1. (a) -0.7822; -0.544;1.681

   (b) 4cos2*t*: 4; -1.665; -3.960

   $4\sin(2t + 90^{\circ})$: 4; -1.665; -3.960

   (c) $3.2\cos(6t+15^{\circ})$: 3.091; 1.012; 2.429

   $3.2\cos(6t+105^{\circ})$: 3.091; 1.012; 2.429

2. (a)

$$5\sin 300t = \boxed{5\cos(300t - 90°)}$$

$$1.95\sin\left(\pi t - 92°\right) = \boxed{1.95\cos(\pi t - 182°)}$$

$$2.7\sin\left(50t + 5°\right) - 10\cos 50t$$
$$= 2.7\sin 50t\cos 5° + 2.7\cos 50t\sin 5° - 10\cos 50t$$
$$= 2.6897\sin 50t - 9.7647\cos 50t = \boxed{10.13\cos(50t + 15.4°)}$$

(b)

$$66\cos(9t - 10°) = \boxed{66\sin(9t + 80°)}$$

$$4.15\cos 10t = \boxed{4.15\sin(10t + 90°)}$$

$$10\cos\left(100t - 9°\right) + 10\sin\left(100t + 19°\right)$$
$$= 11.0195\sin 100t + 13.1325\cos 100t$$
$$= 17.14\cos(100t - 40°)$$
$$= \boxed{17.14\sin(100t + 50°)}$$

3. (a) v_1 leads i_1 by -45^o

(b) v_1 leads by -45 + 80 = 35^o

(c) v_1 leads by -45 + 40 = -5^o

(d) $5\sin(10t - 19^o) = 5\cos(10t - 19^o)$ therefore v_1 leads by -45 + 109 = 64^o

4. $v_1 = 34\cos(10t + 125°)$

(a) $i_1 = 5\cos 10t; v_1$ lags i_1 by $\boxed{-235°}$ $(-360° + 125°)$

(b) $i_1 = 5\cos(10t - 80°); v_1$ lags i_1 by $\boxed{-155°}$ $(-235° + 80°)$

(c) $i_1 = 5\cos(10t - 40°); v_1$ lags i_1 by $\boxed{-195°}$ $(-235° + 40°)$

(d) $i_1 = 5\cos(10t + 40°); v_1$ lags i_1 by $\boxed{-275°}$ $(-235° - 40°)$

(e) $i_1 = 5\sin(10t - 19°) = 5\cos(10t - 109°); v_1$ lags i_1 by $\boxed{-126°}$ $(-235° + 109°)$

5. (a) cos4t leads sin4t; sin4t lags cos4t

(b) the first is lagging by 80^o

(c) the second is lagging by 80^o

(d) the second is lagging by 88^o

(e) Neither term lags

6. (a) $\cos 3t - 7\sin 3t = 0$

$7.07\cos(3t + 1.4289) = 0$

$3t + 1.4289 = 1.5708$

$3t = 0.1419$

$t = \boxed{0.0473 \text{ s}}$

Also, $3t = 0.1419 + \pi$

$t = \boxed{1.0945 \text{ s}}$

and, $3t = 0.1419 + 2\pi$

$t = \boxed{2.1417 \text{ s}}$

(b) $\cos\left(10t + 45°\right) = 0$

$10t + 0.7854 = 1.5708$

$10t = 0.7854 \Rightarrow t = \boxed{0.0785 \text{ s}}$

Also, $10t = 0.7854 + \pi \Rightarrow t = \boxed{0.3927 \text{ s}}$

and, $10t = 0.7854 + 2\pi \Rightarrow t = \boxed{0.7069 \text{ s}}$

(c) $\cos 5t - \sin 5t = 0$

$5t + 0.7854 = 1.5708$

$5t = 0.7854 \Rightarrow t = \boxed{0.1571 \text{ s}}$

Also, $5t = 0.7854 + \pi \Rightarrow t = \boxed{0.7854 \text{ s}}$

and, $5t = 0.7854 + 2\pi \Rightarrow t = \boxed{1.4137 \text{ s}}$

(d) $\cos 2t + \sin 2t - \cos 5t + \sin 5t = 0$

$1.4142\cos(1.5t - 0.7854) = 0$

$1.5t - 0.7854 = 1.5708$

$1.5t = 2.3562 \Rightarrow t = \boxed{1.5708 \text{ s}}$

Also, $1.5t = 2.3562 + \pi \Rightarrow t = \boxed{3.6652 \text{ s}}$

and, $1.5t = 2.3562 + 2\pi \Rightarrow t = \boxed{5.7596 \text{ s}}$

7. (a) t = 0; t = 550 ms; t = 0; t = 126 ms

8. (a) $v(t) = 2t; 0 \le t < 0.5s$

$\therefore v(0.25s) = \boxed{0.5 \text{ V}}$

(b) Using the first term of the Fourier series only,

$$v(t) = \frac{8}{\pi^2}\sin \pi t$$

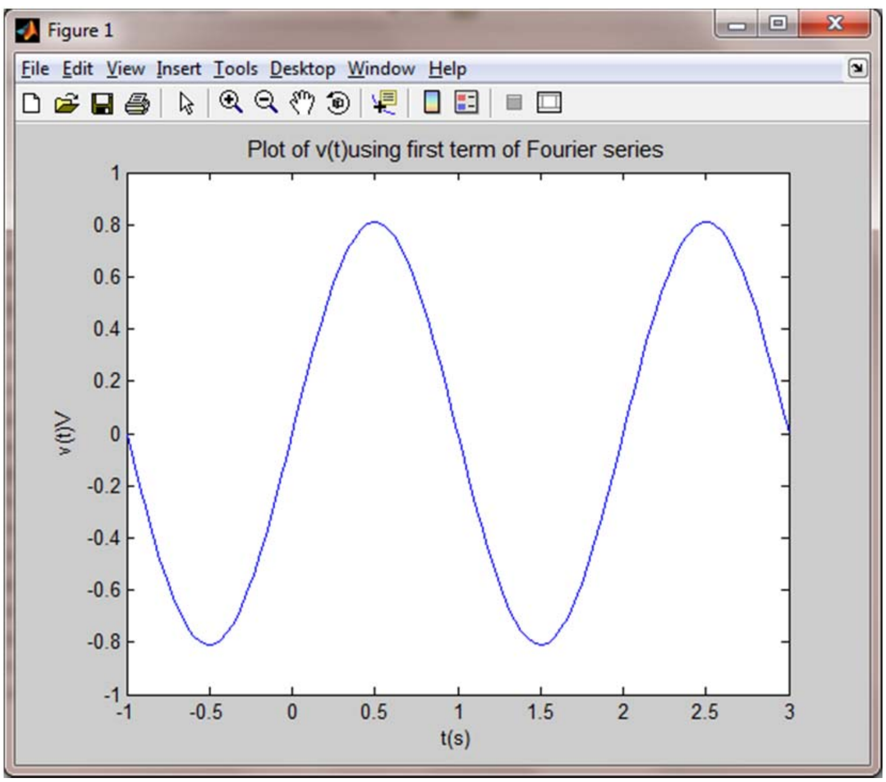
$$v(0.25s) = \frac{8}{\pi^2}\sin 45° = \boxed{0.5732 \text{ V}}$$

(c) Using the first three terms of the Fourier series,

$$v(t) = \frac{8}{\pi^2}\sin \pi t - \frac{8}{3^2\pi^2}\sin 3\pi t + \frac{8}{5^2\pi^2}\sin 5\pi t$$

$$v(0.25s) = \boxed{0.4866 \text{ V}}$$

(d)

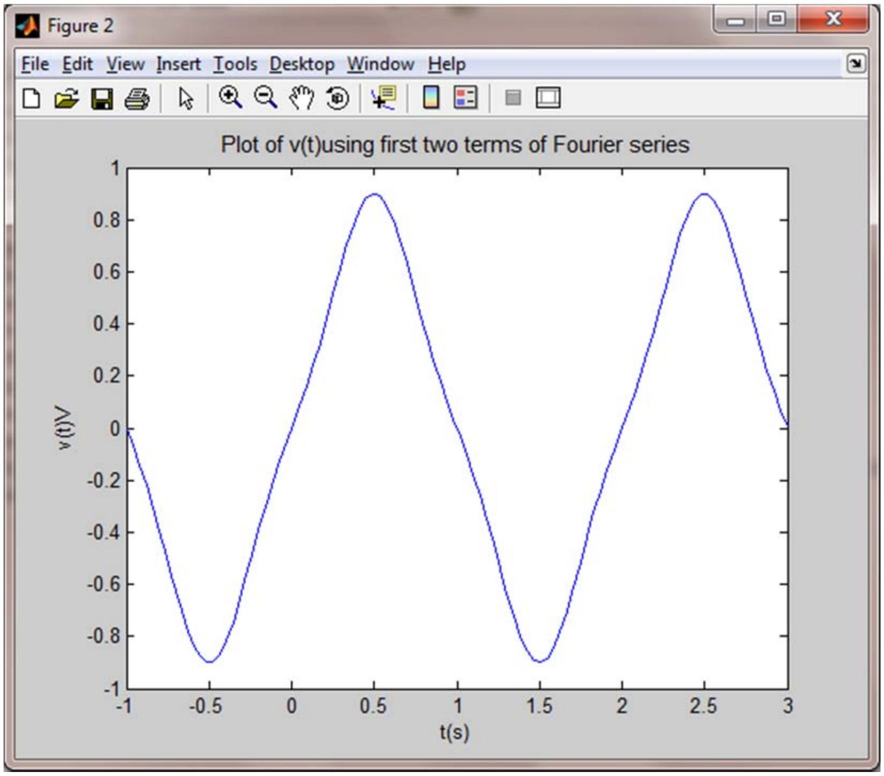



```
t=linspace(-1,3);
v = 8/(pi^2)*sin(pi*t);
figure(1);
plot(t,v);
xlabel('t(s)')
```

ylabel('v(t)V')

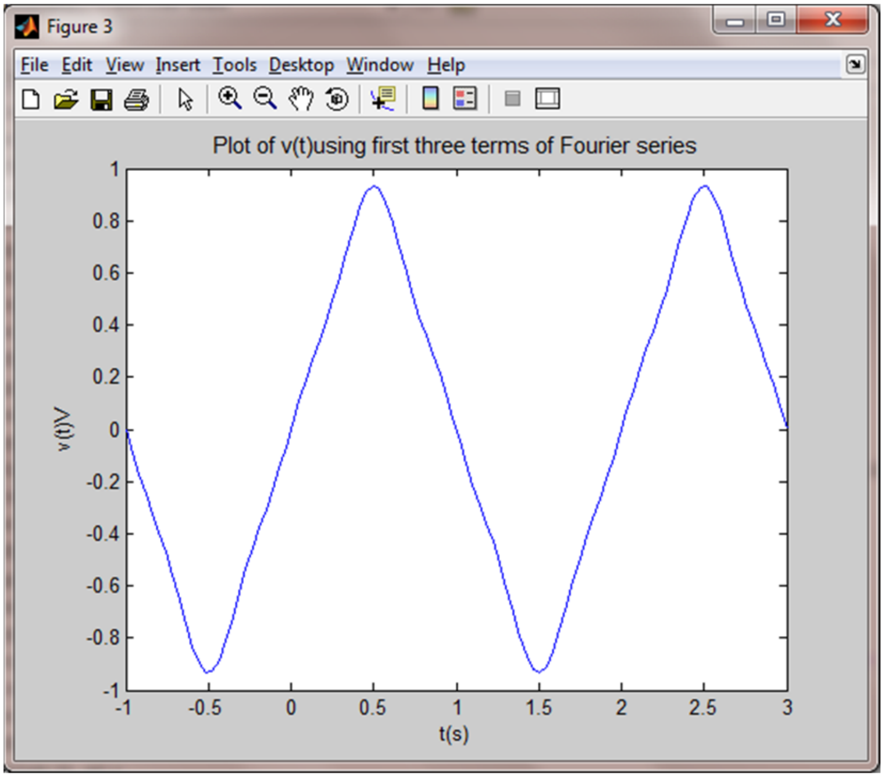
title('Plot of v(t)using first term of Fourier series','FontSize',11)

(e)




```
t=linspace(-1,3);
v = 8/(pi^2)*(sin(pi*t)-1/(3^2)*sin(3*pi*t));
figure(2);
plot(t,v);
xlabel('t(s)')
ylabel('v(t)V')
title('Plot of v(t)using first two terms of Fourier series','FontSize',11)
```

(f)




```
t=linspace(-1,3);
v = 8/(pi^2)*(sin(pi*t)-1/(3^2)*sin(3*pi*t)+ 1/(5^2)*sin(5*pi*t));
figure(3);
plot(t,v);
xlabel('t(s)')
ylabel('v(t)V')
title('Plot of v(t)using first three terms of Fourier series','FontSize',11)
```

9. (b)

V_{rms}	V_m
110 V	156 V
115 V	163 V
120 V	170 V

10. In this problem, when we apply Thevenin's theorem with the inductor as the load, we get,

$$v_{oc} = v_s \cdot \frac{1}{1+10} = \left(4.53\cos\left(0.333\times10^{-3}t+30°\right)\right)\frac{1}{11} = 0.4118\cos\left(0.333\times10^{-3}t+30°\right)\text{ V}$$

$$R_{th} = \frac{1\times10}{1+10} = \frac{10}{11} = 0.909\ \Omega$$

Now for a series RL circuit with $L = 3mH, R_{th} = 0.909\Omega$ and a source voltage of $0.4118\cos\left(0.333\times10^{-3}t+30°\right)$ V, we get,

$$i_L(t) = \frac{V_m}{\sqrt{R_{th}^{\ 2}+\omega^2L^2}}\cos\left(\omega t - \tan^{-1}\frac{\omega L}{R}+30°\right)$$

$$= \frac{0.4118}{\sqrt{(0.909)^2+\left(0.333\times10^{-3}\times3\times10^{-3}\right)^2}}\cos\left(0.333\times10^{-3}t-\tan^{-1}\frac{\left(0.333\times10^{-3}\times3\times10^{-3}\right)}{0.909}+30°\right)$$

$$= 0.453\cos\left(0.333\times10^{-3}t+30°\right)A$$

$$\therefore i_L(t=0) = 0.453\cos(30°) = \boxed{392.3\text{ mA}}$$

Now,

$$v_L(t) = L\frac{di_L}{dt} = -3\times10^{-3}\times0.333\times10^{-3}\times0.453\sin\left(0.333\times10^{-3}t+30°\right)$$

$$= 0.4526\cos\left(0.333\times10^{-3}t+120°\right)\ \mu\text{V}$$

$$v_L(t=0) = -0.2262\ \mu\text{V}$$

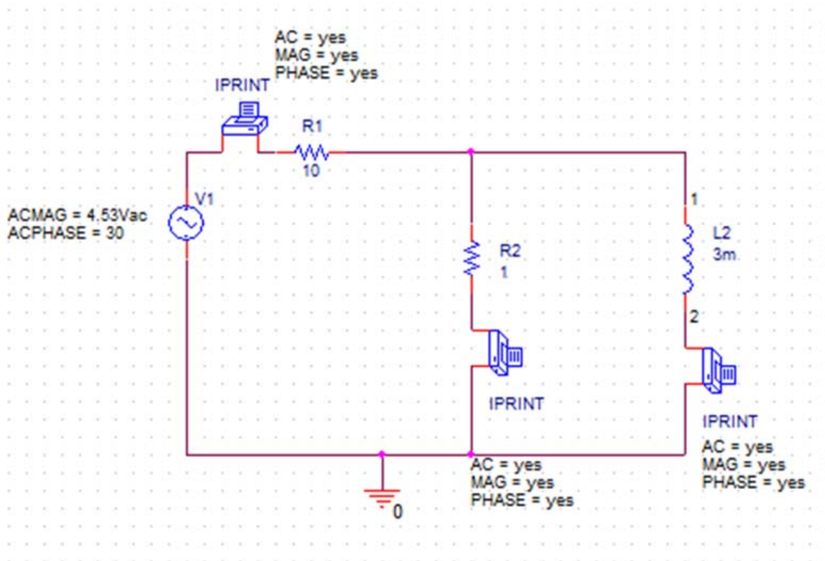
$$i_R(t=0) = \frac{v_L(t=0)}{R} = \boxed{-0.2262\ \mu\text{A}}$$

$$i_s(t=0) = i_R + i_L = \boxed{392.3\text{ mA}}$$

(b) $\boxed{v_L(t) = 0.4526\cos\left(0.333\times10^{-3}t+120°\right)\ \mu\text{V}}$

Pspice Verification:

This has been verified using the phasor in Pspice.




```
  FREQ          IM(V_PRINT1)IP(V_PRINT1)

    5.300E-05    4.530E-01    3.000E+01
**** 06/14/12 15:54:20 ******* PSpice Lite (April 2011) ******* ID# 10813 ****
 ** Profile: "SCHEMATIC1-prob10_10"  [ C:\ORCAD\ORCAD_16.5_LITE\examples\prob10_1

 ****     AC ANALYSIS                      TEMPERATURE =   27.000 DEG C

******************************************************************************

  FREQ          IM(V_PRINT2)IP(V_PRINT2)

    5.300E-05    4.526E-07    1.200E+02
```

11. $8.84\cos(100t - 0.785)$ A

12. In this problem, when we apply Thevenin's theorem with the inductor as the load, we get,

$$v_{oc} = 25\cos 100t \times \frac{1\|(1+2)}{(1+2)} \times 2 = 12.5\cos 100t \text{ V}$$

$$R_{th} = (1+1)\Omega \| 2\Omega = 1\Omega$$

Now for a series RL circuit with $L = 10mH, R_{th} = 1\Omega$ and a source voltage of $12.5\cos 100t$ V, we get,

$$i_L(t) = \frac{V_m}{\sqrt{R_{th}{}^2 + \omega^2 L^2}}\cos\left(\omega t - \tan^{-1}\frac{\omega L}{R}\right)$$

$$= \frac{12.5}{\sqrt{1^2 + \left(100\times10\times10^{-3}\right)^2}}\cos\left(100t - \tan^{-1}\frac{\left(100\times10\times10^{-3}\right)}{1}\right)$$

$$= 8.84\cos\left(100t - 45°\right) \text{ A}$$

Now,

$$v_L(t) = L\frac{di_L}{dt} = -8.84\times10\times10^{-3}\times100\sin\left(100t - 45°\right)$$

$$= 8.84\cos\left(100t + 45°\right) \text{ V}$$

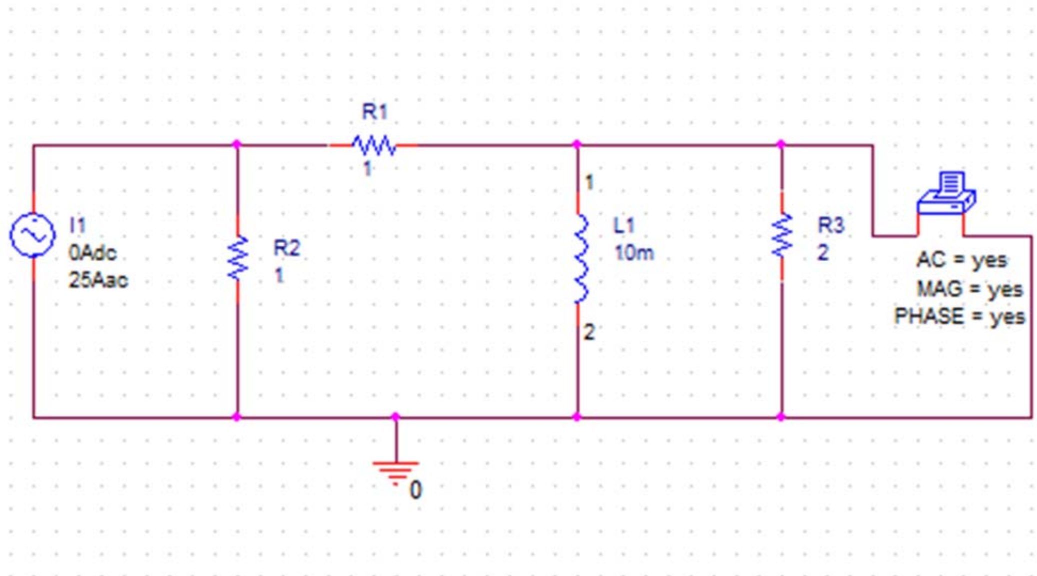
Voltage across the 2Ω resistor is equal to $v_L(t)$.

