{6400}{16.8} = 380.95\,\text{mW}$

When the dissipation in R_1 is 250 mW, the voltage across R_1 is

$v_{R_1}^2 = 0.25(16.8 \times 10^3) = 4200, \qquad v_{R_1} = 64.81\,\text{V}$

$\therefore\ v_o = 80 - 64.81 = 15.19\,\text{V}$

$\therefore \quad \dfrac{80R_e}{R_1+R_e} = 15.19, \qquad \therefore\ R_e = 3.94\,\text{k}\Omega$

$\therefore \quad \dfrac{5.6R_L}{5.6+R_L} = 3.94, \qquad R_L = 13.27\,\text{k}\Omega$ (minimum value)

P 3.22

$$i_4 = \frac{G_4}{\sum G}10^{-3} \qquad i_2 = 2i_3 = \frac{4G_4}{\sum G} \times 10^{-3}$$

$$i_3 = 2i_4 = \frac{2G_4}{\sum G} \times 10^{-3} \qquad i_1 = 2i_2 = \frac{8G_4}{\sum G} \times 10^{-3}$$

$$i_1 + i_2 + i_3 + i_4 = 10^{-3} = \frac{G_4}{\sum G} \times 10^{-3}(8+4+2+1)$$

$$\therefore \frac{15G_4}{\sum G} = 1 \quad \text{or} \quad 15G_4 = \sum G$$

$$i_4 R_4 = 1$$

$$\therefore \left(\frac{G_4}{\sum G} \times 10^{-3}\right)\left(\frac{1}{G_4}\right) = 1$$

$$\therefore \sum G = 10^{-3}$$

$$\therefore G_4 = \frac{10^{-3}}{15}, \qquad R_4 = \frac{1}{G_4} = 15{,}000\,\Omega$$

$$i_3 = \frac{G_3 \times 10^{-3}}{\sum G} = \frac{2G_4}{\sum G} \times 10^{-3}$$

$$\therefore G_3 = 2G_4 = \frac{2 \times 10^{-3}}{15}, \qquad R_3 = \frac{1}{G_3} = 7500\,\Omega$$

$$i_2 = \frac{G_2 10^{-3}}{\sum G} = \frac{4G_4 \times 10^{-3}}{\sum G}$$

$$\therefore G_2 = 4G_4, \qquad R_2 = \frac{15}{4} \times 10^3 = 3750\,\Omega$$

$$i_1 = \frac{G_1 \times 10^{-3}}{\sum G} = \frac{8G_4 \times 10^{-3}}{\sum G}$$

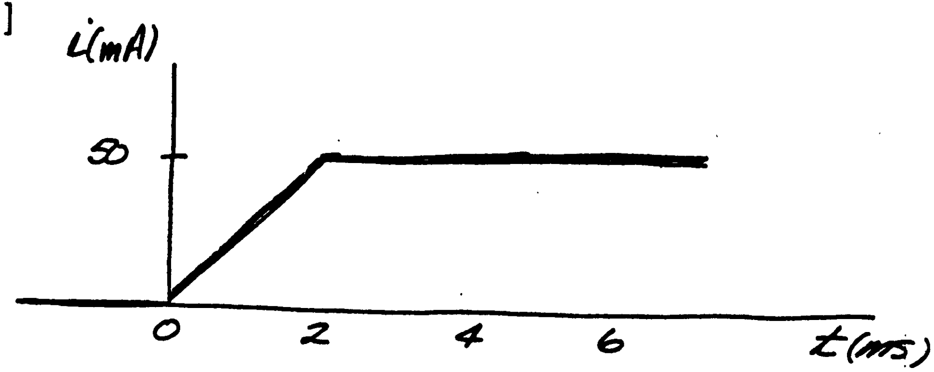
$$\therefore G_1 = 8G_4, \qquad R_1 = \frac{15 \times 10^3}{8} = 1875\,\Omega$$

P7.3 [a] $$i = \frac{1}{L}\int_0^t v_s\,dx + i(0) = \frac{10^6}{200}\int_0^t 5\times10^{-3}\,dx + 0, \qquad 0 \le t \le 2\,\text{ms}$$
$$= \frac{5000}{200}t, \qquad 0 \le t \le 2\,\text{ms}$$
$$= 25t, \qquad 0 \le t \le 2\,\text{ms}$$

