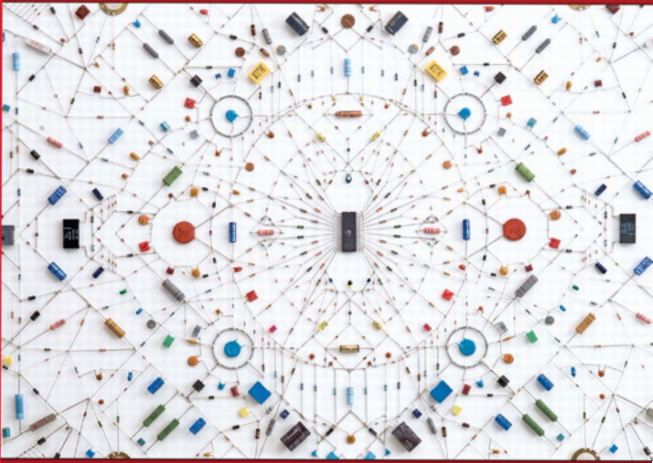
INSTRUCTOR SOLUTIONS MANUAL for

NILSSON · RIEDEL



ELECTRIC CIRCUITS

10th Edition

1 Circuit Variables

Assessment Problems

AP 1.1 Use a product of ratios to convert two-thirds the speed of light from meters per second to miles per second:

$$\left(\frac{2}{3}\right)\frac{3\times 10^8\ \text{m}}{1\ \text{s}}\cdot\frac{100\ \text{cm}}{1\ \text{m}}\cdot\frac{1\ \text{in}}{2.54\ \text{cm}}\cdot\frac{1\ \text{ft}}{12\ \text{in}}\cdot\frac{1\ \text{mile}}{5280\ \text{feet}}=\frac{124{,}274.24\ \text{miles}}{1\ \text{s}}$$

Now set up a proportion to determine how long it takes this signal to travel 1100 miles:

$$\frac{124{,}274.24\ \text{miles}}{1\ \text{s}}=\frac{1100\ \text{miles}}{x\ \text{s}}$$

Therefore,

$$x=\frac{1100}{124{,}274.24}=0.00885=8.85\times 10^{-3}\ \text{s}=8.85\ \text{ms}$$

AP 1.2 To solve this problem we use a product of ratios to change units from dollars/year to dollars/millisecond. We begin by expressing $10 billion in scientific notation:

$$\$100\ \text{billion}\ =\$100\times 10^9$$

Now we determine the number of milliseconds in one year, again using a product of ratios:

$$\frac{1\ \text{year}}{365.25\ \text{days}}\cdot\frac{1\ \text{day}}{24\ \text{hours}}\cdot\frac{1\ \text{hour}}{60\ \text{mins}}\cdot\frac{1\ \text{min}}{60\ \text{secs}}\cdot\frac{1\ \text{sec}}{1000\ \text{ms}}=\frac{1\ \text{year}}{31.5576\times 10^9\ \text{ms}}$$

Now we can convert from dollars/year to dollars/millisecond, again with a product of ratios:

$$\frac{\$100\times 10^9}{1\ \text{year}}\cdot\frac{1\ \text{year}}{31.5576\times 10^9\ \text{ms}}=\frac{100}{31.5576}=\$3.17/\text{ms}$$

AP 1.3 Remember from Eq. (1.2), current is the time rate of change of charge, or $i = \frac{dq}{dt}$ In this problem, we are given the current and asked to find the total charge. To do this, we must integrate Eq. (1.2) to find an expression for charge in terms of current:

$$q(t) = \int_0^t i(x)\,dx$$

We are given the expression for current, i, which can be substituted into the above expression. To find the total charge, we let $t \to \infty$ in the integral. Thus we have

$$q_{\text{total}} = \int_0^\infty 20e^{-5000x}\,dx = \frac{20}{-5000}e^{-5000x}\Big|_0^\infty = \frac{20}{-5000}(e^{-\infty} - e^0)$$

$$= \frac{20}{-5000}(0-1) = \frac{20}{5000} = 0.004\text{ C} = 4000\,\mu\text{C}$$