Power dissipated in 2Ω resistor is given by,

$$p_R(t) = \frac{v_R{}^2}{R} = \frac{v_L{}^2}{R} = \boxed{39.07\cos^2\left(100t + 45°\right) \text{ W}}$$

Pspice Verification:

This has been verified using the phasor in Pspice.



FREQ	VM(N00183,0)	VP(N00183,0)
1.592E+01	8.839E+00	4.500E+01

13. 1.92cos(40t – 0.876) V

14. Let 'i' be the current flowing in the circuit in the clockwise direction. Then, on applying KVL, we get,

$$15i + v_C = 3\cos 40t$$

Substituting, $i = i_C = C\dfrac{dv_C}{dt}$ on the above KVL equation, we get,

$$30\times10^{-3}\frac{dv_C}{dt} + v_C = 3\cos 40t$$

Let us choose to express the response as,

$$v_C(t) = A\cos(40t+\theta)$$
$$\frac{dv_C}{dt} = -40A\sin(40t+\theta)$$

On rewriting the KVL equation, we get,

$$-1.2A\sin(40t+\theta) + A\cos(40t+\theta) = 3\cos 40t$$
$$\sqrt{A^2+(-1.2A)^2}\cos\left((40t+\theta)+\tan^{-1}\left(\frac{1.2A}{A}\right)\right) = 3\cos 40t$$

On equating the terms, we get,

$$A = 1.92$$
$$\theta = -\tan^{-1}(1.2) = -50.19^\circ$$
$$\therefore v_C(t) = 1.92\cos(40t - 50.19^\circ)\ \text{V}$$

Energy stored in a capacitor is given by,

$$w_C = \frac{1}{2}Cv_C{}^2(t)$$

At t=10 ms,

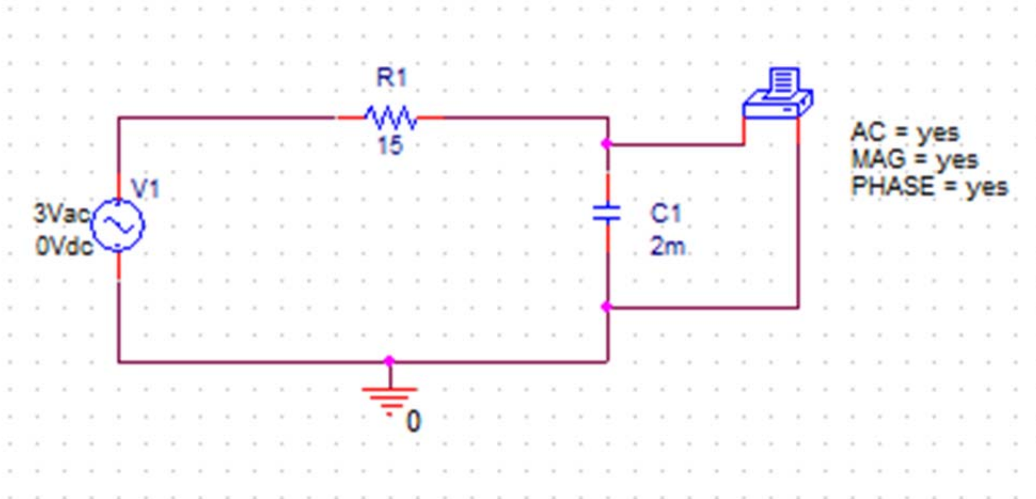
$$w_C(10\text{ms}) = \frac{1}{2}\times2\times10^{-3}\times1.71^2 = \boxed{2.92\ \text{mJ}}$$

At t=40 ms,

$$w_C(40\text{ms}) = \frac{1}{2}\times2\times10^{-3}\times1.45^2 = \boxed{2.1\ \text{mJ}}$$

Pspice Verification:

Phasor method is used to verify the solution.



FREQ	VM(N00132,0)	VP(N00132,0)
6.366E+00	1.921E+00	-5.019E+01

15. 7.02cos(6t – 0.359) A

16. (a) $50\angle-75° = 50\cos(-75°) + j50\sin(-75°) = \boxed{12.94 - j48.29}$

(b)

$19e^{j30°} = 19\cos(30°) + j19\sin(30°) = \boxed{16.45 + j9.5}$

$2.5\angle-30° + 0.5\angle45° = 2.5\cos(-30°) + j2.5\sin(-30°) + 0.5\cos(45°) + j0.5\sin(45°)$

$= \boxed{2.52 - j0.89}$

(c) $(2 + j2)(2 - j2) = 8 = \boxed{8\angle0°}$

(d) $(2 + j2)(5\angle22°) = (2.82\angle45°)(5\angle22°) = \boxed{14.14\angle67°}$

17. (a) $2.88\angle 11.5^o$

(b) $1\angle 90^o$

(c) $1\angle 0^o$

(d) $2.82 + j0.574$

(e) $2.87 - j4.90$

18. (a) $4(8 - j8) = \boxed{45.25\angle -45°}$

(b) $4\angle 5° - 2\angle 15° = (3.98 + j0.35) - (1.93 + j0.52) = 2.05 - j0.17 = \boxed{2.05\angle -4.74°}$

(c) $(2 + j9) - 5\angle 0° = -3 + j9 = \boxed{9.5\angle 108.44°}$

(d) $\dfrac{-j}{10 + j5} - 3\angle 40° + 2 = \dfrac{-j}{10 + j5} - (2.3 + j1.93) + 2 = -0.34 - j2.01 = \boxed{2.03\angle 260.4°}$

(e) $(10 + j5)(10 - j5)(3\angle 40°) + 2 = 225\angle 40° + 2 = 174.36 + j144.63 = \boxed{226.54\angle 39.68°}$

19. (a) $7.79 + j4.50$

(b) $6.74 - j0.023$

(c) $7.67 + j87.5$

(d) $2.15 + j2.50$

(e) $2.89 + j241$

20. (a) $\dfrac{2+j3}{1+8\angle 90°}-4=\dfrac{2+j3}{1+j8}-4=-3.6-j0.2=\boxed{3.6\angle 183.18°}$

(b) $\left(\dfrac{10\angle 25°}{5\angle -10°}+\dfrac{3\angle 15°}{3-j5}\right)j2=\left(2\angle 35°+0.52\angle -44.04°\right)\left(2\angle 90°\right)=-1.58+j4.02$

$=\boxed{4.32\angle 111.46°}$

(c) $\left[\dfrac{(1-j)(1+j)+1\angle 0°}{-j}\right](3\angle -90°)+\dfrac{j}{5\angle -45°}$

$=9\angle 0°+0.2\angle 135°=8.86+j0.14=\boxed{8.86\angle 0.91°}$

21. $88.7\sin(20t - 27.5^o)$ mA; $2.31\sin(20t + 62.5^o)$ V

22. Let i_L in the complex form be $i_L = Ae^{j(35t+\theta^\circ)}$ A.

Given, $i_s = 5\sin(35t - 10°) = 5e^{j(35t-100^\circ)}$ A

$$v_L = L\frac{di_L}{dt} = 0.4\frac{d}{dt}\left(Ae^{j(35t+\theta^\circ)}\right) = j14Ae^{j(35t+\theta^\circ)}$$

$$v_R = i_L R = 6Ae^{j(35t+\theta^\circ)}$$

$$v_S = v_C = v_R + v_L = A(6+j14)e^{j(35t+\theta^\circ)}$$

$$i_C = C\frac{dv_C}{dt} = 0.01\frac{d}{dt}\left(A(6+j14)e^{j(35t+\theta^\circ)}\right) = A(-4.9+j2.1)e^{j(35t+\theta^\circ)}$$

Applying KCL, we get,

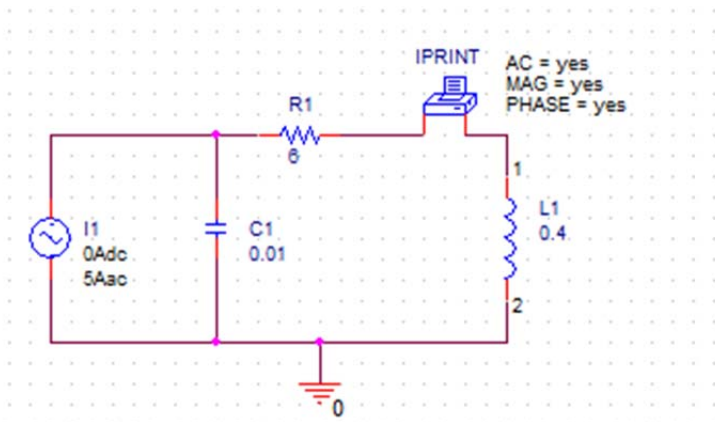
$$i_s = i_C + i_L$$

$$5e^{j(35t-100^\circ)} = 4.43Ae^{j(35t+\theta^\circ+151.69^\circ)}$$

$$\Rightarrow A = 1.129 \text{ and } \theta = -251.69° = 108.31°$$

$$\therefore i_L = 1.129e^{j(35t+108.31^\circ)} = \boxed{1.129\cos(35t + 108.31°) \text{ A}}$$

Pspice Verification:




```
FREQ          IM(V_PRINT1)IP(V_PRINT1)

 5.570E+00    1.129E+00    1.083E+02
```

23.

$$\left[(62.5)^2 + (1.25\omega)^2\right]^{1/2} \cos\left(\omega t + 31.3^\circ + \tan^{-1}\frac{1.25\omega}{62.5}\right) \text{ mA}$$

24. This problem can be easily solved by performing a source transformation which results in a circuit with voltage source, resistance and inductance.

Given, $i_s = 5e^{j10t}$
$v_s = 10e^{j10t}$

The steady-state expression for $i_L(t)$ can be found as:

$$i_L(t) = \frac{V_m}{\sqrt{R^2 + \omega^2 L^2}} \cos\left(\omega t - \tan^{-1}\left(\frac{\omega L}{R}\right)\right)$$

$$= \frac{10}{\sqrt{2^2 + 10^2 \times 0.4^2}} \cos\left(10t - \tan^{-1}\left(\frac{10 \times 0.4}{2}\right)\right)$$

$$= \boxed{2.24\cos(10t - 63.44°)\ \text{A}}$$

25. (a) $75.9\angle 0^{o}$

(b) $5\angle -42^{o}$

(c) $1\angle 104^{o}$

(d) $8.04\angle -78.4^{o}$

26. (a) $11\sin 100t = 11\cos(100t - 90°) = \boxed{11\angle -90°}$

(b) $11\cos 100t = \boxed{11\angle 0°}$

(c) $11\cos(100t - 90°) = \boxed{11\angle -90°}$

(d) $3\cos 100t - 3\sin 100t = 3\angle 0° - 3\angle -90° = 3 + j3 = \boxed{4.24\angle 45°}$

27. (a) $9\cos(2\pi\times10^3 t + 65^o)$ V

(b) $500\cos(2\pi\times10^3 t + 6^o)$ mA

(c) $14.7\cos(2\pi\times10^3 t + 4^o)$ V

28. (a) $\frac{2-j}{5\angle 45^\circ}\text{V} = \frac{2.24\angle -26.56^\circ}{5\angle 45^\circ} = \boxed{0.45\angle -71.56^\circ \text{ V}}$

(b) $\frac{6\angle 20^\circ}{1000} - j\text{ V} = 0.00564 - j1 = \boxed{1\angle -89.67^\circ \text{ V}}$

(c) $(j)(52.5\angle -90^\circ)\text{V} = \boxed{52.5\angle 0^\circ \text{ V}}$

29. (a) 0; 11

(b) -11; 0

(c) 0; 11

(d) -3; -3

30. (a) $v(t) = 9\cos(100\pi t + 65°)$ V

At t = 10 ms: $v(t) = 9\cos 245° = \boxed{-3.8 \text{ V}}$

At t = 25 ms: $v(t) = 9\cos 515° = \boxed{-8.16 \text{ V}}$

(b) $v(t) = 2\cos(100\pi t + 31°)$ V

At t = 10 ms: $v(t) = 2\cos 211° = \boxed{-1.71 \text{ V}}$

At t = 25 ms: $v(t) = 2\cos 481° = \boxed{-1.03 \text{ V}}$

(c) $v(t) = 22\cos(100\pi t + 14°) - 8\cos(100\pi t + 33°)$ V

At t = 10 ms: $v(t) = 22\cos 194° - 8\cos 213° = \boxed{-14.64 \text{ V}}$

At t = 25 ms: $v(t) = 22\cos 464° - 8\cos 483° = \boxed{-0.97 \text{ V}}$

31. (a) $2\angle 0^o$

(b) $400\angle -90^o$ mV

(c) $10\angle 90^o$ μV

32. (a) Phasor current through the resistor:

Using ohm's law, we get:

$$\mathbf{V}_R = \mathbf{I}R$$

$$\mathbf{I} = \frac{\mathbf{V}_R}{R} = \boxed{1\angle 30^\circ \text{ A}}$$

(b) At ω=1 rad/s, the voltage across the capacitor-inductor combination is 0 as their equivalent impedance is 0.

$$Z_{eq} = -j + j = 0$$

$$\therefore \frac{\mathbf{V}_R}{\mathbf{V}_{C-L}} = \boxed{\infty}$$

(c) At ω = 2 rad/s,

$$Z_{eq} = -j0.5 + j2 = j1.5$$

$$\mathbf{V}_{C-L} = (1\angle 30^\circ)(1.5\angle 90^\circ) = 1.5\angle 120^\circ \text{ V}$$

$$\therefore \frac{\mathbf{V}_R}{\mathbf{V}_{C-L}} = \frac{1\angle 30^\circ}{1.5\angle 120^\circ} = \boxed{0.67\angle -90^\circ}$$

33. (a) $20\angle 0^\circ$ mV

(b) $31.8\angle -90^\circ$ μV

(c) $3.14\angle 90^\circ$ V

(d) $20\angle -0.1^\circ$ V

(e) $3.14\angle 89.6^\circ$

(f) 20 mV; 0; 0; 20 mV; 21.9 mV

34. (a) Given:

$$\mathbf{I}_{10} = 2\angle 42° \text{ mA}$$
$$\mathbf{V} = 40\angle 132° \text{ mV}$$
$$\omega = 1000 \text{ rad / s}$$
$$\mathbf{Z} = \frac{\mathbf{V}}{\mathbf{I}_{10}} = \frac{40\angle 132°}{2\angle 42°} = 20\angle 90° \ \Omega$$

The phase angle of 90degrees shows that it is an inductor.

(b) $\omega = 1000$ rad/s

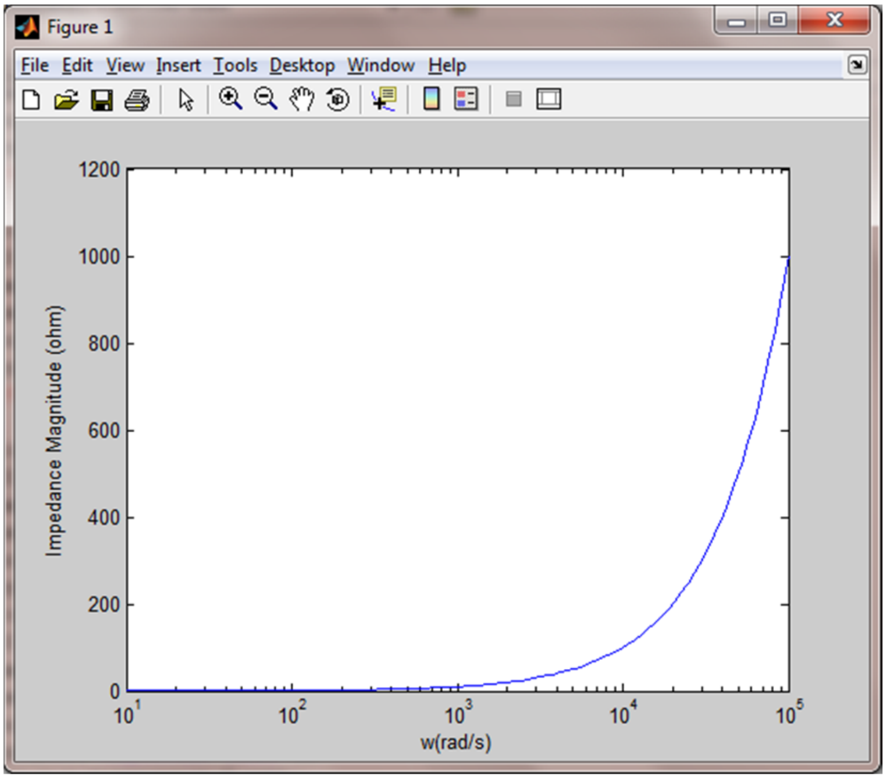
$$Z_L = j\omega L = j20\,\Omega$$
$$\Rightarrow L = \boxed{20 \text{ mH}}$$

35. (a) 2.5 Ω; (b) $50\angle 35^o$; $100\angle 35^o$

36. (a) The equivalent impedance of a 1Ω resistor in series with a 10mH inductor as a function of ω is given by,

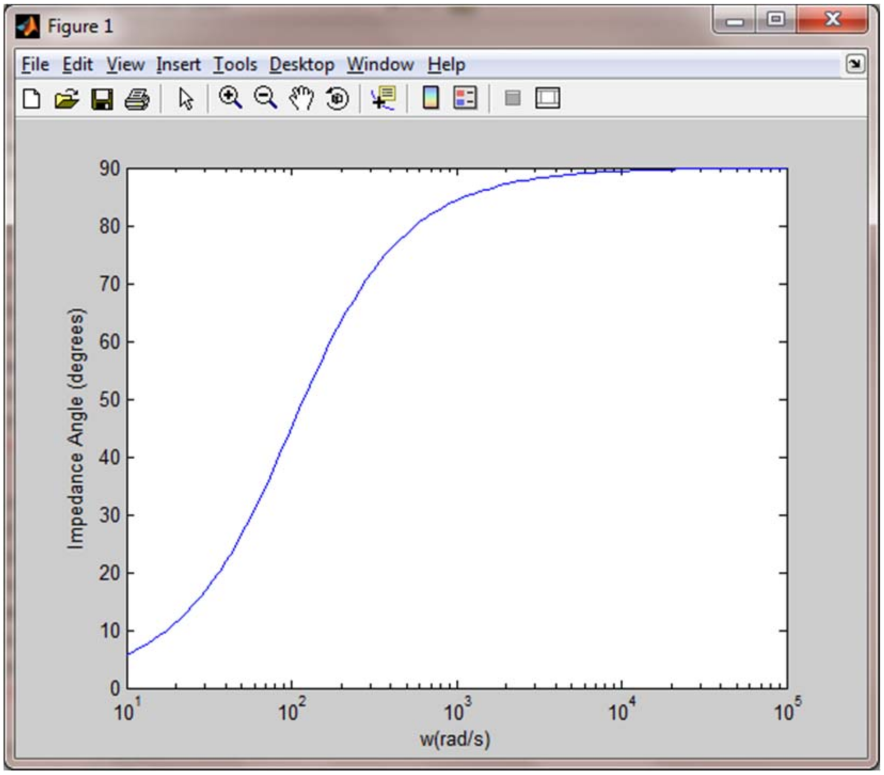
$$\mathbf{Z}_{eq} = R + j\omega L = \boxed{1 + j\omega 0.01\ \Omega}$$