$2\,\text{ms} \le t \le \infty$

$$i = \frac{1}{L}\int_{2\times10^{-3}}^t 0\,dx + i(2\times10^{-3}) = 0 + 50\,\text{mA}$$
$$\therefore\ i = 25t\,\text{mA}, \qquad 0 \le t \le 2\,\text{ms}$$
$$i = 50\,\text{mA}, \qquad 2\,\text{ms} \le t \le \infty$$

[b]

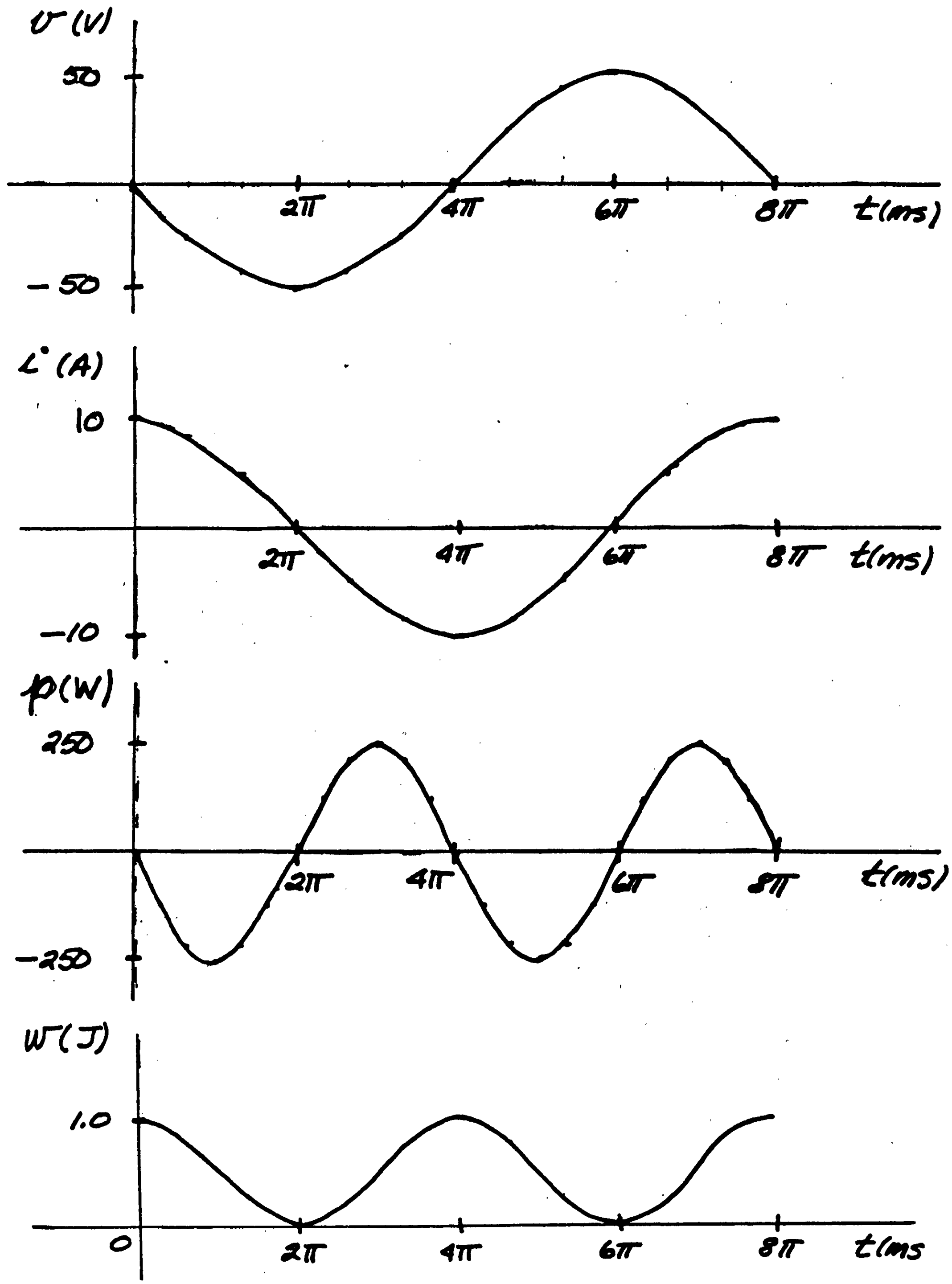


P7.5 [a] $i = \frac{1}{L}\int_{t_o}^{t} v\,d\tau + i(t_o) = \frac{10^3}{20}\int_{4\pi\times10^{-3}}^{t} -50\sin 250x\,dx - 10$