AP 1.4 Recall from Eq. (1.2) that current is the time rate of change of charge, or $i = \frac{dq}{dt}$. In this problem we are given an expression for the charge, and asked to find the maximum current. First we will find an expression for the current using Eq. (1.2):

$$i = \frac{dq}{dt} = \frac{d}{dt}\left[\frac{1}{\alpha^2} - \left(\frac{t}{\alpha} + \frac{1}{\alpha^2}\right)e^{-\alpha t}\right]$$

$$= \frac{d}{dt}\left(\frac{1}{\alpha^2}\right) - \frac{d}{dt}\left(\frac{t}{\alpha}e^{-\alpha t}\right) - \frac{d}{dt}\left(\frac{1}{\alpha^2}e^{-\alpha t}\right)$$

$$= 0 - \left(\frac{1}{\alpha}e^{-\alpha t} - \alpha\frac{t}{\alpha}e^{-\alpha t}\right) - \left(-\alpha\frac{1}{\alpha^2}e^{-\alpha t}\right)$$

$$= \left(-\frac{1}{\alpha} + t + \frac{1}{\alpha}\right)e^{-\alpha t}$$

$$= te^{-\alpha t}$$

Now that we have an expression for the current, we can find the maximum value of the current by setting the first derivative of the current to zero and solving for t:

$$\frac{di}{dt} = \frac{d}{dt}(te^{-\alpha t}) = e^{-\alpha t} + t(-\alpha)e^{\alpha t} = (1-\alpha t)e^{-\alpha t} = 0$$

Since $e^{-\alpha t}$ never equals 0 for a finite value of t, the expression equals 0 only when $(1-\alpha t) = 0$. Thus, $t = 1/\alpha$ will cause the current to be maximum. For this value of t, the current is

$$i = \frac{1}{\alpha}e^{-\alpha/\alpha} = \frac{1}{\alpha}e^{-1}$$

Note with the short circuit from a to b that i_Δ is zero, hence $316i_\Delta$ is also zero.

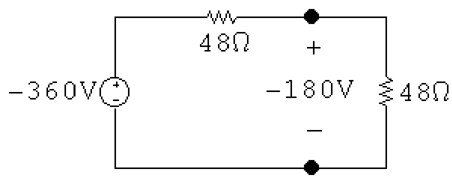
The mesh currents are:

$$\begin{aligned} 80i_1 - 16i_2 + 0i_3 &= -400 \\ -16i_1 + 48i_2 - 32i_3 &= 0 \\ 0i_1 - 32i_2 + 80i_3 &= 200 \end{aligned}$$

Solving, $i_1 = -5\,\text{A}; \quad i_2 = 0\,\text{A}; \quad i_3 = 2.5\,\text{A}$

Then, $i_{sc} = i_1 - i_3 = -7.5\,\text{A}$

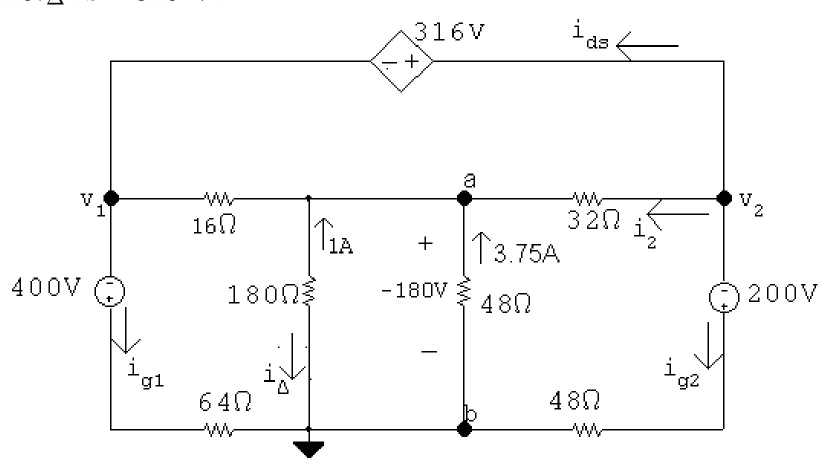
$$R_{Th} = \frac{-360}{-7.5} = 48\,\Omega$$