(b)




```
w = logspace(1,5,100);
Z = 1+i*w*0.01;
mag = abs(Z);
semilogx(w, mag);
xlabel('w(rad/s)');
ylabel('Impedance Magnitude (ohm)');
```

(c)




```
w = logspace(1,5,100);
Z = 1+i*w*0.01;
theta = angle(Z);
theta_degrees = angledim(theta,'radians','degrees');
semilogx(w, theta_degrees);
xlabel('w(rad/s)');
ylabel('Impedance Angle (degrees)');
```

37. (a) $1001\angle -2.9^{o}\ \Omega$

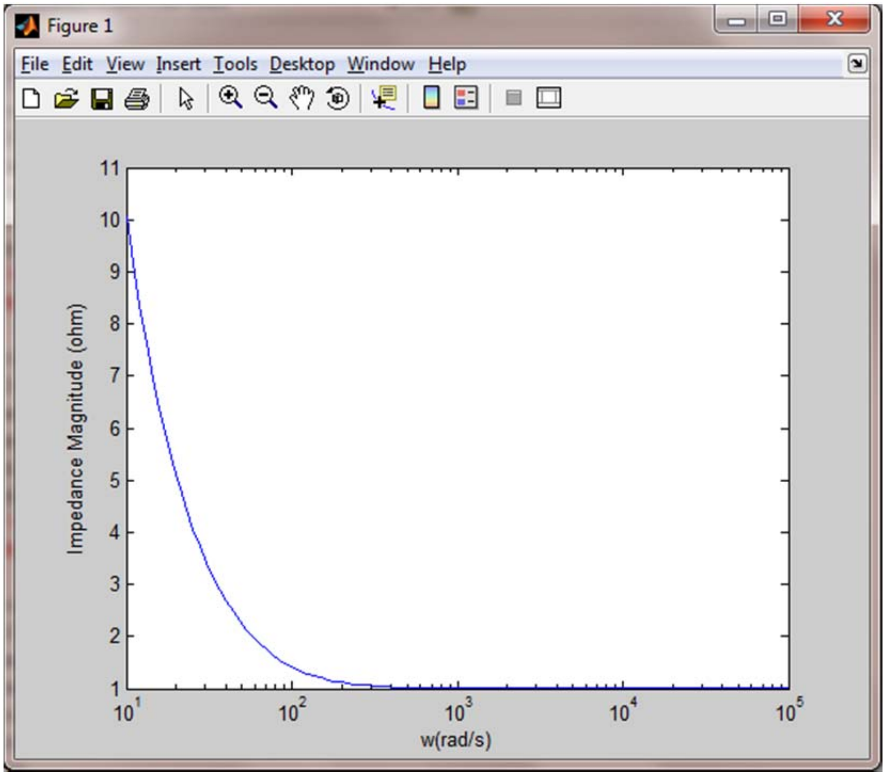
(b) $20\angle 90^{o}\ \Omega$

(c) $20\angle 88.8^{o}\ \Omega$

38. (a) The equivalent impedance of a 1Ω resistor in series with a 10mF capacitor as a function of ω is given by,

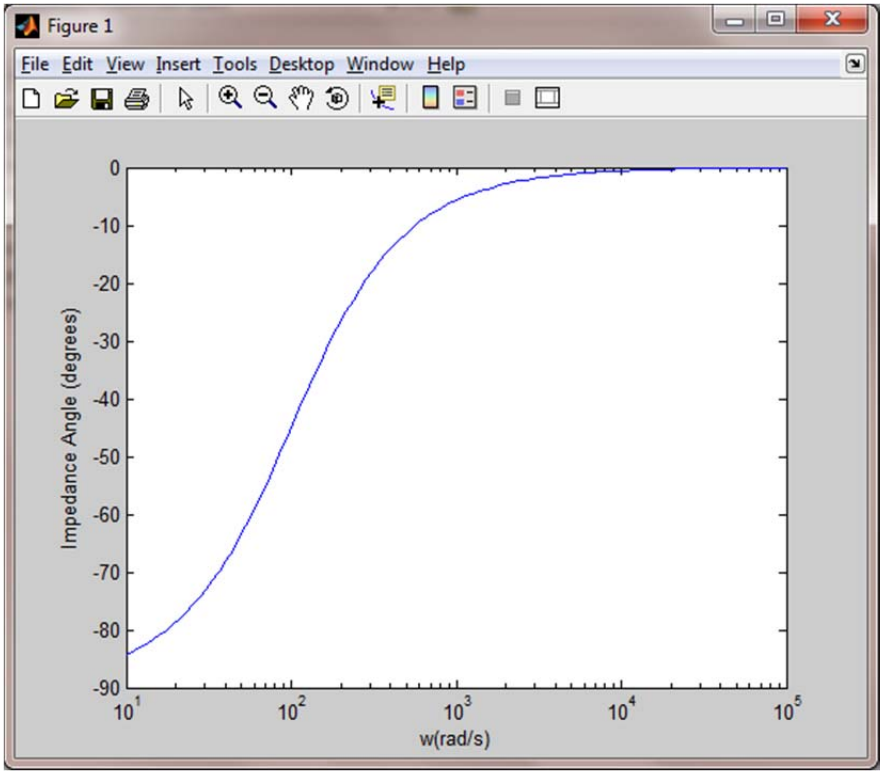
$$\mathbf{Z}_{eq} = R - \frac{j}{\omega C} = \boxed{1 - \frac{j100}{\omega}\ \Omega}$$

(b)




```
w = logspace(1,5,100);
Z = 1-i*100*w.^-1;
mag = abs(Z);
semilogx(w, mag);
xlabel('w(rad/s)');
ylabel('Impedance Magnitude (ohm)');
```

(c)




```
w = logspace(1,5,100);
Z = 1-i*100*w.^-1;
theta = angle(Z);
theta_degrees = angledim(theta,'radians','degrees');
semilogx(w, theta_degrees);
xlabel('w(rad/s)');
ylabel('Impedance Angle (degrees)');
```

39. (a) $31.2\angle -38.7^o$ mS

(b) $64.0\angle -51.3^o$ mS

(c) $20\angle 89.9^o$ S

(d) $1\angle -89.9^o$ mS

(e) $1000\angle 89.9^o$ S

40. Looking into the open terminals we see that the parallel combination of 20 mH and 55 Ω is in series with the series combination of 10 mF and 20Ω , this combination is in parallel with 25 Ω.

(a) ω = 1 rad/s

$$\mathbf{Z}_L = j\omega L = j0.02\,\Omega$$

$$\mathbf{Z}_C = -\frac{j}{\omega C} = -j100\,\Omega$$

$$\mathbf{Z}_{eq} = \frac{\left(\dfrac{55\times j0.02}{55+j0.02}+20-j100\right)\times 25}{\left(\dfrac{55\times j0.02}{55+j0.02}+20-j100\right)+25} = 22.66 - j5.19 = \boxed{23.24\angle -12.9°\,\Omega}$$

(b) ω = 10 rad/s

$$\mathbf{Z}_L = j\omega L = j0.2\,\Omega$$

$$\mathbf{Z}_C = -\frac{j}{\omega C} = -j10\,\Omega$$

$$\mathbf{Z}_{eq} = \frac{\left(\dfrac{55\times j0.2}{55+j0.2}+20-j10\right)\times 25}{\left(\dfrac{55\times j0.2}{55+j0.2}+20-j10\right)+25} = 11.74 - j2.88 = \boxed{12.08\angle -13.78°\,\Omega}$$

(c) ω = 100 rad/s

$$\mathbf{Z}_L = j\omega L = j2\,\Omega$$

$$\mathbf{Z}_C = -\frac{j}{\omega C} = -j\,\Omega$$

$$\mathbf{Z}_{eq} = \frac{\left(\dfrac{55\times j2}{55+j2}+20-j\right)\times 25}{\left(\dfrac{55\times j2}{55+j2}+20-j\right)+25} = 11.14 - j0.30 = \boxed{11.14\angle -1.54°\,\Omega}$$

41. $11.3 \angle -5.3^o\ \Omega$

42. (a) 3Ω in series with 2mH

$\mathbf{Z}_{eq} = 3 + j4 = 5\angle 53.13°\Omega$

$\mathbf{V} = \mathbf{IZ} = (3\angle -20°)(5\angle 53.13°) = \boxed{15\angle -33.13° \text{ V}}$

(b) 3Ω in series with 125μF

$\mathbf{Z}_{eq} = 3 - j4 = 5\angle -53.13°\Omega$

$\mathbf{V} = \mathbf{IZ} = (3\angle -20°)(5\angle -53.13°) = \boxed{15\angle -73.13° \text{ V}}$

(c) 3Ω, 2mH, and 125μF in series

$\mathbf{Z}_{eq} = 3 + j4 - j4 = 3\angle 0°\Omega$

$\mathbf{V} = \mathbf{IZ} = (3\angle -20°)(3) = \boxed{9\angle -20° \text{ V}}$

(d) 3Ω, 2mH and 125μF in series but ω = 4 krad/s

$\mathbf{Z}_{eq} = 3 + j8 - j2 = 6.71\angle 63.44°\Omega$

$\mathbf{V} = \mathbf{IZ} = (3\angle -20°)(6.71\angle 63.44°) = \boxed{20.13\angle -43.44° \text{ V}}$

43. (a) $30 - j0.154\ \Omega$

(b) $23.5 + j9.83\ \Omega$

(c) $30 + j0.013\ \Omega$

(d) $30 + j1.3\times10^{-5}\ \Omega$

(e) $30 + 1.3\times10^{-8}\ \Omega$

44. One method is to use the current divider rule in order to calculate i(t). In the given circuit, there are three parallel branches.

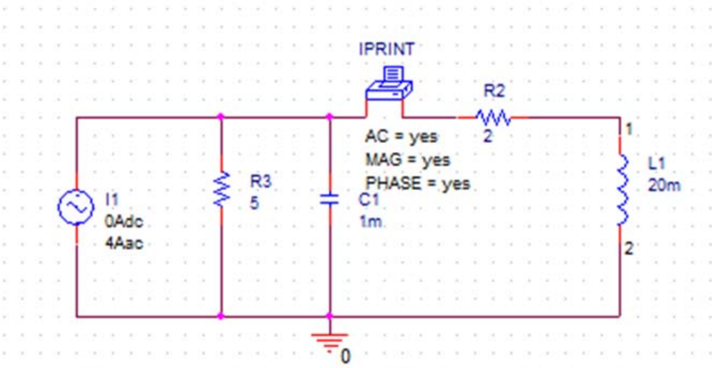
$$\mathbf{Z}_{eq} = \frac{1}{5^{-1} + (-j10)^{-1} + (2+j2)^{-1}} = 2 + j0.67 = 2.11\angle 18.52°\ \Omega$$

$$\mathbf{Z} = (2 + j2)\Omega = 2.83\angle 45°\Omega$$

$$\mathbf{I} = \mathbf{I}_s \frac{\mathbf{Z}_{eq}}{\mathbf{Z}} = \frac{(4\angle -20°)(2.11\angle 18.52°)}{2.83\angle 45°} = 2.98\angle -46.48°\ \text{A}$$

$$\boxed{\therefore i(t) = 2.98\cos(100t - 46.48°)\ \text{A}}$$

PSpice Verification:




```
FREQ        IM(V_PRINT1)IP(V_PRINT1)

 1.592E+01   2.981E+00   -4.656E+01
```

45. (a) *One possible solution*: A 1 Ω resistor in series with 1 H and 10^{-4} F.

(b) *One possible solution*: A 6.894 Ω resistor in series with 11.2 mH.

(c) *One possible solution*: A 3 Ω resistor in series with 2.5 mF.

46. One out of many possible design solutions:

(a) At $\omega = 10$ rad/s, the equivalent admittance is given as, $\mathbf{Y} = 1\ \text{S}$. We can construct this using a 1 S conductance (1Ω resistor) in parallel with an inductor L and a capacitor C such that $\omega C - \frac{1}{\omega L} = 0$. Selecting L as 5H arbitrarily yields the value of a capacitor as 2mF.

Thus, one design can be 1Ω resistor in parallel with 5H inductor and 2mF capacitor.

(b) At $\omega = 10$ rad/s, the equivalent admittance is given as,

$\mathbf{Y} = 12\angle -18°\ \text{S} = 11.4127 - j3.7082\ \text{S}$. We can construct this using a 11.4127 S conductance (87.6 mΩ resistor) in parallel with an inductor L such that

$-\frac{j}{\omega L} = -j3.7082\ \text{S}$. This yields the value of the inductor as 26.9 mH.

Thus, one design can be 87.6 mΩ resistor in parallel with 26.9 mH inductor.

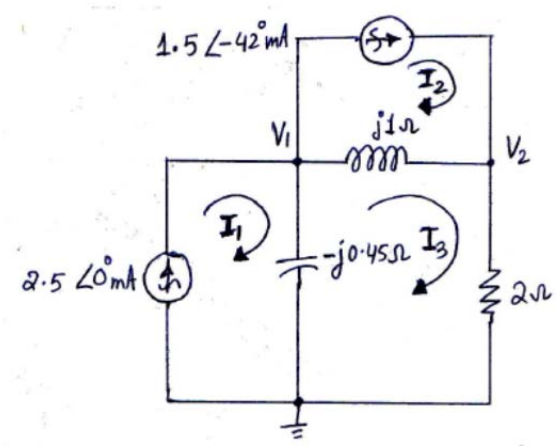
(c) At $\omega = 10$ rad/s, the equivalent admittance is given as, $\mathbf{Y} = 2 + j\ \text{mS}$. We can construct this using a 2 mS conductance (500Ω resistor) in parallel with a capacitor C such that $j\omega C = j0.001\ \text{S}$. This yields the value of the capacitor as 0.1 mF.

Thus, one design can be 500 Ω resistor in parallel with 0.1 mF capacitor.

47. **BOTH SOURCES ARE SUPPOSED TO OPERATE AT 100 rad/s**. Then,

$v_1(t) = 2.56\cos(100t + 139.2^o)$ V; $v_2(t) = 4.35\cos(100t + 138.3^o)$ V.

48. (a)



(b) In mesh 1, we have $\mathbf{I}_1 = 2.5\angle 0°$ mA .

In mesh 2, we have $\mathbf{I}_2 = 1.5\angle -42°$ mA .

In mesh 3, we have,

$$(\mathbf{I}_3 - \mathbf{I}_1)\mathbf{Z}_C + (\mathbf{I}_3 - \mathbf{I}_2)\mathbf{Z}_L + 2\mathbf{I}_3 = 0$$

$$\mathbf{I}_3 = \frac{\mathbf{I}_1\mathbf{Z}_C + \mathbf{I}_2\mathbf{Z}_L}{2 + \mathbf{Z}_C + \mathbf{Z}_L} = \frac{2.5\times 10^{-3}\times(-j0.4545) + (1.1147 - j1.0037)\times 10^{-3}\times j}{2 - j0.4545 + j}$$

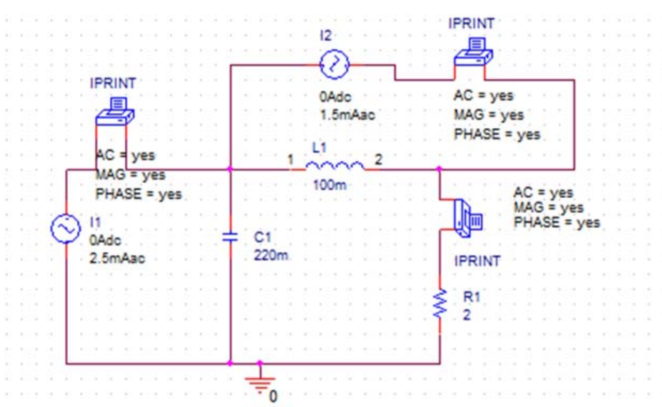
$$= \frac{1.004\angle -1.23°}{2.073\angle 15.25°} = 0.4843\angle -16.48° \text{ mA}$$

$$\therefore i_1(t) = 2.5\cos 10t \text{ mA}$$

$$\therefore i_2(t) = 1.5\cos(10t - 42°) \text{ mA}$$

$$\therefore i_3(t) = 0.4843\cos(10t - 16.48°) \text{ mA}$$

Pspice Verification:



```
FREQ        IM(V_PRINT1)IP(V_PRINT1)

1.592E+00   4.843E-04  -1.649E+01
*** 06/16/12 23:24:09 ******* PSpice Lite (April 2011) ******* ID# 10813 ****
** Profile: "SCHEMATIC1-prob10_48"  [ C:\ORCAD\ORCAD_16.5_LITE\examples\prob1(

****     AC ANALYSIS                     TEMPERATURE =   27.000 DEG C

******************************************************************************

FREQ        IM(V_PRINT2)IP(V_PRINT2)

1.592E+00   2.500E-03   2.120E-11
*** 06/16/12 23:24:09 ******* PSpice Lite (April 2011) ******* ID# 10813 ****
** Profile: "SCHEMATIC1-prob10_48"  [ C:\ORCAD\ORCAD_16.5_LITE\examples\prob1(

****     AC ANALYSIS                     TEMPERATURE =   27.000 DEG C

******************************************************************************

FREQ        IM(V_PRINT3)IP(V_PRINT3)

1.592E+00   1.500E-03  -4.200E+01
```

49. $v_1(t) = 928\cos(10t - 86.1^o)\ \mu V$; $v_2(t) = 969\cos(10t - 16.5^o)\ \mu V$.