$$= -2500\left[\frac{-\cos 250x}{250}\right|_{4\pi\times10^{-3}}^{t} - 10 = 10[\cos 250t - \cos\pi] - 10$$

$i = 10\cos 250t$ A

[b]



[c] Absorbing power: $2\pi - 4\pi$ ms, $6\pi - 8\pi$ ms

Delivering power: $0 - 2\pi$ ms, $4\pi - 6\pi$ ms

P7.13 [a] $w(0) = \frac{1}{2}C[v(0)]^2 = \frac{1}{2}(0.2) \times 10^{-6}(150)^2 = 2250 \times 10^{-6} = 2.25\,\text{mJ}$

[b] $v = (A_1 t + A_2)e^{-5000t}$

$v(0) = A_2 = 150\,\text{V}$

$$\frac{dv}{dt} = -5000e^{-5000t}(A_1 t + A_2) + e^{-5000t}(A_1)$$

$$= (-5000A_1 t - 5000A_2 + A_1)e^{-5000t}$$

$$\frac{dv}{dt}(0) = A_1 - 5000A_2$$

$$i = C\frac{dv}{dt}, \qquad i(0) = C\frac{dv(0)}{dt}$$

$$\therefore\ \frac{dv(0)}{dt} = \frac{i(0)}{C} = \frac{250 \times 10^{-3}}{0.2 \times 10^{-6}} = 1250 \times 10^3$$

$$\therefore\ 1.25 \times 10^6 = A_1 - 5000(150)$$

$$A_1 = 1.25 \times 10^6 + 75 \times 10^4 = 2.0 \times 10^6\,\frac{\text{V}}{\text{s}}$$

[c] $v = (2 \times 10^6 t + 150)e^{-5000t}$

$$i = C\frac{dv}{dt} = 0.2 \times 10^{-6}\frac{d}{dt}(2 \times 10^6 t + 150)e^{-5000t}$$

$$i = \frac{d}{dt}\left[(0.4t + 30 \times 10^{-6})e^{-5000t}\right]$$

$$= (0.4t + 30 \times 10^{-6})(-5000)e^{-5000t} + e^{-5000t}(0.4)$$

$$= (-2000t - 150 \times 10^{-3} + 0.4)e^{-5000t}$$

$$= (0.25 - 2000t)e^{-5000t}\,\text{A}, \qquad t \geq 0$$

P7.15 [a] $v = \frac{1}{C}\int_0^t -50\times 10^{-3}\,dx + 15 = (10^7)(-50\times 10^{-3})\,x\Big|_0^t +15$

$v = -50\times 10^4 t + 15, \qquad 0 \le t \le 10\,\mu s$

$v(10\,\mu s) = -50\times 10^4(10\times 10^{-6}) + 15 = -5 + 15 = 10\,V$

[b] $v = 10^7\int_{10\times 10^{-6}}^t 0.1\,dx + 10 = 10^6\,x\Big|_{10\times 10^{-6}}^t +10 = 10^6 t - 10 + 10$

$v = 10^6 t, \qquad 10\,\mu s \le t \le 20\,\mu s$

$v(20\,\mu s) = 10^6(20\times 10^{-6}) = 20\,V$

[c] $v = 10^7\int_{20\times 10^{-6}}^t 0.16\,dx + 20 = 10^7(0.16)[t - 20\times 10^{-6}] + 20$

$= 1.6\times 10^6 t - 32 + 20$

$v = 1.6\times 10^6 t - 12, \qquad 20\,\mu s \le t \le 40\,\mu s$

[d] $v(40\,\mu s) = 64 - 12 = 52\,V$

$v(t) = 52, \qquad 40\,\mu s \le t \le \infty$