For maximum power transfer $R_o = R_{Th} = 48\,\Omega$

[b] $p_{max} = \dfrac{180^2}{48} = 675\,\text{W}$

[c] The problem reduces to the analysis of the following circuit. In constructing the circuit we have used the fact that i_Δ is -1 A, and hence $316i_\Delta$ is -316 V.



Using the node voltage method to find v_1 and v_2 yields

$$\frac{v_1 + 400}{64} + \frac{v_1 + 180}{16} + \frac{v_2 + 180}{32} + \frac{v_2 + 200}{48} = 0$$

$$v_2 - v_1 = 316$$

Solving, $v_1 = -336$ V; $\quad v_2 = -20\,\text{V}$.

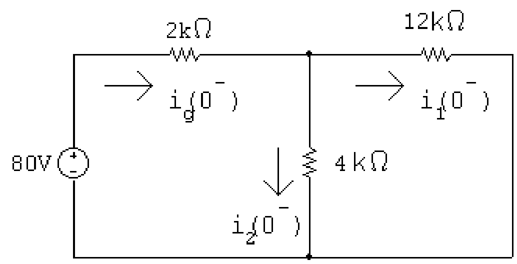
$$w_{10\Omega} = \int_0^{10^{-3}} 9 \times 10^{-5} e^{-2t/\tau}\, dt = 4.5\tau \times 10^{-5}(1 - e^{-2\times 10^{-3}/\tau})$$

$$\tau = \frac{1}{1000 \ln 2} \qquad \therefore \qquad w_{10\Omega} = 48.69\,\text{nJ}$$

$$w_L(0) = \frac{1}{2} L i_L^2(0) = \frac{1}{2}(14.43 \times 10^{-3})(3 \times 10^{-3})^2 = 64.92\,\text{nJ}$$

$$\%\ \text{diss in 1 ms} = \frac{48.69}{64.92} \times 100 = 75\%$$

P 7.8 **[a]** $t < 0$



$4\,\text{k}\Omega \| 12\,\text{k}\Omega = 3\,\text{k}\Omega$

Find the current from the voltage source by combining the resistors in series and parallel and using Ohm's law:

$$i_g(0^-) = \frac{80}{(2000 + 3000)} = 16\,\text{mA}$$

Find the branch currents using current division:

$$i_1(0^-) = \frac{3000}{12{,}000}(0.016) = 4\,\text{mA}$$

$$i_2(0^-) = \frac{3000}{4000}(0.016) = 12\,\text{mA}$$

[b] The current in an inductor is continuous. Therefore,

$$i_1(0^+) = i_1(0^-) = 4\,\text{mA}$$

$$i_2(0^+) = -i_1(0^+) = -4\,\text{mA} \qquad \text{(when switch is open)}$$

[c] $\tau = \dfrac{L}{R} = \dfrac{0.64 \times 10^{-3}}{16 \times 10^3} = 4 \times 10^{-5}\,\text{s}; \qquad \dfrac{1}{\tau} = 25{,}000$