50. In the circuit given by Fig. 10.60, we have,

$$\mathbf{V}_1 - \mathbf{I}_1(j30) = \mathbf{V}_2 + 55(\mathbf{I}_1 - \mathbf{I}_2) \text{ and}$$
$$\mathbf{V}_1 - \mathbf{I}_1(j30) = \mathbf{V}_3 + \mathbf{I}_2(-j20)$$

On simplification. we get,

$$\mathbf{I}_1(55 + j30) - 55\mathbf{I}_2 = -2.2635 + j9.848$$
$$\mathbf{I}_1(j30) - \mathbf{I}_2(j20) = -0.1045 + j9.0665$$

Solving for I_1 and I_2, we get,

$$\mathbf{I}_1 = 0.6247 + j0.3339 = \boxed{0.71\angle 28.12° \text{ A}}$$
$$\mathbf{I}_2 = 0.4838 + j0.4956 = \boxed{0.69\angle 45.69° \text{ A}}$$

51. $0.809\angle -4.8^{o}$

52. Using phasor domain, in mesh 1, we get,

$$2\mathbf{I}_1 + j10(\mathbf{I}_1 - \mathbf{I}_2) = 2.5\angle 9°$$

$$\Rightarrow \mathbf{I}_1(2 + j10) - \mathbf{I}_2(j10) = 2.4692 + j0.3911 \qquad [1]$$

In mesh 2, we get,

$$j10(\mathbf{I}_2 - \mathbf{I}_1) - j0.3\mathbf{I}_2 + 5\mathbf{I}_1 = 0$$

$$\Rightarrow \mathbf{I}_1(5 - j10) + \mathbf{I}_2(j9.7) = 0 \qquad [2]$$

On solving eqns [1] and [2] we get,

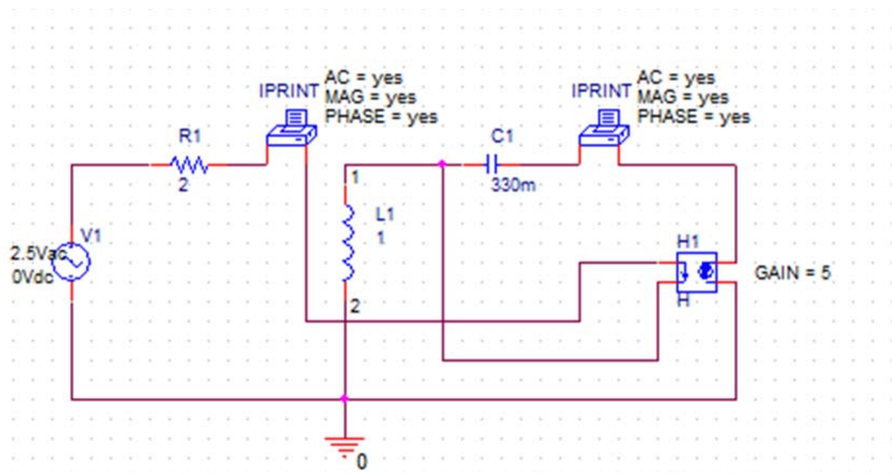
$$\mathbf{I}_1 = 0.3421 + j0.0695 = 0.35\angle 11.48° \text{ A}$$

$$\mathbf{I}_2 = 0.3169 + j0.2479 = 0.4\angle 38.04° \text{A}$$

$$\therefore i_1(t) = 0.35\cos(10t + 11.48°) \text{ A and}$$

$$i_2(t) = 0.4\cos(10t + 38.04°) \text{ A}$$

Pspice verification:



```
FREQ        IM(V_PRINT1)IP(V_PRINT1)

 1.592E+00   3.490E-01   1.150E+01
*** 06/17/12 14:13:22 ******* PSpice Lit
** Profile: "SCHEMATIC1-prob10_52"  [ C:

****     AC ANALYSIS

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FREQ        IM(V_PRINT2)IP(V_PRINT2)

 1.592E+00   4.024E-01   3.807E+01
```

53. $2.73\angle 152^{o}$ A

54. Using node voltage analysis in phasor domain, we get the nodal equations as,

$$\mathbf{I}_1 + \frac{\mathbf{V}_1}{j2} + \frac{(\mathbf{V}_1 - \mathbf{V}_2)}{-j4} + \frac{(\mathbf{V}_1 - \mathbf{V}_2)}{1 + j3.8} = 0 \qquad [1]$$

$$\mathbf{I}_2 - \frac{\mathbf{V}_2}{2} + \frac{(\mathbf{V}_1 - \mathbf{V}_2)}{-j4} + \frac{(\mathbf{V}_1 - \mathbf{V}_2)}{1 + j3.8} = 0 \qquad [2]$$

$$\mathbf{I}_1 = 15\angle 0^\circ = 15A$$

$$\mathbf{I}_2 = 25\angle 131^\circ = -16.4015 + j18.8677A$$

On simplifying the equations [1] and [2], we get,

$$\mathbf{V}_1(0.0648 - j0.4961) + \mathbf{V}_2(-0.0648 - j0.0039) = -15$$

$$\mathbf{V}_1(0.0648 + j0.0039) + \mathbf{V}_2(-0.5648 - j0.0039) = -16.4015 + j18.8677$$

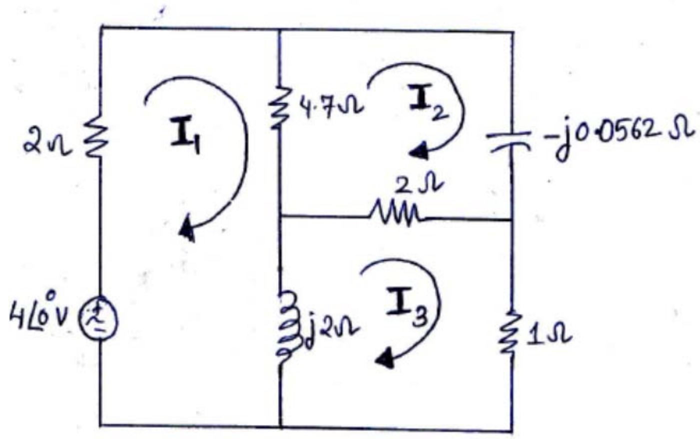
$$\mathbf{V}_2 = -29.5221 + j29.7363 = \boxed{41.9\angle 134.8^\circ \text{ V}}$$

Matlab Verification:

```
>> syms v1 v2;
eqn1 = (15+v1/(2i)+(v1-v2)/(-4i)+(v1-v2)/(1+3.8i));
eqn2 = (-16.4015+18.8677i+(v1-v2)/(1+3.8i)+(v1-v2)/(-4i)-v2/2);
answer=solve(eqn1, eqn2, 'v1', 'v2');
digits(4);
V2 = vpa(answer.v2)
V2 = -29.52+29.74*i
```

55. $1.14\cos(20t + 12^{o})$ V

56.



Using phasor domain, in mesh 1, we get,

$$2\mathbf{I}_1 + 4.7(\mathbf{I}_1 - \mathbf{I}_2) + j2(\mathbf{I}_1 - \mathbf{I}_2) = 4$$

$$\Rightarrow (6.7 + j2)\mathbf{I}_1 - 4.7\mathbf{I}_2 - j2\mathbf{I}_3 = 4 \qquad [1]$$

In mesh 2, we get,

$$4.7(\mathbf{I}_2 - \mathbf{I}_1) - j0.0562\mathbf{I}_2 + 2(\mathbf{I}_2 - \mathbf{I}_3) = 0$$

$$\Rightarrow -4.7\mathbf{I}_1 + (6.7 - j0.0562)\mathbf{I}_2 - 2\mathbf{I}_3 = 0 \qquad [2]$$

In mesh 3, we get,

$$j2(\mathbf{I}_3 - \mathbf{I}_1) + 2(\mathbf{I}_3 - \mathbf{I}_2) + \mathbf{I}_3 = 0$$

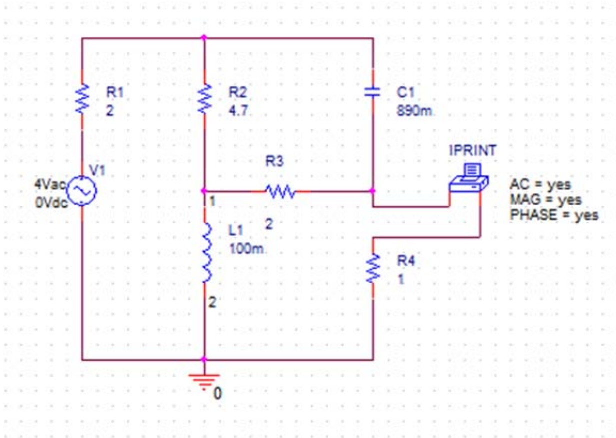
$$\Rightarrow -j2\mathbf{I}_1 - 2\mathbf{I}_2 + (3 + j2)\mathbf{I}_3 = 0 \qquad [3]$$

Here, $\mathbf{I}_x = \mathbf{I}_3$. On solving we get,

$$\mathbf{I}_x = \mathbf{I}_3 = 1.1104 + j0.2394 = 1.136\angle 12.16° \text{ A}$$

$$\boxed{\therefore i_x(t) = 1.136\cos(20t + 12.16°) \text{ A}}$$

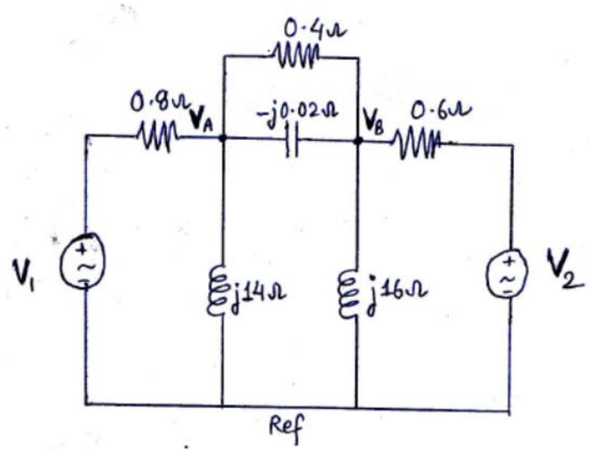
Pspice Verification:



FREQ	IM(V_PRINT1)	IP(V_PRINT1)
3.183E+00	1.136E+00	1.216E+01

57. $155\cos(14t + 37^{o})$ A; $82.2\cos(14t = 101^{o})$ A; $42.0\cos(14t = 155^{o})$ A; $71.7\cos(14t + 50^{o})$ A.

58.



Using node voltage analysis in phasor domain, we get the nodal equations as,

At node A,

$$\frac{(\mathbf{V}_1-\mathbf{V}_A)}{0.8}-\frac{(\mathbf{V}_A-\mathbf{V}_B)}{0.4}-\frac{(\mathbf{V}_A-\mathbf{V}_B)}{-j0.02}-\frac{\mathbf{V}_A}{j14}=0 \qquad [1]$$

At node B,

$$\frac{(\mathbf{V}_2-\mathbf{V}_B)}{0.6}+\frac{(\mathbf{V}_A-\mathbf{V}_B)}{0.4}+\frac{(\mathbf{V}_A-\mathbf{V}_B)}{-j0.02}-\frac{\mathbf{V}_B}{j16}=0 \qquad [2]$$

Given,

$$\mathbf{V}_1=0.009\angle 0.5°=0.009+j0.000078\text{ V}$$
$$\mathbf{V}_2=0.004\angle 1.5°=0.004+j0.0001\text{ V}$$

On simplifying the nodal equations [1] and [2], we get,

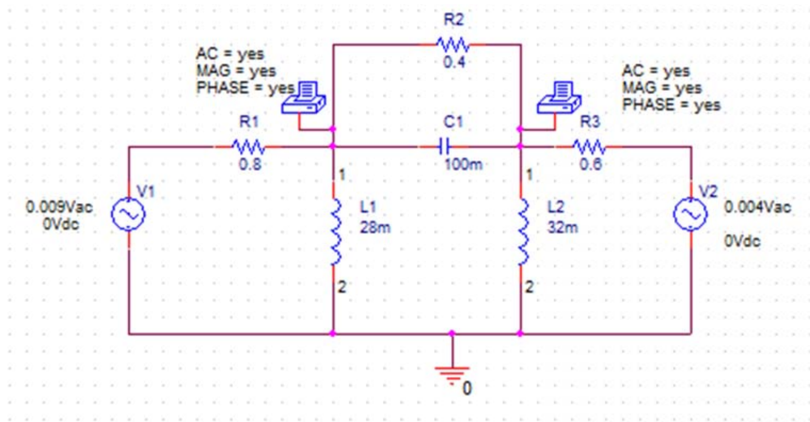
$$\mathbf{V}_A(-3.75-j49.9286)+\mathbf{V}_B(2+j50)=-\frac{0.009+j0.000078}{0.8}$$
$$\mathbf{V}_A(2+j50)+\mathbf{V}_2(-4.1667-j49.9375)=-\frac{0.004+j0.0001}{0.6}$$

and on solving, we get,

$$\mathbf{V}_A=0.00613+j0.00033=0.00613\angle 3.09°\text{ V}$$
$$\mathbf{V}_B=0.00612+j0.00040=0.00613\angle 3.75°\text{ V}$$

$$\therefore v_A=0.00613\cos(500t+3.09°)\text{ V and}$$
$$v_B=0.00613\cos(500t+3.75°)\text{ V}$$

Pspice Verification:




```
FREQ        VM(N00227)  VP(N00227)

 7.957E+01   6.138E-03   3.122E+00
*** 06/18/12 09:52:20 ******* PSpice Li
** Profile: "SCHEMATIC1-prob10_58"  [ C

****     AC ANALYSIS

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FREQ        VM(N00296)  VP(N00296)

 7.957E+01   6.136E-03   3.787E+00
```
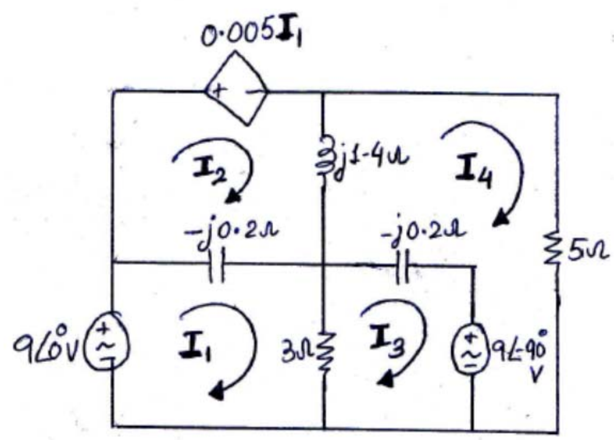

59. (a)

$$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{-R_f}{\dfrac{R_f - j/\omega C_1}{A} - \dfrac{j}{\omega C_1}}$$

(b)

$$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{-\omega R_f C_1}{\frac{1}{A}\left[\omega R_f C_1 + (R_f C_f - j)\right] + (\omega R_f C_f - j)}$$

60.



Using phasor domain, in mesh 1, we get,

$$(-j0.2)(\mathbf{I}_1-\mathbf{I}_2)+3(\mathbf{I}_1-\mathbf{I}_3)=9$$

$$\Rightarrow(3-j0.2)\mathbf{I}_1+j0.2\mathbf{I}_2-3\mathbf{I}_3=9 \qquad [1]$$

In mesh 2, we get,

$$0.005\mathbf{I}_1+j1.4(\mathbf{I}_2-\mathbf{I}_3)-j0.2(\mathbf{I}_2-\mathbf{I}_1)=0$$

$$\Rightarrow(0.005+j0.2)\mathbf{I}_1+j1.2\mathbf{I}_2-j1.4\mathbf{I}_4=0 \qquad [2]$$

In mesh 3, we get,

$$-j0.2(\mathbf{I}_3-\mathbf{I}_4)+3(\mathbf{I}_3-\mathbf{I}_1)+\mathbf{I}_3-j9=0$$

$$\Rightarrow-3\mathbf{I}_1+(3-j0.2)\mathbf{I}_3+j0.2\mathbf{I}_4=j9 \qquad [3]$$

In mesh 4, we get,

$$5\mathbf{I}_4-j0.2(\mathbf{I}_4-\mathbf{I}_3)+j1.4(\mathbf{I}_4-\mathbf{I}_2)=-j9$$

$$\Rightarrow-j1.4\mathbf{I}_2+j0.2\mathbf{I}_3+\mathbf{I}_4(5+j1.2)=-j9 \qquad [4]$$

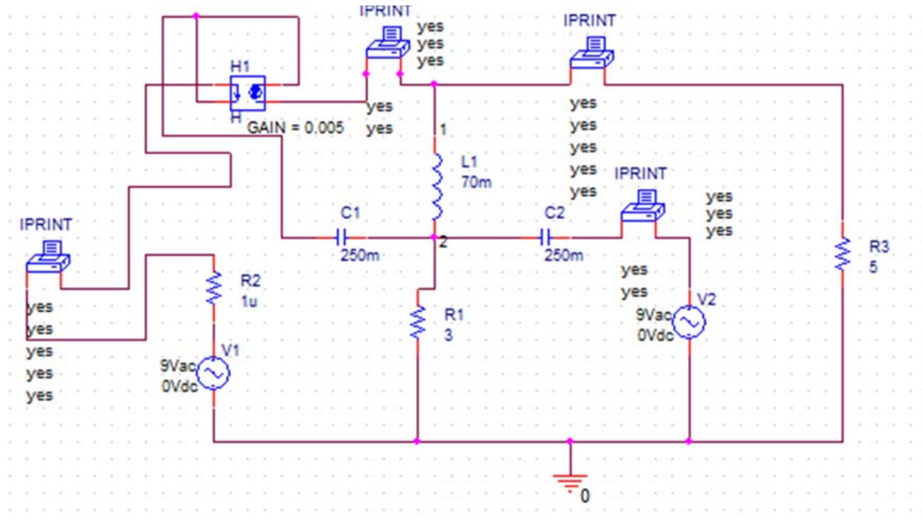
On solving we get,

$$\mathbf{I}_1=-18.33+j20=27.13\angle132.5°\text{ A}$$
$$\mathbf{I}_2=5.092-j3.432=6.14\angle-33.98°\text{ A}$$
$$\mathbf{I}_3=-19.76+j21.55=29.24\angle132.5°\text{ A}$$
$$\mathbf{I}_4=1.818-j0.02=1.82\angle-0.63°\text{ A}$$

Therefore,

$$i_1(t) = 27.13\cos(20t + 132.5°)\ \text{A}$$
$$i_2(t) = 6.14\cos(20t - 33.98°)\ \text{A}$$
$$i_3(t) = 29.24\cos(20t + 132.5°)\ \text{A}$$
$$i_4(t) = 1.82\cos(20t - 0.63°)\ \text{A}$$

Pspice Verification:




```
 FREQ        IM(V_PRINT1)IP(V_PRINT1)IR(V_PRINT1)II(V_PRINT1)

  3.183E+00   2.712E+01   1.325E+02  -1.833E+01   1.999E+01
*** 06/21/12 13:48:06 ******* PSpice Lite (April 2011) ******* I
** Profile: "SCHEMATIC1-prob10_60_old"  [ C:\ORCAD\ORCAD_16.5_LI

****     AC ANALYSIS                     TEMPERATURE =   27.000

******************************************************************

 FREQ        IM(V_PRINT3)IP(V_PRINT3)IR(V_PRINT3)II(V_PRINT3)

  3.183E+00   3.052E+01   1.350E+02  -2.158E+01   2.157E+01
```

```
 FREQ        IM(V_PRINT4)IP(V_PRINT4)IR(V_PRINT4)II(V_PRINT4)

  3.183E+00   1.818E+00  -6.301E-01   1.818E+00  -2.000E-02
*** 06/21/12 13:48:06 ******* PSpice Lite (April 2011) *******
** Profile: "SCHEMATIC1-prob10_60_old"  [ C:\ORCAD\ORCAD_16.5_

****     AC ANALYSIS                      TEMPERATURE =   27.0

***************************************************************

 FREQ        IM(V_PRINT5)IP(V_PRINT5)IR(V_PRINT5)II(V_PRINT5)

  3.183E+00   6.141E+00  -3.398E+01   5.092E+00  -3.432E+00
```