$$i_1(t) = i_1(0^+)e^{-t/\tau} = 4e^{-25{,}000t}\,\text{mA}, \qquad t \geq 0$$

[d] $i_2(t) = -i_1(t) \qquad \text{when} \quad t \geq 0^+$

$$\therefore \quad i_2(t) = -4e^{-25{,}000t}\,\text{mA}, \qquad t \geq 0^+$$

$$250V_m \cos\theta = V_m^2 + 5000; \qquad 250V_m \sin\theta = 2500$$

$$(250)^2V_m^2 = (V_m^2 + 5000)^2 + 2500^2$$

$$62{,}500V_m^2 = V_m^4 + 10{,}000V_m^2 + 31.25 \times 10^6$$

or

$$V_m^4 - 52{,}500V_m^2 + 31.25 \times 10^6 = 0$$

Solving,

$$V_m^2 = 26{,}250 \pm 25{,}647.86; \qquad V_m = 227.81\,\text{V and } V_m = 24.54\,\text{V}$$

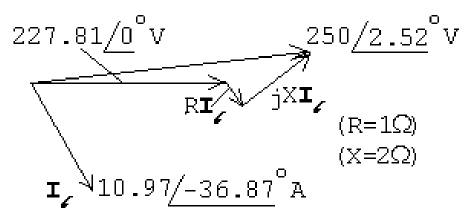
If $V_m = 227.81$ V:

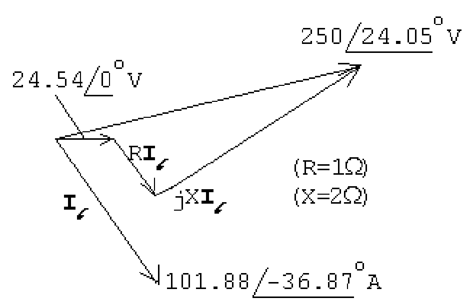
$$\sin\theta = \frac{2500}{(227.81)(250)} = 0.044; \qquad \therefore \quad \theta = 2.52^\circ$$

If $V_m = 24.54$ V:

$$\sin\theta = \frac{2500}{(24.54)(250)} = 0.4075; \qquad \therefore \quad \theta = 24.05^\circ$$

[b]





P 12.43 **[a]** $F(s) = \dfrac{K_1}{s} + \dfrac{K_2}{(s+3)^3} + \dfrac{K_3}{(s+3)^2} + \dfrac{K_4}{s+3}$

$$K_1 = \frac{135}{(s+3)^3}\bigg|_{s=0} = 5$$

$$K_2 = \frac{135}{s}\bigg|_{s=-3} = -45$$

$$K_3 = \frac{d}{ds}\left[\frac{135}{s}\right] = \left[\frac{-135}{s^2}\right]_{s=-3} = -15$$

$$K_4 = \frac{1}{2}\frac{d}{ds}\left[\frac{-135}{s^2}\right] = \left[\frac{1}{2}(-2)\left(\frac{-135}{s^3}\right)\right]_{s=-3} = -5$$

$$f(t) = [5 - 22.5t^2e^{-3t} - 15te^{-3t} - 5e^{-3t}]u(t)$$

[b] $F(s) = \dfrac{K_1}{(s+1-j1)^2} + \dfrac{K_1^*}{(s+1+j1)^2} + \dfrac{K_2}{s+1-j1} + \dfrac{K_2^*}{s+1+j1}$

$$K_1 = \frac{10(s+2)^2}{(s+1+j1)^2}\bigg|_{s=-1+j1} = -j5 = 5\underline{/-90^\circ}$$

$$K_2 = \frac{d}{ds}\left[\frac{10(s+2)^2}{(s+1+j1)^2}\right] = \left[\frac{10(2)(s+2)}{(s+1+j1)^2} - \frac{10(2)(s+2)^2}{(s+1+j1)^3}\right]_{s=0}$$

$$= -j5 = 5\underline{/-90^\circ}$$

$$f(t) = [10te^{-t}\cos(t-90^\circ) + 10e^{-t}\cos(t-90^\circ)]u(t)$$

[c]

$$F(s) = \begin{array}{r|l} & \quad\quad\quad\quad\quad 25 \\ \hline s^2+15s+54 & 25s^2+395s+1494 \\ & 25s^2+375s+1350 \\ \hline & \quad\quad\quad 20s+144 \end{array}$$

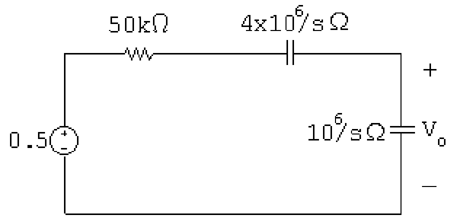
$$F(s) = 25 + \frac{20s+144}{s^2+15s+54} = 25 + \frac{K_1}{s+6} + \frac{K_2}{s+9}$$

$$K_1 = \frac{20s+144}{s+9}\bigg|_{s=-6} = 8$$

$$K_2 = \frac{20s+144}{s+6}\bigg|_{s=-9} = 12$$

$$f(t) = 25\delta(t) + [8e^{-6t} + 12e^{-9t}]u(t)$$

P 13.91 [**a**]



$$V_o = \frac{0.5}{50{,}000 + 5 \times 10^6/s} \cdot \frac{10^6}{s}$$

$$\frac{500{,}000}{50{,}000s + 5 \times 10^6} = \frac{10}{s + 100}$$

$$v_o = 10e^{-100t}u(t)\,\text{V}$$

[**b**] At $t = 0$ the current in the $1\,\mu$F capacitor is $10\delta(t)\,\mu$A

$$\therefore \qquad v_o(0^+) = 10^6 \int_{0^-}^{0^+} 10 \times 10^{-6}\delta(t)\,dt = 10\,\text{V}$$

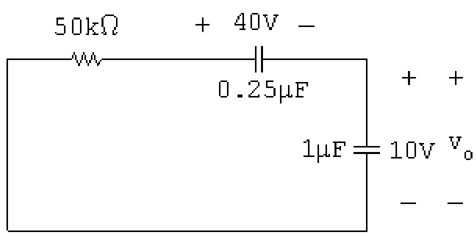
After the impulsive current has charged the $1\,\mu$F capacitor to 10 V it discharges through the 50 kΩ resistor.

$$C_e = \frac{C_1C_2}{C_1 + C_2} = \frac{0.25}{1.25} = 0.2\,\mu\text{F}$$

$$\tau = (50{,}000)(0.2 \times 10^{-6}) = 10^{-2}$$

$$\frac{1}{\tau} = 100 \text{ (checks)}$$

Note – after the impulsive current passes the circuit becomes



The solution for v_o in this circuit is also

$$v_o = 10e^{-100t}u(t)\,\text{V}$$

P 13.92 [**a**] The circuit parameters are

$$R_\text{a} = \frac{120^2}{1200} = 12\,\Omega \qquad R_\text{b} = \frac{120^2}{1800} = 8\,\Omega \qquad X_\text{a} = \frac{120^2}{350} = \frac{288}{7}\,\Omega$$

The branch currents are

$$\mathbf{I}_1 = \frac{120\underline{/0^\circ}}{12} = 10\underline{/0^\circ}\text{ A(rms)} \qquad \mathbf{I}_2 = \frac{120\underline{/0^\circ}}{j1440/35} = -j\frac{35}{12} = \frac{35}{12}\underline{/-90^\circ}\text{ A(rms)}$$

Choose a capacitor value of 64 nF. Using the selected values of R_1 and R_2 the maximum gain for $\alpha = 1$ is

$$20\log_{10}\left(\frac{50}{10}\right)_{\alpha=1} = 13.98 \text{ dB}$$

When $C_1 = 64$ nF the frequency $1/R_2C_1$ is

$$\frac{1}{R_2C_1} = \frac{10^9}{50{,}000(64)} = 312.5 \text{ rad/s} = 49.7 \text{ Hz}$$