61. Left hand source contributions: $5.58\angle -91.8^{o}$ V; $1.29\angle -75.9^{o}$ V

Right hand source contributions: $1.29\angle -75.9^{o}$ V; $9.08\angle -115^{o}$ V

62. Using node voltage analysis in phasor domain, we get the nodal equations as,

At node 1,

$$\mathbf{I}_1 - \mathbf{I}_2 - \frac{(\mathbf{V}_1 - \mathbf{V}_2)}{-j5} - \frac{\mathbf{V}_1}{j3} = 0 \qquad [1]$$

At node 2,

$$\mathbf{I}_2 + \frac{(\mathbf{V}_1 - \mathbf{V}_2)}{-j5} - \frac{\mathbf{V}_2}{2} = 0 \qquad [2]$$

$$\mathbf{I}_1 = 33\times10^{-3}\angle 3^\circ \text{ mA}$$
$$\mathbf{I}_2 = 51\times10^{-3}\angle -91^\circ \text{ mA}$$

On simplifying the nodal equations [1] and [2], we get,

$$\mathbf{V}_1(j0.1333) + \mathbf{V}_2(-j0.2) = \mathbf{I}_2 - \mathbf{I}_1$$
$$\mathbf{V}_1(j0.2) + \mathbf{V}_2(-0.5 - j0.2) = -\mathbf{I}_2$$

and on solving these we get,

$$\mathbf{V}_1 = -0.4694 - j0.1513 = 493.18\angle -162.14^\circ \text{ mV}$$
$$\mathbf{V}_2 = -0.0493 - j0.27 = 274.46\angle -100.34^\circ \text{ mV}$$

63. $7.995\cos(40t + 2.7^{o}) + 0.343\cos(30t + 90.1^{o})$ mV;

$7.995\cos(40t + 2.4^{o}) + 1.67\cos(30t - 180^{o})$ mV

64. Calculate Thevenin Impedance

$$Z_{thevenin} = j2 + 4\angle 10° = 3.94 + j2.69 = \boxed{4.77\angle 34.32°\ \Omega}$$

Calculate Thevenin voltage:

$$\mathbf{V}_1 = (1.5\angle 24°)(j2) = (1.5\angle 24°)(2\angle 90°) = 3\angle 114°\ \text{V}$$

$$\mathbf{V}_2 = -(2\angle 38°)(4\angle 10°) = -8\angle 48°\ \text{V}$$

$$\mathbf{V}_{TH} = \mathbf{V}_1 - \mathbf{V}_2 = (3\angle 114°) + (8\angle 48°) = 4.13 + j8.68 = \boxed{9.61\angle 64.55°\ \text{V}}$$

Current $\mathbf{I}_1$ through the impedance (2-j2) **Ω** is found as:

$$\mathbf{Z}_{total} = 3.94 + j2.69 + 2 - j2 = 5.94 + j0.69 = 5.97\angle 6.626°\ \Omega$$

$$\mathbf{I}_1 = \frac{\mathbf{V}_{TH}}{\mathbf{Z}_{total}} = \frac{9.61\angle 64.55°}{5.97\angle 6.63°} = \boxed{1.6\angle 57.92°\ \text{A}}$$

65. $1.56\angle 27.8^{\circ}$ A

66. (a) Thevenin Equivalent

$$\mathbf{Z}_{thevenin} = (12 - j34) \| (j10) = \frac{340 + j120}{12 - j24} = 1.67 + j13.33 = \boxed{13.43\angle 82.86°\ \Omega}$$

Using current divider to find the current through j10 branch,

$$\mathbf{I} = \frac{\mathbf{I}_s.\mathbf{Z}_{eq}}{\mathbf{Z}} = \frac{22\angle 30°(340 + j120)}{12 - j24}$$

$$= 29.55\angle 22.87°\ \text{A}$$

$$\mathbf{V}_{TH} = \mathbf{V}_{oc} = (29.55\angle 22.87°)(10\angle 90°) = \boxed{295.46\angle 112.87°\ \text{V}}$$

(b) Norton Equivalent

$$\mathbf{Z}_{norton} = \mathbf{Z}_{thevenin} = 1.67 + j13.33 = \boxed{13.43\angle 82.86°\ \Omega}$$

$$\mathbf{I}_N = \mathbf{I}_{sc} = 22\angle 30°\ A$$

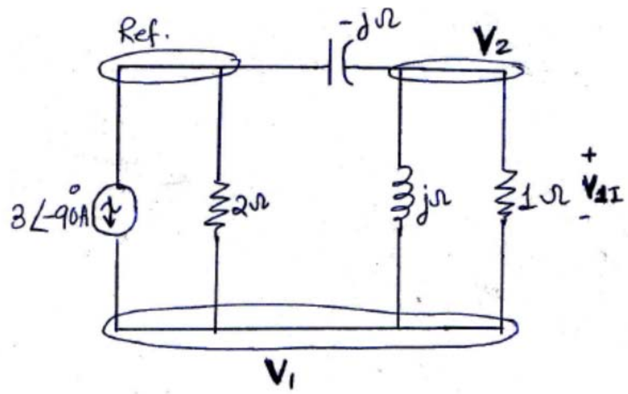
(c) Current flowing from a to b

$$\mathbf{Z}_{total} = 1.67 + j13.33 + 7 - j2 = 8.67 + j11.33 = \boxed{14.26\angle 52.57°\ \Omega}$$

$$\mathbf{I}_1 = \frac{\mathbf{V}_{TH}}{\mathbf{Z}_{total}} = \frac{295.46\angle 112.87°}{14.26\angle 52.57°} = \boxed{20.72\angle 60.3°\ \text{A}}$$

67. (b) $259\angle 84.5^{o}\ \mu V$

68. Let us first consider the current source only.



Using node voltage analysis in phasor domain, we get the nodal equations as,

At node 1,

$$\mathbf{I}_S + \frac{(\mathbf{V}_2 - \mathbf{V}_1)}{1} = \frac{\mathbf{V}_1}{2} + \frac{(\mathbf{V}_1 - \mathbf{V}_2)}{j1}$$

$$\Rightarrow \mathbf{V}_1(1.5 - j) + \mathbf{V}_2(-1 + j) = -j3 \qquad [1]$$

At node 2,

$$\frac{(\mathbf{V}_1 - \mathbf{V}_2)}{-j1} - \frac{\mathbf{V}_2}{-j} = \frac{(\mathbf{V}_2 - \mathbf{V}_1)}{1}$$

$$\Rightarrow \mathbf{V}_1(1 - j) - \mathbf{V}_2 = 0 \qquad [2]$$

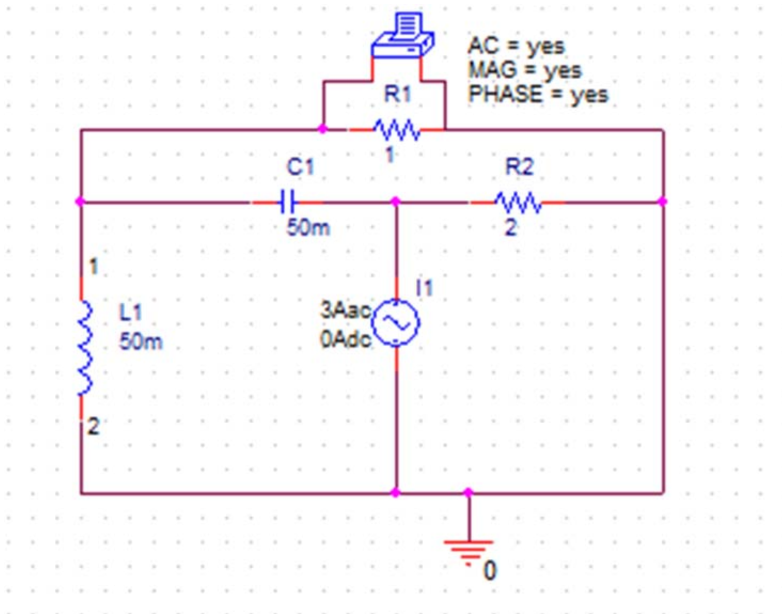
$$\mathbf{I}_S = 3\angle -90° A$$

On solving the nodal equations [1] and [2], we get,

$$\mathbf{V}_{1I} = -0.9231 - j1.3846 \text{ V}$$
$$\mathbf{V}_{2I} = -2.3077 - j0.4615 \text{ V}$$
$$\mathbf{V}_1 = \mathbf{V}_{2I} - \mathbf{V}_{1I} = -1.3846 + j0.9231 = 1.66\angle 146.3° \text{ V}$$

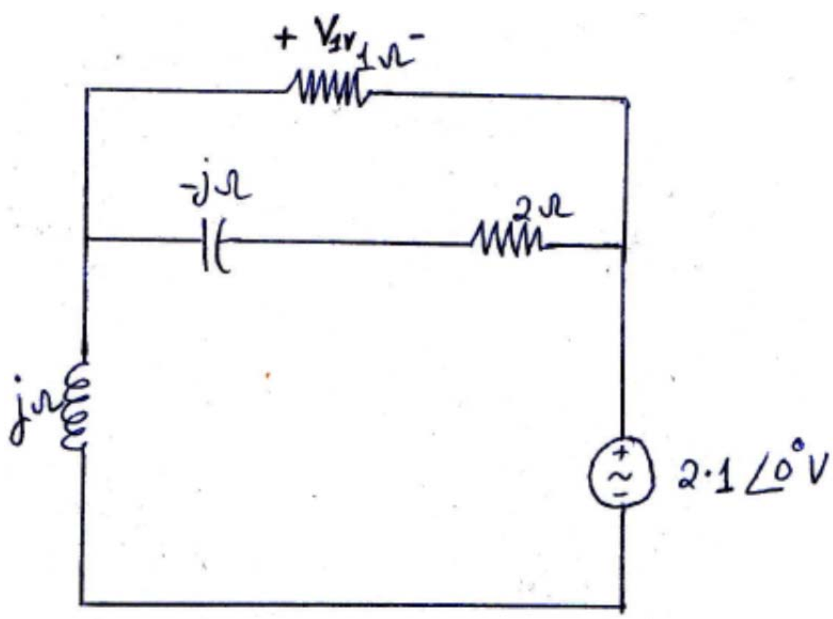
$$v_{1I}(t) = 1.66\cos(20t + 146.3°) \text{ V}$$

Pspice Verification:




```
FREQ          VM(N00166,0)VP(N00166,0)

3.183E+00     1.664E+00     1.463E+02
```

Now let us consider the voltage source only.



Then the current flowing in the circuit will be,

$$\mathbf{I}_s = \frac{\mathbf{V}_s}{\mathbf{Z}} = \frac{2.1}{\frac{2-j}{3-j}+j} = 1.1307 - j1.4538 \text{ A}$$

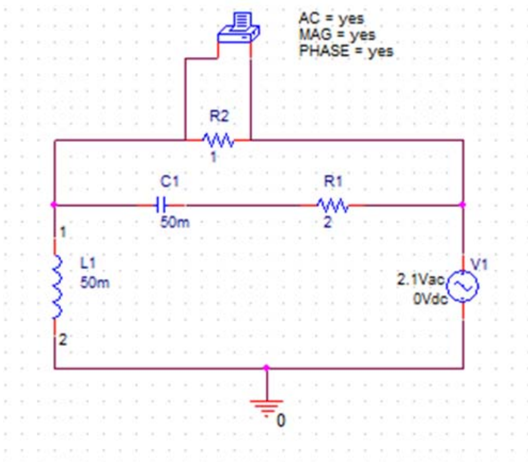
Using current divider to find the current through 1Ω branch,

$$\mathbf{I}_1 = \frac{\mathbf{I}_s.\mathbf{Z}_{eq}}{\mathbf{Z}_R} = (1.1307 - j1.4538)(0.7 - j0.1)$$

$$\mathbf{V}_{1\text{V}} = -\mathbf{I}_1.\mathbf{Z}_R = -0.6461 + j1.1307 = 1.3\angle 119.74° \text{ V}$$

$$\boxed{v_{1\text{V}}(t) = 1.3\cos(20t + 119.74°) \text{ V}}$$

Pspice Verification:



FREQ	VM(N00211,N00222)	VP(N00211,N00222)
3.183E+00	1.302E+00	1.197E+02

69. (a) $24\cos^2(20t - 163^o)$ W

70. Using phasor analysis, we get the open circuit voltage as,

$$\mathbf{V}_{oc} = 1\angle 0° \text{ V}$$

For finding the short circuit current through terminal a-b, we can apply KVL,

$$1\angle 0° = -j\left(0.25\mathbf{I}_N\left(j2\right)+\mathbf{I}_N\right)+j2\mathbf{I}_N = \left(0.5+j\right)\mathbf{I}_N$$

$$\mathbf{I}_N = \frac{1\angle 0°}{\left(0.5+j\right)} = 0.4 - j0.8 = \boxed{0.89\angle -63.43° \text{ A}}$$

Now for finding the equivalent impedance,

$$\mathbf{Z}_N = \frac{\mathbf{V}_{OC}}{\mathbf{I}_N} = 0.5 + j\,\Omega$$

For a parallel combination of a resistor and a capacitor or an inductor,

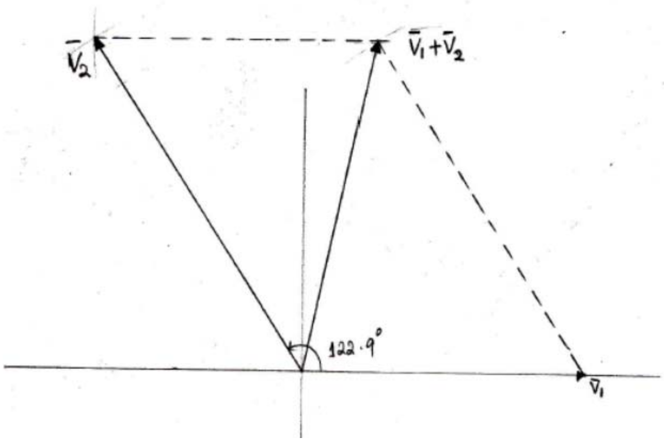
$$\mathbf{Z}_{eq} = \frac{1}{R^{-1}+(jX)^{-1}} = 0.5 + j$$

$\Rightarrow \boxed{R = \frac{1}{0.4} = 2.5\,\Omega}$ and $X = \frac{1}{0.8} = 1.25$ from which at $\omega = 1$ rad / s, we get,

the value of $\boxed{L = 1.25\ H}$

71. (b) I_S leads I_R by 83^o; I_C by -7^o; I_x by 146^o

72. Taking 50 V = 1 inch, from the figure, we get the angle as ±122.9º. (The figure below shows for the angle +122.9° only.)



Analytical Solution: On solving,

$$|100+140\angle\alpha|=120$$

$$|100+140\cos\alpha+j140\sin\alpha|=120$$

$$\alpha=\pm 122.88°$$

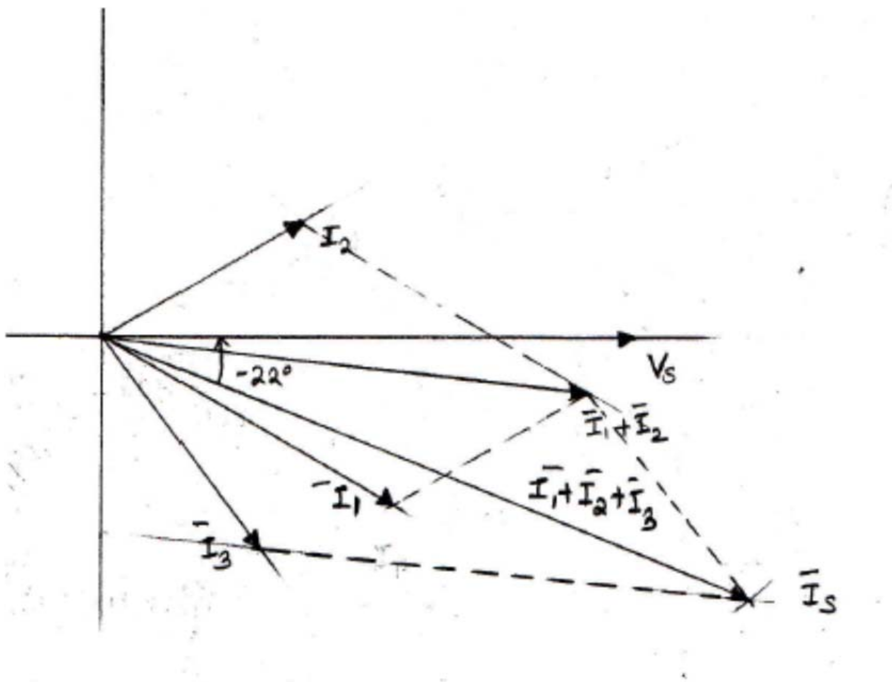
73. (a) $\mathbf{V}_R = 51.2\angle -140^o$ V; $\mathbf{V}_L = 143\angle 13^o$ V; $\mathbf{I}_L = 57\angle -85^o$ A; $\mathbf{I}_C = 51.2\angle -50^o$ A; $\mathbf{I}_R = 25.6\angle 26^o$ A

74. (a) $\mathbf{V}_S = 120\angle 0°$ V

$\mathbf{Z}_1 = 40\angle 30°\ \Omega$
$\mathbf{Z}_2 = 50 - j30 = 58.31\angle -30.96°\ \Omega$
$\mathbf{Z}_3 = 30 + j40 = 50\angle 53.13°\ \Omega$

$$\mathbf{I}_1 = \frac{\mathbf{V}_S}{\mathbf{Z}_1} = \frac{120\angle 0°}{40\angle 30°} = 3\angle -30°\text{ A}$$
$$\mathbf{I}_2 = \frac{\mathbf{V}_S}{\mathbf{Z}_2} = \frac{120\angle 0°}{58.31\angle -30.96°} = 2.05\angle -30.96°\text{ A}$$
$$\mathbf{I}_3 = \frac{\mathbf{V}_S}{\mathbf{Z}_3} = \frac{120\angle 0°}{50\angle 53.13} = 2.4\angle -53.13°\text{ A}$$

(b) Here the scale is : 50V = 1 inch and 2A = 1 inch.

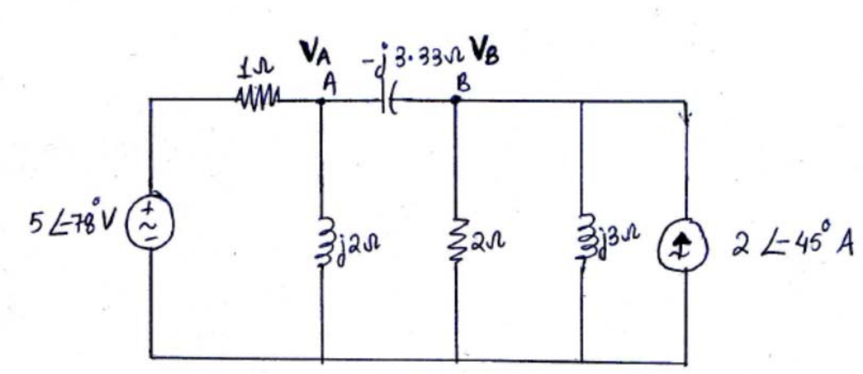


(c) From the graph, we find that,

$\mathbf{I}_S = 6.2\angle -22°$ A

75. (b) $0.333\angle 124^{o}$

76. (a)



(b) Thevenin Impedance

$$\mathbf{Z}_{TH} = (1 \| j2) + (2 \| j3)\,\Omega$$

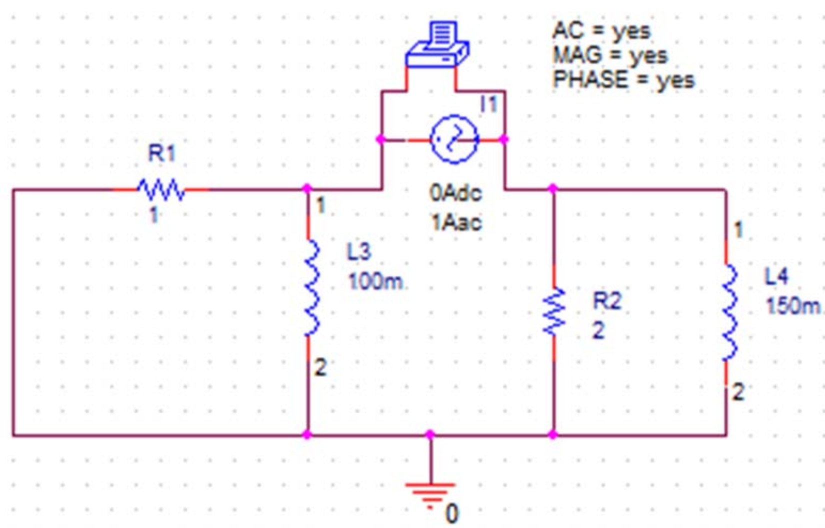
$$= \frac{j2}{1+j2} + \frac{j6}{2+j3}$$

$$= \frac{-18+j10}{-4+j7}$$

$$= \frac{20.6\angle 150.94°}{8.06\angle 119.74°}$$

$$= \boxed{2.55\angle 31.2°\,\Omega}$$

Pspice Verification:



```
FREQ          VM(N00233,N00263)VP(N00233,N00263)

 3.183E+00    2.554E+00    3.120E+01
```

Thevenin voltage:

In order to find the thevenin voltage, after removing the capacitor and on applying node voltage method, we can write the nodal equations as,

At node A,

$$\frac{5\angle -78° - \mathbf{V}_{A'}}{1} = \frac{\mathbf{V}_{A'}}{j2} \qquad [1]$$

At node B,

$$\frac{4\angle -45° - \mathbf{V}_{B'}}{2} = \frac{\mathbf{V}_{B'}}{j3} \qquad [2]$$

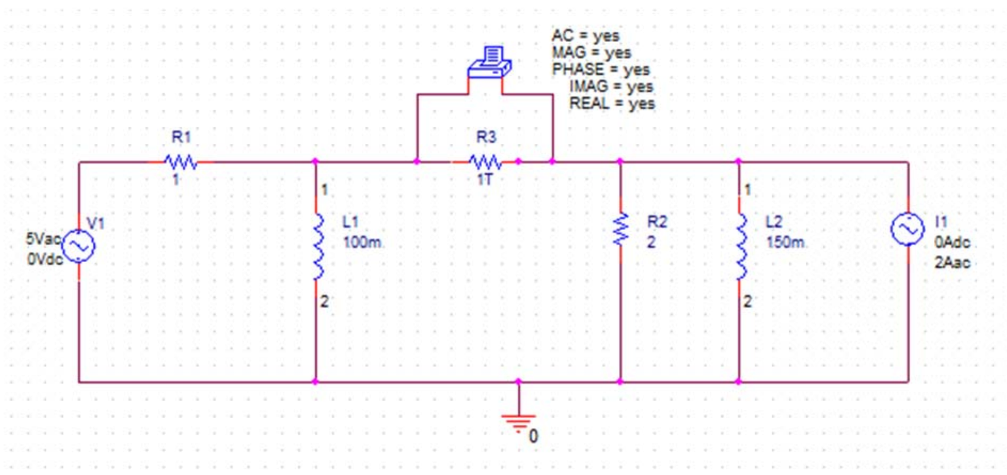
Solving the nodal equations [1] and [2], we get,

$\mathbf{V}_{A'} = 4.472\angle -51.43°$ V and

$\mathbf{V}_{B'} = 3.328\angle -11.31°$ V

$$\mathbf{V}_{TH} = \mathbf{V}_{A'} - \mathbf{V}_{B'}$$
$$= 4.472\angle -51.43° - 3.328\angle -11.31°$$
$$= -0.4752 - j2.8437$$
$$= \boxed{2.88\angle -99.49° \text{ V}}$$

Pspice Verification:



```
FREQ        VM(N00225,N00247)VP(N00225,N00247)VR(N00225,N00247)VI(N00225,N00247)

 3.183E+00   2.884E+00   -9.949E+01   -4.756E-01   -2.844E+00
```

Calculate $v_c(t)$:

$$\mathbf{Z}_c = -j3.33 = 3.33\angle -90°\ \Omega$$
$$\mathbf{Z}_{total} = 2.18 - j2.01 = 2.96\angle -42.67°\ \Omega$$
$$\mathbf{V}_c = \frac{\mathbf{V}_{TH} \times \mathbf{Z}_c}{\mathbf{Z}_{total}}$$
$$= \frac{(2.88\angle -99.49°)(3.33\angle -90°)}{2.96\angle -42.67°}$$
$$= 3.24\angle -146.82° V$$
$$\boxed{v_c(t) = 3.24\cos(20t - 146.82°)\ \text{V}}$$

Pspice Verification:

```
FREQ         VM(N00225,N00247)VP(N00225,N00247)

 3.183E+00    3.238E+00   -1.469E+02
```

(c) The current flowing out of the positive terminal of the voltage source is given by $\frac{5\angle -78° - \mathbf{V}_A}{1}$ A. If we apply nodal voltage analysis, we get,

At node A,

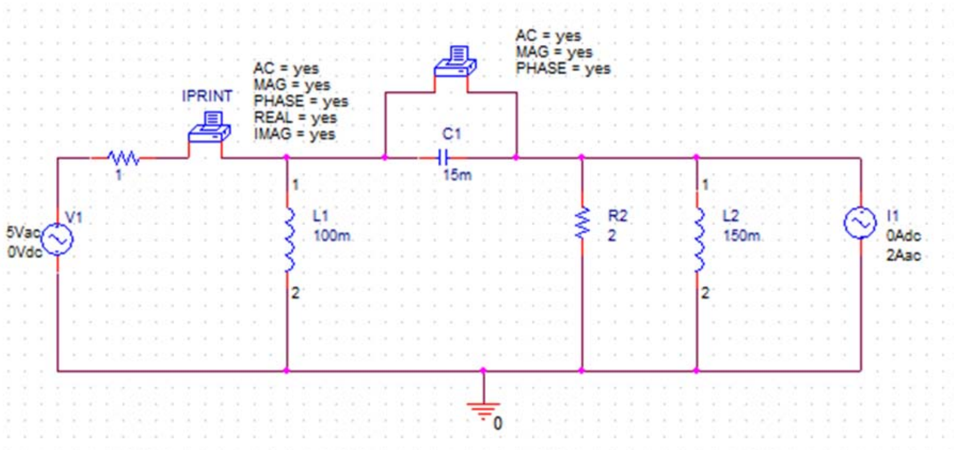
$$\frac{5\angle -78° - \mathbf{V}_A}{1} = \frac{\mathbf{V}_A}{j2} + \frac{\mathbf{V}_C}{-j3.33}$$

From (b), we have, $\mathbf{V}_C = 3.24\angle -146.82°$ V

On solving, we get,

$$\mathbf{V}_A = 2.0348 - j3.057 = 3.67\angle -56.35°\ \text{V}$$
$$\mathbf{I} = -0.995 - j1.833 = 2.08\angle -118.49°\ \text{A}$$
$$\boxed{i(t) = 2.08\cos(20t - 118.49°)\ \text{A}}$$

Pspice Verification:

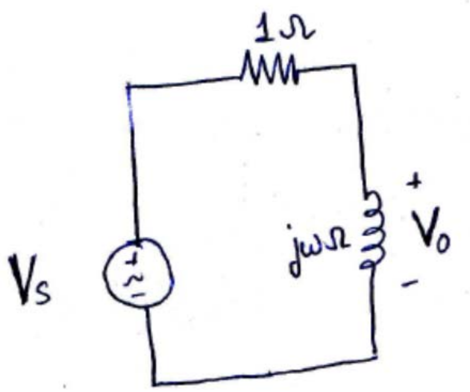


FREQ	IM(V_PRINT2)	IP(V_PRINT2)	IR(V_PRINT2)	II(V_PRINT2)
3.183E+00	2.087E+00	-1.186E+02	-9.984E-01	-1.832E+00

77. If both sources operate at 20 rad/s, $v_c(t) = 510\sin(20t - 124^o)$ mV. However, in the present case,

$v_c(t) = 563\sin(20t - 77.3^o) + 594\sin(19t + 140^o)$ mV.

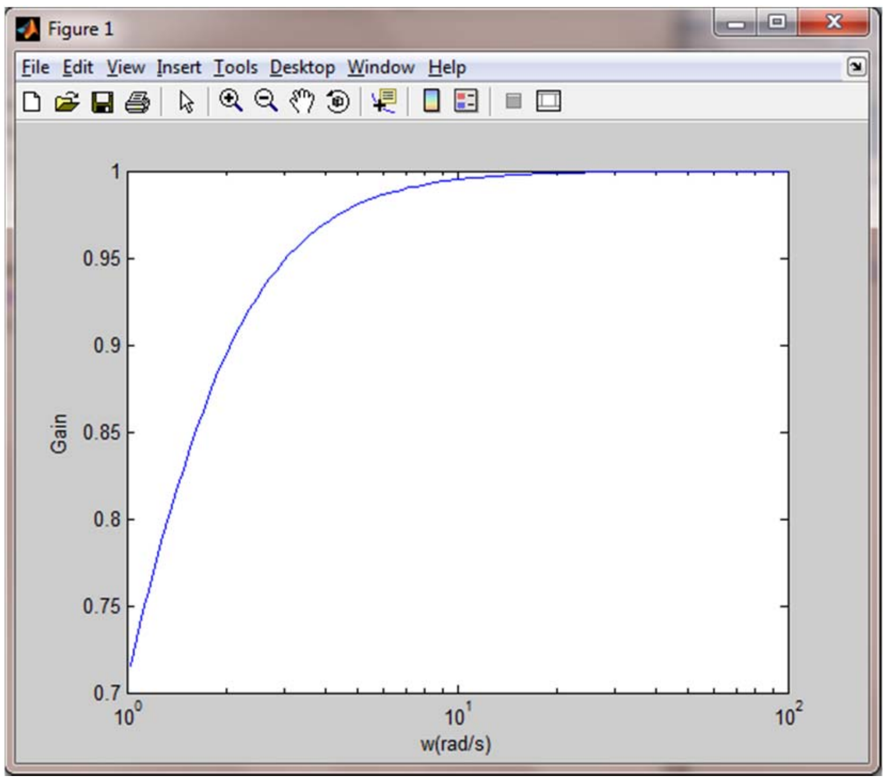
78. (a)



(b) Using the voltage divider rule, we get,

$$\frac{\mathbf{V}_O}{\mathbf{V}_S} = \frac{j\omega}{1 + j\omega} = \boxed{\frac{\omega}{\sqrt{1+\omega^2}} \angle\left(90° - \tan^{-1}(\omega)\right)}$$

(c)



(d) From the plot of the gain, we see that the circuit transfers high frequencies more effectively to the output.

79. (b) $1\angle -90^{\circ}$

(d)

$$\left|\frac{\mathbf{V}_o}{\mathbf{V}_s}\right| = \frac{1}{\sqrt{1+\omega^2}}$$

The circuit transfers low frequencies to the output more effectively, as the "gain" approaches zero as the frequency approaches infinity.

80. One out of many possible design solutions:

Here, the impedance is given as,

$$\mathbf{Z} = \frac{(22 - j7)}{5\angle 8°} = 4.618\angle -25.65° = 4.1629 - j2\,\Omega$$

If $\mathbf{Z} = 4.1629 - j2\,\Omega$ is constructed using a series combination of single resistor, capacitor and an inductor, then, $\mathrm{R} = 4.16\Omega$ and $-j2 = j\omega L - \frac{j}{\omega C}$. Selecting L as 200nH arbitrarily yields the value of the capacitor as 0.12pF.

Thus, one design will be 4.16Ω resistor in series with 200nH inductor and 0.12pF capacitor.

1. $v_1(t) = v_s(t)/5$
   $p_1(t) = v_1(t)^2/1 = v_s(t)^2/25$

   (a) $v_s = 9$ V
   $v_1 = v_1(0) = v_1(1) = v_1(2)$
   $p_1 = p_1(0) = p_1(1) = p_1(2) = v_1^2/1 = v_s^2/25 = 9^2/25 =$ **3.24 W**

   (b) $v_s = 9\sin 2t$ V
   $p_1(0) = v_s(0)^2/25 = [9\sin(2*0)]^2 =$ **0 W**
   $p_1(1) = v_s(1)^2/25 = [9\sin(2*1)]^2/25=$ **2.68 W**
   $p_1(2) = v_s(2)^2/25 = [9\sin(2*2)]^2/25=$ **1.86 W**

   (c) $v_s = 9\sin(2t + 13^o) = 9\sin(2t + 0.227)$ V
   $p_1(0) = v_s(0)^2/25 = [9\sin(0.227)]^2/25=$ **0.164 W**
   $p_1(1) = v_s(1)^2/25 = [9\sin(2 + 0.227)]^2/25=$ **2.03 W**
   $p_1(2) = v_s(2)^2/25 = [9\sin(4 + 0.227)]^2/25=$ **2.53 W**

   (d) $v_s = 9e^{-t}$ V
   $p_1(0) = v_s(0)^2/25 = 9^2/25 =$ **3.24 W**
   $p_1(1) = v_s(1)^2/25 = (9e^{-1})^2/25 =$ **0.44 W**
   $p_1(2) = v_s(2)^2/25 = (9e^{-2})^2/25 =$ **59.3 mW**

2. KVL: $-v_s + 500i + v_c = 0 \Rightarrow i = (v_s - v_c)/500$

(a) $v_s(t) = 30\,u(-t)$ V

$v_c(t) = 30e^{-t/RC} = 30e^{-t/0.002}$ V

$i = -\frac{30}{500} e^{-t/0.002}$, $t > 0$

$p_s(1.5\text{ ms}) =$ 0 W

$p_R(1.5\,ms) = i^2(1.5ms) * 500 = 401.6\,\mu W$

$p_C(1.5\,ms) = v_C(1.5ms) * i(1.5ms) = \left(30e^{-0.0015/0.002}\right) * \left(-\frac{30}{500} e^{-0.0015/0.002}\right)$

$= -401.6\,mW$

(b) $v_s(t) = 10 + 20\,u(t)$ V

$v_C(t) = 10 + 20\left(1 - e^{-t/RC}\right) = 30 - 20e^{-t/2ms}$, $t > 0$

$i = \frac{30-(30-20e^{-t/2ms})}{500} = 40e^{-t/2ms}\ mA$, $t > 0$

$i(1.5ms) =$ 18.9 mA

$p_S(1.5ms) = -(30)(0.0189)W = -566.8\,mW$

$p_R(1.5\,ms) = i^2(1.5ms) * 500 = 178.5\,mW$

$p_C(1.5\,ms) = v_C(1.5ms) * i(1.5ms) = 388.3\,mW$

3. (a) $v_s = -10u(-t)$ V

$i(0^-) = -10/1 = -10$ A

$i(0^+) = -10/1 = -10$ A

$i(t>0) = -10e^{-tR/L} = -10e^{-4t}$ A, $i(200ms) = -4.49$ A

$p_s(0^-) = -(-10)(-10) =$ -100 W; $p_R(0^-) = (-10)^2(1) =$ 100 W; $p_L(0^-) = v_L(0^-)\, i(0^-) = (0)(-10) =$ 0 W

$p_s(0^+) = -(0)(-10) =$ 0 W; $p_R(0^+) = (-10)^2(1) =$ 100 W;

$p_L(0^+) = v_L(0^+)\, i(0^+) = \left(L\frac{di(0^+)}{dt}\right) i(0^+) = \frac{1}{4}(-10)(-4)e^{-4t}(-10e^{-4t})|_{t=0} = -100\ W$

$p_s(200ms) =$ 0 W;

$p_R(200ms) = i^2(200ms)(1) = 20.19\ W$;

$$p_L(200ms) = v_L(200ms)i(200ms) = \left(L\frac{di(200ms)}{dt}\right) i(200ms)$$

$$= \frac{1}{4}(-10)(-4)e^{-4t}(-10e^{-4t})|_{t=200ms} = -20.19\ W$$

(b) $v_s = 20 + 5u(t)$ V

$i(t) = 20 + 5(1 - e^{-4t})u(t)\ A;\ v_L(t) = L\frac{di}{dt} = 5e^{-4t}u(t)\ V$

$p_s(0^-) = -(20)(20) =$ -400 W; $p_R(0^-) = (20)^2(1) =$ 400 W; $p_L(0^-) = v_L(0^-)\, i(0^-) = (0)(20) =$ 0 W

$p_s(0^+) = -(25)(20) =$ -500 W; $p_R(0^+) = i(0^+)^2(1) = [(25 - 5e^{-4t})|_{t=0}]^2 = 20^2 = 400\ W$;

$p_L(0^+) = v_L(0^+)\, i(0^+) = (5)(20) = 100\ W$

$$p_S(200ms) = -(25)(25 - 5e^{-4t})\Big|_{t=\frac{1}{5}} = -568.83\ W$$

$$p_R(200ms) = i(200ms)^2(1) = \left[(25 - 5e^{-4t})\Big|_{t=\frac{1}{5}}\right]^2 = 517.71\ W$$

$$p_L(200ms) = v_L(200ms)i(200ms) = 5e^{-4t}(25 - 5e^{-4t})\Big|_{t=\frac{1}{5}} = 51.12\ W$$

4. We assume the circuit has reached sinusoidal steady state at t = 10 μs

1 kΩ → 1 kΩ, 15 mH → j3k
Zeq = 1k//j3k = 900 + j300 Ω
Veq = (900 + j300)(0.1∠0°) = (94.87∠0.322 rad) V

$$p_R(10\ \mu s) = \frac{[94.87\cos(2\times10^5(10\times10^6)+0.322)]^2}{1000} = 4.2\ W$$

$$I_L = \frac{94.87\angle 0.322\ \text{rad}}{3000\angle \pi/2\ \text{rad}} = (31.62\angle -1.25\ \text{rad})\ mA$$

$$p_L(10\ \mu s) = v_{eq}(10\ \mu s)i_L(10\ \mu s) =$$
$$(94.87\cos(2\times10^5(10\times10^6)+0.322))(0.03162\cos(2\times10^5(10\times10^6)-1.25) = -1.5\ W$$

$$p_S(10\ \mu s) = v_{eq}(10\ \mu s)i_S(10\ \mu s)$$
$$= (94.87\cos(2\times10^5(10\times10^6)+0.322))0.1\cos\left(2\times10^5(10\times10^6)\right)$$
$$= -2.7\ W$$