The magnitude of the transfer function at 312.5 rad/s is

$$|H(j312.5)|_{\alpha=1} = \left|\frac{50\times10^3 + j312.5(10)(50)(64)10^{-3}}{10\times10^3 + j312.5(10)(50)(64)10^{-3}}\right| = 3.61$$

Therefore the gain at 49.7 Hz is

$$20\log_{10}(3.61)_{\alpha=1} = 11.1 \text{ dB}$$

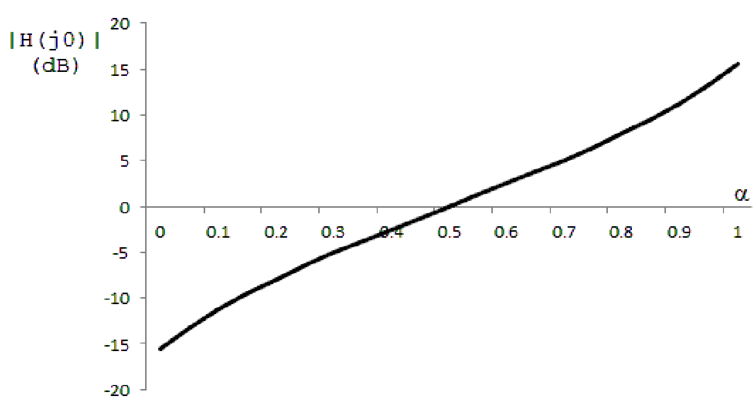
P 15.62 $20\log_{10}\left(\dfrac{R_1+R_2}{R_1}\right) = 20$

$$\therefore \quad \frac{R_1+R_2}{R_1} = 10; \qquad \therefore \quad R_2 = 9R_1$$

Choose $\quad R_1 = 100\,\text{k}\Omega$. Then $\quad R_2 = 900\,\text{k}\Omega$

$$\frac{1}{R_2C_1} = 150\pi \text{ rad/s}; \qquad \therefore \quad C_1 = \frac{1}{(150\pi)(900\times10^3)} = 2.36\,\text{nF}$$

P 15.63 $|H(j0)| = \dfrac{R_1+\alpha R_2}{R_1+(1-\alpha)R_2} = \dfrac{10+\alpha(50)}{10+(1-\alpha)50}$

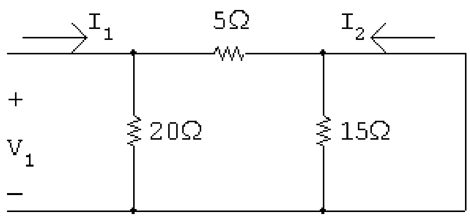


18

Two-Port Circuits

Assessment Problems

AP 18.1 With port 2 short-circuited, we have



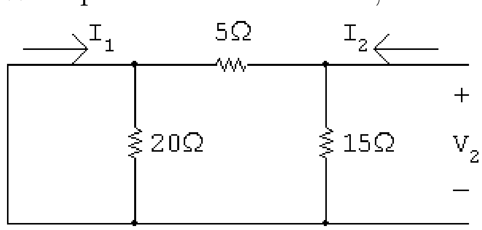
$$I_1 = \frac{V_1}{20} + \frac{V_1}{5}; \qquad \frac{I_1}{V_1} = y_{11} = 0.25\,\text{S}; \qquad I_2 = \left(\frac{-20}{25}\right) I_1 = -0.8 I_1$$

When $V_2 = 0$, we have $\quad I_1 = y_{11}V_1 \quad$ and $\quad I_2 = y_{21}V_1$

Therefore $\quad I_2 = -0.8(y_{11}V_1) = -0.8y_{11}V_1$

Thus $\quad y_{21} = -0.8y_{11} = -0.2\,\text{S}$

With port 1 short-circuited, we have



$$I_2 = \frac{V_2}{15} + \frac{V_2}{5}; \qquad \frac{I_2}{V_2} = y_{22} = \left(\frac{4}{15}\right)\,\text{S}$$