5. $v_C(0^-) = (6)(4) = 24$ V

(a) For t > 0, $v(t) = v_C(t) = 24e^{-\frac{t}{RC}} = 24e^{-\frac{t}{0.06}}\,V$

$$p_R(t) = \frac{v^2(t)}{R} = \frac{\left(24e^{-\frac{t}{0.06}}\right)^2}{6} \Rightarrow \boxed{p_R(t) = 96e^{-\frac{t}{0.03}}\ W}$$

$$p_C(t) = v_C(t)i_C(t) = v(t)\left[C\frac{dv(t)}{dt}\right]$$

$$= \left(24e^{-\frac{t}{0.06}}\right)\left(10\times10^{-3}\left(-\frac{24}{0.006}\right)e^{-\frac{t}{0.06}}\right) \Rightarrow \boxed{p_C(t) = -96e^{-\frac{t}{0.03}}\ W}$$

(b) $p_R(60\,ms) = 96e^{-\frac{0.06}{0.03}} = 96e^{-2} \Rightarrow \boxed{p_R(60\,ms) = 13\,W}$

6. $v_C(0^-) = (6)(8) = 48$ V, $i_c(0^-) = 0$ A,
$p_R(0^-) = v_C(0^-)^2/R = 48^2/6 = 384$ W, $p_C(0^-) = v_C(0^-)(0) = 0$ W,
$p_S(0^-) = -v_C(0^-)i_s(0^-) = -384$ W

$v_C(0^+) = 48$ V, $i_R = 48/6 = 8$ A, $i_C(0^+) = i_s(0^+) - i_R(0^+) = 1 – 8 = -7$ A
$p_R(0^+) = v_C(0^+)^2/R = 48^2/6 = 384$ W, $p_C(0^+) = v_C(0^+)\, i_C(0^+) = (48)(-7) = -336$ W ,
$p_S(0^+) = -v_C(0^+)i_s(0^+) = -(48)(1) = -48$ W

For t > 0, $v_C(t) = K_1 + K_2 e^{-\frac{t}{RC}} = K_1 + K_2 e^{-\frac{t}{0.06}}$
$t \to \infty, v_C(\infty) = K_1 = i_s(\infty)R = 1(6) = 6\ V$

$v_C(0) = K_1 + K_2 = 48 \Rightarrow K_2 = 42$

$\therefore v_C(t) = 6 + 42e^{-\frac{t}{0.06}}\ V$

$v_C(75\ ms) = 18\ V$

$i_C(75\ ms) = i_s(75\ ms) - i_R(75\ ms) = 1 - \frac{18}{6} = -2\ A$

$p_R(75\ ms) = \frac{18^2}{6} \Rightarrow \boxed{p_R(75\ ms) = 54\ W}$

$p_C(75\ ms) = (18)(-2) \Rightarrow \boxed{p_C(75\ ms) = -36\ W}$

$p_s(75\ ms) \Rightarrow \boxed{p_s(75\ ms) = -18\ W}$

7. We assume the circuit is in sinusoidal steady state

$1\ \Omega \rightarrow 1\ \Omega$, $4\ \Omega \rightarrow 4\ \Omega$, $4\ \mu F \rightarrow -j25k\Omega$

$i_{1\Omega} \approx i_s = 2.5\cos(10t)\ A,\ i_{4\Omega} \approx 0$

$$p_{1\Omega}(t) = i_s{}^2(t)(1) = \frac{6.25}{2}(1 + \cos(20t))\ W$$

$p_{1\Omega}(0) = 6.25\ W, p_{1\Omega}(10\ ms) = 6.19\ W, p_{1\Omega}(20\ ms) = 6\ W$

$p_{4\Omega}(t) \approx 0\ for\ all\ time$

$p_{4\ \mu F}(t) \approx 0\ for\ all\ time$

$p_s(0) = -6.25\ W, p_s(10\ ms) = -6.19\ W, p_s(20\ ms) = -6\ W$

8.

$i_L(0^-) = 0\ A$

$v_L(0^-) = v_C(0^-) = 0\ V$

$i_L(0^+) = 0\ A$

$v_L(0^+) = v_C(0^+) = 0\ V$

$R = 10//11 = \frac{10}{11}\Omega\ \ , \alpha = \frac{1}{2RC} = \frac{11}{40} = 0.275\ \ , \omega_0 = \frac{1}{\sqrt{LC}} = 1\ rad/s$

$\alpha < \omega_0 \Rightarrow\ Underdamped\ case{:}\ \omega_d = \sqrt{\omega_0^2 - \alpha^2} = 0.9614\frac{rad}{s}$

Forced response general solution:

$i_L(t) = i_f + i_{nat} = 10 + e^{-\alpha t}(B_1 cos\omega_d t + B_2 sin\omega_d t)\ \ A$

$i_L(0^+) = 10 + B_1 = 0 \Rightarrow B_1 = -10\ A$

$\frac{di_L(t)}{dt} = e^{-\alpha t}(-\omega_d B_1 sin\omega_d t + \omega_d B_2 cos\omega_d t) - \alpha e^{-\alpha t}(B_1 cos\omega_d t + B_2 sin\omega_d t)$

$\frac{di_L(0^+)}{dt} = \frac{v_L(0^+)}{L} = \frac{v_C(0^+)}{L} = 0\ A \Rightarrow$

$\omega_d B_2 - \alpha B_1 = 0 \Rightarrow B_2 = \frac{\alpha B_1}{\omega_d} = -2.86\ \ A$

$\therefore\ i_L(t) = 10 + e^{-0.275t}(-10cos0.9614t - 2.86sin0.9614t)\ \ A$

$p_L(t) = v_L(t)i_L(t) = Li_L(t)\frac{di_L(t)}{dt}$

$p_L(0) = 0\ W$

$p_L(1) = 12.54\ \ W$

9. For t > 0, $v_C(t) = V(0^+)e^{-\frac{t}{RC}} = V(0^+)e^{-\frac{t}{0.12}}\ V$

$w_C(0^+) = \frac{1}{2}Cv_C{}^2(0^+) = 100\ mJ\ \Rightarrow v(0^+) = \sqrt{2}\ V$

$\therefore v_C(t) = \sqrt{2}e^{-\frac{t}{0.12}}\ V \Rightarrow v(120\ ms) = 0.52\ V \Rightarrow p_R(120\ ms) = \frac{(0.52\ )^2}{1.2} = 226\ mW$

Energy dissipated: $w_C(t) = \frac{1}{2}Cv_C{}^2(t) = 0.1e^{-\frac{t}{0.06}}\ W$

Energy remaining at t = 1 s is: $w_C(1\ s) = 0.1 - 0.1e^{-\frac{1}{0.06}} \approx 0\ W$
or 100 mJ of energy dissipated in the first second.

$$T_f = T_i + \Delta T = 273.15 + 23 + \frac{100 \times 10^{-6} kJ}{(10^{-3} kg)\left(0.9 \frac{kJ}{kg.K}\right)} = 273.15 + 23 + 0.111 = 296.261\ K$$

or a temperature increase of 0.111 °C.

10. (a) $p = (30\times10^{3})^{2}\,(1.2\times10^{-3}) = \boxed{1.08\text{ MW}}$

(b) $W = (1.08\times10^{6})(150\times10^{-6}) = \boxed{162\text{ J}}$

11. 18 kΩ → 18 kΩ, 1 μF → -j22.22 kΩ

Zeq = 18 – j 22.2 kΩ = $28.6\angle -51^o\ k\Omega$

$V_{eq} = Z_{eq}I_s = (28.6 \times 10^3\angle -51^o)(9 \times 10^{-3}\angle 15^o) = 257.4\angle{-36^o}\ V$

$(a)\ p_l(t) = (257.4\cos(45t{-}36^o))(9 \times 10^{-3}\cos(45t + 15^o))$

$= \boxed{0.73 + 1.16\cos(90t - 21^o)\ W}$

$(b)\ \boxed{P_l = 0.73\ W}$

12. 1 Ω → 1 Ω, 1 mH → j0.155 Ω

(a) $P_R = \frac{V_m^2}{2R} = \frac{100^2}{2} = 5\ kW$

$I_L = \dfrac{V}{Z_L} = \dfrac{100\angle 45^o}{0.155\angle 90^o} = 645.16\angle{-45^o}\ \ A$

$P_L = \dfrac{1}{2} V_m I_{Lm} \cos(\theta - \varphi) = \dfrac{1}{2}(100)(645.16)\cos(45+45) = 0\ W$

$Z_{load} = 1//j0.155 = 0.1532\angle 81.2^o\ \ \Omega$

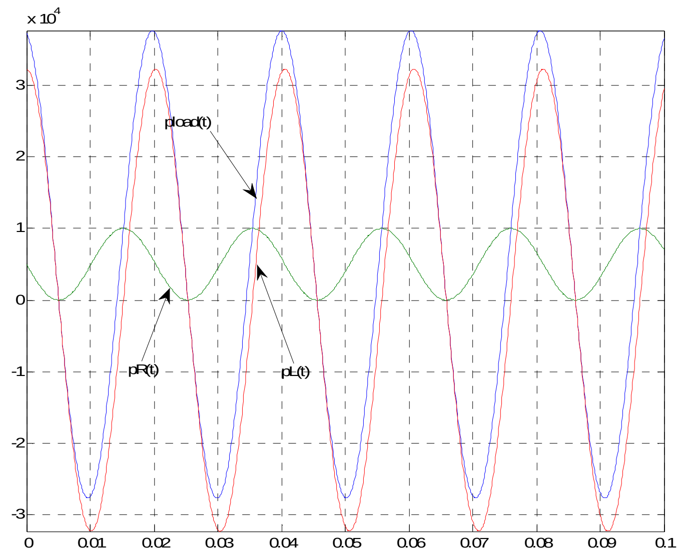
$I_{load} = V/Z_{load} = 652.7\angle{-36.2^o}\ A$

(b) $p_{load}(t) = v(t)i_{load}(t) = (100\cos(155t+45^o))(652.7\cos(155t-36.2^o)$

$\Rightarrow p_{load}(t) = 5 + 32.64\cos(310t + 8.8^o)\ kW$

$p_R(t) = \dfrac{v^2(t)}{R} = \dfrac{(100\cos(155t+45^o))^2}{1} = 5(1+\cos(310t+9090^o))\ kW$

$p_L(t) = v(t)i_L(t) = (100\cos(155t+45^o))(645.16\cos(155t-45^o)$
$= 32.26\cos(310t)\ \ kW$



13. $I = 4 - j2 = \sqrt{20}\angle -26.6^o$ A

(a) Z = 9 Ω, $P = \frac{I_m^2}{2}R = \frac{20(9)}{2} = 90\ W$

(b) Z = -j1000 Ω, $V = ZI = 1000\sqrt{20}\angle -116.6\,^o$V,
$P = \frac{V_m I_m}{2}\cos(\theta - \varphi) = \frac{1000\sqrt{20}\sqrt{20}}{2}\cos(90^o) = 0\ W$

(c) $Z = 1 - j2 + j3 = 1 + j = \sqrt{2}\angle 45^o\,\Omega$, $V = ZI = \sqrt{2}\sqrt{20}\angle 18.4^o$ V,
$P = \frac{\sqrt{2}\sqrt{20}\sqrt{20}}{2}\cos(45^o) = 10\ W$

(d) $Z = 6\angle 32^o\,\Omega$, $V = ZI = 6\sqrt{20}\angle{-5.4^o}$ V, $P = \frac{6\sqrt{20}\sqrt{20}}{2}\cos(-5.4^o) = 59.73\ W$

(e) $Z = \frac{1.5\angle -19^o}{2+j}\ k\Omega = 671\angle -45.6^o\ \Omega$, $V = ZI = 671\sqrt{20}\angle{-72.2^o}$,
$P = \frac{671\sqrt{20}\sqrt{20}}{2}\cos(-45.6^o) = 4.7\ kW$

14. Mesh equations:

$-79\angle{-40^o} + 5I_1 + j7(I_1 - I_2) = 0$ $\quad$ $152 + j7(I_2 - I_1) - j3.1I_2 = 0$

Solve mesh equations: $I_1 = 29.18\angle - 118.5^o$ A, $I_2 = 25.96\angle - 164.22^o$ A

$$P_R = \frac{I_m^2 R}{2} = 2129\ W$$

$$P_{S1} = -\frac{V_m I_m}{2}\cos(\theta - \varphi) = -\frac{(79)(29.18)}{2}\cos(-40^o + 118.5^o) = -230\ W$$

$$P_{S2} = \frac{(152)(25.96)}{2}\cos(0^o + 164.22^o) = -1899\ W$$

$P_L = 0\ W$, $\quad P_c = 0\ W$

Power balance: 2129 W = (230 + 1899) W

15. (a) $Z_{in} = 1 + \frac{(3+j2.8)(-j1.5)}{3+j2.8-j1.5} = 2.4\angle -47.4^o\ \Omega$

$$Is = \frac{194\angle 3^o}{2.4\angle -47.4^o} = 80.5\angle 50.4^o\ \ A$$

$$Ps = -\frac{1}{2}(194)(80.5)\cos(3^o - 50.4^o) = -5.29\ kW$$

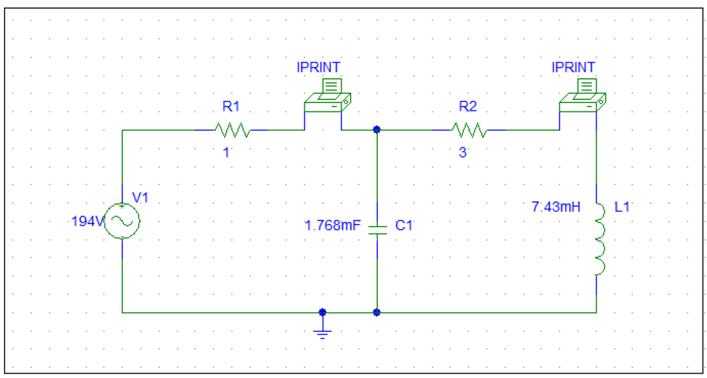
$$P_{1\Omega} = \frac{1}{2}(80.5)^2(1) = 3.24\ kW$$

$$I_{3\Omega} = \frac{-j1.5}{3 + j2.8 - j1.5}(80.5\angle 50.4^o) = 37\angle -63^o\ A$$

$$P_{3\Omega} = \frac{1}{2}(37)^2(3) = 2.05\ kW$$

$$P_L = 0\ W, \quad P_C = 0\ W$$

(b) Pspice simulation



FREQ	IM(V_PRINT1)	IP(V_PRINT1)
6.000E+01	8.049E+01	5.040E+01
FREQ	IM(V_PRINT2)	IP(V_PRINT2)
6.000E+01	3.693E+01	-6.304E+01

16.

$$V_{th} = \frac{j700}{225 + j700}(15\angle 60^o) = 14.28\angle 78^o V$$

$$Z_{th} = \frac{225(j700)}{225 + j700} = 204 + j65.5\ \Omega$$

(a) $Z_L = Z_{th}^* = \boxed{204 - j65.5\ \Omega}$

(b) $P_L = \frac{|Vth|^2}{8 * R_{th}} = \frac{14.28^2}{8 * 204} = \boxed{125\ mW}$

17. $V_{th} = \frac{9000-j8000}{9225+j8000}(15\angle 60^o) = 14.8\angle 59.3^o V$

$$Z_{th} = \frac{225(9000 - j8000)}{9225 - j8000} = 222 + j2.7 \;\; \Omega$$

(a) $Z_L = Z_{th}^* = 222 - j2.7\ \Omega$

(b) $P_L = \frac{|Vth|^2}{8*R_{th}} = \frac{14.8^2}{8*222} = 123.3\ mW$

18. KCLs:

$$\frac{V_x-20}{2} - 2V_c + \frac{V_x-V_c}{3} = 0 \qquad \qquad 5V_x - 14V_c = 60 \qquad \qquad V_x = 9.223\angle{-83.88^o}V$$
$$\frac{V_c}{-j2} + \frac{V_c-V_x}{3} = 0 \quad \Rightarrow \quad j2V_x + (3-j2)V_c = 0 \quad \Rightarrow \quad V_c = 5.122\angle{-140.2^o}V$$

Power associated with dependent source:

$$P_{2VC} = -\frac{1}{2}(9.223)(2 \times 5.122)\cos(-83.88^o + 140.2^o) = -26.22\ W$$

So the power supplied by the dependent source is 26.22 W.

19.

(a)

KVL: $j1.92I_x + 4.8(I_x - j2) + 8(I_x - 1.6I_x) = 0 \Rightarrow I_x = 5\ A$

$I_{4.8\Omega} = 5 - j2 = 5.385\angle{-21.8^o}\,A, \qquad I_{8\Omega} = 0.6I_x = 3\ A$

$V_{4.8\Omega} = 4.8I_{4.8\Omega} = 25.85\angle{-21.8^o}\,V, \qquad V_{8\Omega} = 8I_{8\Omega} = 24\ V$

$P_{4.8\Omega} = \frac{1}{2}(5.385)^2(4.8) = \boxed{69.6\ W}, \qquad P_{8\Omega} = \frac{1}{2}(3)^2(8) = \boxed{36\ W}$

(b) $P_{-j2A} = \frac{1}{2}(25.85)(2)\cos(-21.8^o - 90^o) = \boxed{-9.6W}$

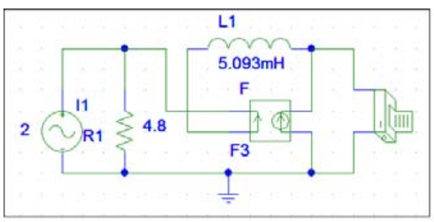
$P_{1.6Ix} = \frac{1}{2}(24)(1.6 \times 5)\cos(180^o) = \boxed{-96W}$

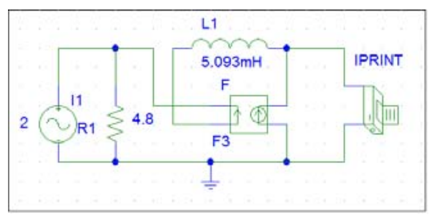
(c) Voc: $\left.\begin{matrix} -(-j2) + \frac{V_1}{4.8} - I_x = 0 \\ I_x = 1.6I_x \Rightarrow I_x = 0 \end{matrix}\right\} \Rightarrow V_{oc} = V_1 = -j9.6 = 9.6\angle 90^o V$

Isc: $\left.\begin{matrix} I_{sc} = 1.6I_x - I_x = 0.6I_x \\ I_x = -\frac{4.8}{4.8+j1.92}(-j2) = 1.857\angle 68.2^o A \end{matrix}\right\} \Rightarrow I_{sc} = 1.114\angle 68.2^o A$

$Z_{TH} = \frac{9.6\angle 90^o}{1.114\angle 68.2^o} = -8 - j3.2\ \Omega \quad \Rightarrow \boxed{Z_L = -8 + j3.2\ \Omega}$

(d) Pspice simulation:





FREQ	VM($N_0002,0)	VP($N_0002,0)	FREQ	IM(V_PRINT11)	IP(V_PRINT11)
6.000E+01	9.600E+00	-9.000E+01	6.000E+01	1.114E+00	6.820E+01

20.

(a) Waveform (a): $I_{avg} = \frac{(-2)(2)+(1)(2)+0(2)}{6} = -\frac{1}{3} = -0.333\ A$

Waveform (b): $I_{avg} = \frac{\frac{1}{2}(5)(1)+0(3)}{4} = \frac{5}{8} = 0.625\ A$

(b) Waveform (a): $I_{avg}^2 = \frac{(-2)^2(2)+(1)^2(2)}{6} = \frac{5}{3} = 1.667\ A^2$

Waveform (b):

$i(t) = 5 \times 10^3 t\ A$

$i^2(t) = 25 \times 10^6 t^2\ A^2$

$$I_{avg}^2 = \frac{1}{4ms}\int_0^{1ms} i^2(t)dt = \frac{1}{4ms} 25 \times 10^6 \frac{t^3}{3}\Bigg|_0^{1ms} = 2.083\ A^2$$

21.

(a) $P = \frac{5^2}{2.2} = \boxed{11.36\ W}$

(b) $v_s = 4\cos 80t - 8sin80t = 4cos80t - 8\cos(80\text{t} - 90^o)$

$\rightarrow V_s = 4\angle 0^o - 8\angle -90^o = 4 + j8 = \sqrt{80}\angle 63.4^o\ V$

$$P = \frac{1}{2}\left(\frac{80^2}{2.2}\right) = \boxed{18.18\ W}$$

(c) $v_s = 10cos100t + 12.5\cos(100\text{t} + 19^o) \rightarrow 10 + 12.5\angle 19^o = 23.18\angle 10.11^o\ V$

$$P = \frac{1}{2}\left(\frac{23.18^2}{2.2}\right) = \boxed{122.12\ W}$$

22.

(a) $7sin30t\ V \rightarrow \frac{7}{\sqrt{2}} = \boxed{4.95\ \ V\ rms}$

(b) $100cos80t\ mA \rightarrow \frac{100}{\sqrt{2}} = \boxed{70.71\ mA\ rms}$

(c) $120\sqrt{2}\cos(5000t - 45^o)\ V \rightarrow \frac{120\sqrt{2}}{\sqrt{2}} = \boxed{120\ V\ rms}$

(d) $\frac{100}{\sqrt{2}}\sin(2t + 72^o)\ A \rightarrow \frac{100}{\sqrt{2}\sqrt{2}} = \boxed{50\ A\ rms}$

23.

(a) $62.5cos100t\ mV\ \rightarrow \frac{62.5}{\sqrt{2}} = 44.19\ mV\ rms$

(b) $1.95cos2t\ A\ \rightarrow \frac{1.95}{\sqrt{2}} = 1.38\ A\ rms$

(c) $208\sqrt{2}\cos(100\pi t - 29^{o})\ V\ \rightarrow \frac{208\sqrt{2}}{\sqrt{2}} = 208\ V\ rms$

(d) $\frac{400}{\sqrt{2}}\sin(2000t - 14^{o})\ A \rightarrow \frac{400}{\sqrt{2}\sqrt{2}} = 200\ A\ rms$

24.

(a) $i(t) = 3\sin 4t\ A \ \rightarrow \ \frac{3}{\sqrt{2}} = \boxed{2.12\ A\ rms}$

(b) $v(t) = 4\sin 20t cos10t = \frac{1}{2}(sin30t + sin10t)\ V \rightarrow \ \sqrt{\left(\frac{1}{2\sqrt{2}}\right)^2 + \left(\frac{1}{2\sqrt{2}}\right)^2} = \boxed{\frac{1}{2}\ V\ rms}$

(c) $i(t) = 2 - sin10t\ mA \rightarrow \ \sqrt{2^2 + \left(\frac{1}{\sqrt{2}}\right)^2} = \boxed{2.12\ mA\ rms}$

(d) $I_{eff} = \sqrt{\frac{1}{3}\int_1^3 (2.82 \times 10^{-3})^2 dt} = \sqrt{\frac{1}{3}(2.82 \times 10^{-3})^2(3-1)} = \boxed{2.3\ mA\ rms}$

25.

(a) $f_0 = 0.167\ Hz,\ T = 6\ s$

$$I_{eff} = \sqrt{\frac{1}{6}\left(\int_0^2 (-2)^2 dt + \int_2^4 (1)^2 dt\right)} = \sqrt{\frac{10}{6}} = 1.291\ A\ rms$$

(b) $f_0 = 250\ Hz, T = 4\ ms$

$$I_{eff} = \sqrt{\frac{1}{4\ ms}\int_0^{1\ ms}\left(\frac{5}{10^{-3}}t\right)^2 dt} = 1.443\ A\ rms$$

26.

(a) $I_{avg} = \frac{(-9)(1)}{3} = \boxed{-3\ mA}$

$$I_{eff} = \sqrt{\frac{1}{3}\int_2^3 (-9)^2\, dt} = \boxed{5.196\ mA\ rms}$$

(b) $F_{avg} = \frac{\frac{1}{2}(-1)(0.05ms)+\frac{1}{2}(1)(0.05ms)}{3} = \boxed{0}$

$$F_{rms} = \sqrt{\frac{1}{0.3ms}(2)\int_0^{0.05ms}\left(-\frac{1}{0.05}t\right)^2 dt} = \frac{1}{3000} = \boxed{0.333\times 10^{-3}\ \ rms}$$

27. 1 kΩ → 1 kΩ, 2H → j1kΩ → Z = 1 +j1 kΩ

Let $i(t) = I_o \cos(500t + \varphi)\ A \rightarrow I = I_o \angle 0^o\ A$

$V = ZI = 1k\sqrt{2}I_o\ \angle 45^o V \rightarrow v(t) = 1k\sqrt{2}I_o \cos(500t + \varphi + 45^o)\ V$

$p(t) = v(t)i(t) = \frac{1k\sqrt{2}I_o^2}{2}\left[\frac{1}{\sqrt{2}} + \cos(1000t + \varphi + 45^o)\right]\ W$

$Require: max[p(t)] = \frac{1k\sqrt{2}I_o^2}{2}\left(\frac{1}{\sqrt{2}} + 1\right) = \frac{1}{4} \Rightarrow I_o = \sqrt{\frac{2}{1k\sqrt{2}\left(\frac{1}{\sqrt{2}}+1\right)4}} \Rightarrow I_o = 14.39\ mA$

$Largest\ rms\ current\ tolerated\ is\text{:}\ \frac{14.39\ mA}{\sqrt{2}} = 10.175\ mA\ rms$

28. (a) $v = 5\,V$

$T = \infty\ s$

$f = 0\ Hz$

$5\ V\ rms$

(b) $v = 2\sin 80t - 7\cos 20t + 5\ V$

$T = \frac{\pi}{10}\ s$

$f = \frac{10}{\pi}\ Hz$

$$V_{eff} = \sqrt{\left(\frac{2}{\sqrt{2}}\right)^2 + \left(\frac{7}{\sqrt{2}}\right)^2 + 5^2} = 7.18\ V\ rms$$

(c) $v = 5\cos 50t + 3\sin 50t = 5\cos 50t + 3\sin(50t - \angle 90^o)\ V \rightarrow\ 5\angle 0^o + 3\angle{-90^o} = 5 - j3 = 5.831\angle{-31^o}\ V \rightarrow 5.831\cos(50t - \angle{-31^o})\ V$

$T = \frac{\pi}{25} s$

$f = \frac{25}{\pi}\ Hz$

$$V_{eff} = \sqrt{\left(\frac{5.831}{\sqrt{2}}\right)^2} = 4.123\ V\ rms\quad or\ just\ \ V_{eff} = \sqrt{\left(\frac{5}{\sqrt{2}}\right)^2 + \left(\frac{3}{\sqrt{2}}\right)^2} = 4.123\ V\ rms$$

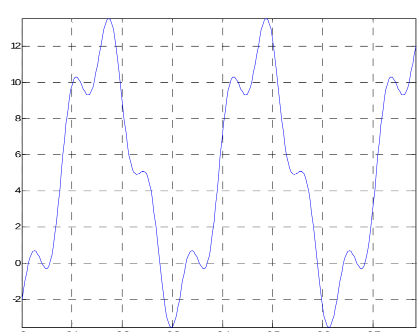
(d) $i = 8\cos^2 90t\ mA = \frac{8}{2}(1 + \cos 180t) = 4 + 4\cos 180t\ mA$

$T = \frac{\pi}{90} s$

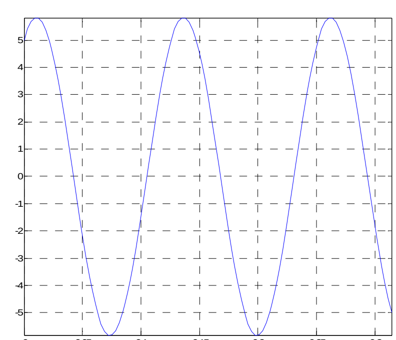
$f = \frac{90}{\pi}\ Hz$

$$I_{eff} = \sqrt{4^2 + \left(\frac{4}{\sqrt{2}}\right)^2} = 4.9\ mA\ rms$$

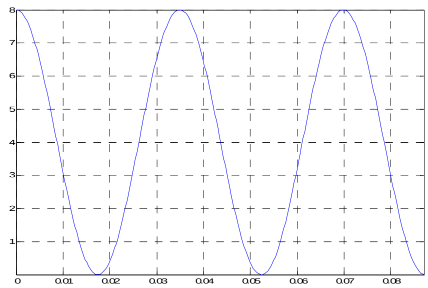
(e) Simulations:



(b)



(c)



(d)

29. 14 mH → j0.56 Ω, 28 mH → 1.12 Ω

$$Z_{eq} = R//j1.12 = \frac{j1.12R}{R + j1.12}$$

$$V_R = \frac{Z_{eq}}{j0.56+Z_{eq}}(120\angle 0^o) = \frac{j1.12R}{-0.6272+j1.68R}(120\angle 0^o)\ V$$

$$V_{14\,mH} = \frac{j0.56}{j0.56+Z_{eq}}(120\angle 0^o) = \frac{-0.6272+j0.56R}{-0.6272+j1.68R}(120\angle 0^o)\ V$$

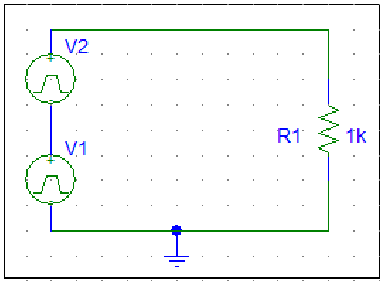
Require: $V_R rms = V_{14\,mH} rms \Leftrightarrow |V_R| = |V_{14\,mH}| \Leftrightarrow \frac{1.12R}{\sqrt{(0.6272)^2+(1.68R)^2}} = \frac{\sqrt{(0.6272)^2+(0.56R)^2}}{\sqrt{(0.6272)^2+(1.68R)^2}}$

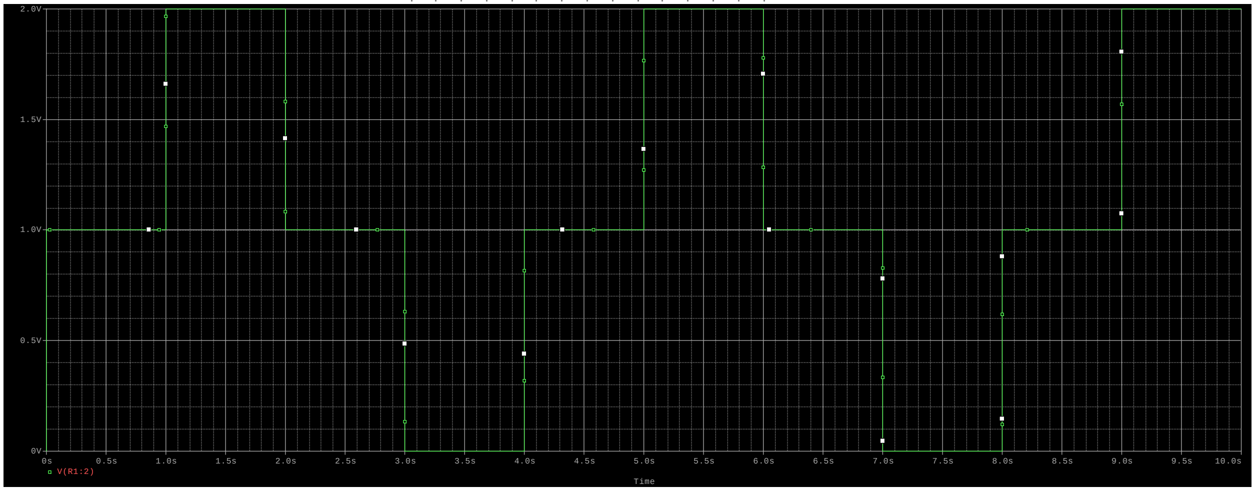
$$\Leftrightarrow 1.12R = \sqrt{(0.6272)^2 + (1.68R)^2} \Leftrightarrow R = \frac{0.6272}{\sqrt{0.9408}} = \boxed{0.6466\ \Omega}$$

$$V_R rms = V_{14\,mH} rms = \frac{120.1}{\sqrt{2}} = \boxed{84.92\ V\ rms}$$

30. $V_{avg} = \frac{(1)(1)+(2)(1)+(1)(1)}{4} = \boxed{1\ V}$

$$V_{eff} = \sqrt{\frac{1}{4}(1^2 + 2^2 + 1^2)} = \boxed{1.225\ V\ rms}$$





31.

(a) $I = \frac{119\angle 3^o}{22+14\angle 32^o} = 3.43\angle -9.36^o A\ rms$

$V_1 = Z_1 I = (14\angle 32^o)(\ 3.43\angle -9.36^o) = 48\angle 22.64^o\ Vrms$

$P_1 = (48)(3.43)\cos(22.64^o + 9.36^o) = \boxed{139.7\ W}$

$P_2 = (3.43)^2(22) = \boxed{259\ W}$

$AP_s = (119)(3.43) = \boxed{408.17\ VA}$

$PF = \cos(3^o + 9.36^o) = \boxed{0.997}$

(b) $I = \frac{119\angle 3^o}{2+6-j} = 14.76\angle 10.125^o A\ rms$

$V_2 = Z_2 I = (6 - j)I = 89.8\angle 0.665^o\ Vrms$

$P_1 = (14.76)^2(2) = \boxed{435.5\ W}$

$P_2 = (89.8)(14.76)\cos(0.665^o - 10.125^o) = \boxed{1307.5\ W}$

$AP_s = (119)(14.76) = \boxed{1756.44\ VA}$

$PF = \cos(3^o - 10.125^o) = \boxed{0.9923}$

(c) $I = \frac{119\angle 3^o}{100\angle 70^o+75\angle 90^o} = 0.69\angle -75.5^o\ A\ rms$

$V_1 = Z_1 I = (100\angle 70^o)(\ 0.69\angle -75.5^o) = 69.03\angle -5.5^o\ V\ rms$

$V_2 = Z_2 I = (75\angle 90^o)(\ 0.69\angle -75.5^o) = 51.8\angle 14.4^o\ V\ rms$

$P_1 = (69.03)(0.69)\cos(-5.5^o + 75.5^o) = \boxed{16.3\ W}$

$P_2 = (51.8)(0.69)\cos(14.4^o + 75.5^o) = \boxed{0\ W}$

$AP_s = (119)(0.69) = \boxed{82.14\ VA}$

$PF = \cos(3^o + 75.5^o) = \boxed{0.1984}$

32.

(a) $PF = \cos(0^o) = 1$

(b) $PF = \cos(90^o) = 0$

(c) $PF = \cos(-90^o) = 0$

(d) $PF = \cos(-56^o) = 0.53$

33.

(a) PF = 1: The load is purely resistive

(b) PF = 0.85 lagging: The load is a resistor and inductor combination

(c) PF = 0.211 leading: The load is a resistor and capacitor combination

(d) $PF = \cos(-90^o)$: The load is a capacitor

34.

(a) Voltage lags current by 126^o
(b) Voltage leads current by $\cos^{-1}(0.55) = 56.6^o$
(c) Voltage lags current by $\cos^{-1}(0.685) = 46.76^o$
(d) Voltage lags current by $\cos^{-1}\left(\frac{100}{500}\right) = 78.46^o$

35.

(a) $P = V_{rms}I_{rms}PF = 25\ W \Rightarrow I_{rms} = \frac{25}{V_{rms}PF} = \frac{25}{(120)(0.88)} = 0.237\ A$

$$Z_L = \frac{V_{rms}}{I_{rms}}\angle - cos^{-1}(0.88) = 506.88\angle - 28.36^o = 446 - j241\ \Omega$$

Therefore, the load may be realized with a 446 Ω resistor in series with an 11 μF capacitor.

(b) $P = V_{rms}I_{rms}PF = 150\ W, \quad AP = V_{rms}I_{rms} = 25\ VA$

$$PF = \frac{AP}{P} = \frac{25}{150} = 0.167\ lagging$$

$$I_{rms} = \frac{25}{110} = 0.227\ A\ rms$$

$$Z_L = \frac{110}{0.227}\angle cos^{-1}(0.167) = 484\angle 80.4^o = 80.83 + j477.2\ \Omega$$

Therefore, the load may be realized with an 80.83 Ω resistor in series with a 1.27 H capacitor.

36.

(a) $Z_{eq} = 1k//(50\angle-100^o) = 50.38\angle-97.156^o\Omega$

$V = Z_{eq}I_s = (50.38\angle-97.156^o)(0.275\angle20^o) = 13.853\angle-77.156^o\ V$

$I_{load} = \dfrac{V}{50\angle-100^o} = 0.2711\angle22.84^o\ A$

$p_{1k\Omega}(t) = \dfrac{v^2(t)}{1k\Omega} = \dfrac{(13.853\cos(40t-77.156^o))^2}{1k\Omega} \Rightarrow \boxed{p_{1k\Omega}(20\ ms) = 13\ mW}$

$p_{load}(t) = v(t)i_{load}(t) = 13.853\cos(40t-77.156^o)\,0.2711\cos(40t-22.84^o)$

$\Rightarrow \boxed{p_{load}(20\ ms) = 1.192\ W}$

(b) $P_{1k\Omega} = \frac{V_m^2}{2R} = \frac{(13.853)^2}{2000} = \boxed{98\ mW}$

$I_{load} = \dfrac{1}{2}V_mI_{m,load}\cos(\theta-\varphi) = \dfrac{1}{2}(13.853)(0.2711)\cos(-77.156^o-22.84^o) = -\dfrac{1}{3}W$

$= \boxed{-333\ mW}$

(c) $AP_{load} = \frac{1}{2}V_mI_{m,load} = \boxed{1.92\ VA}$

(d) $PF_{souce} = \cos(-77.156^o-20^o) = \cos(-97.156^o) = \boxed{0.125\ leading}$

37.

(a) Load is resistor, R_L. Then, $V = \frac{275\angle 20^o mA}{\frac{1k\Omega}{R_L}} = V_m\angle 20^o\ V.$

Therefore, $PF_{source} = \cos(0) = 1$

(b) Load: 1000+j900 Ω.

$Z_{eq} = 1k//(1000 + j900) = 613.43\angle 17.76^o\Omega$

$V = Z_{eq}I_s = (613.43\angle -17.76^o)(0.275\angle 20^o) = 169\angle 37.76^o\ V$

$PF_{souce} = \cos(37.76^o - 20^o) = \cos(17.76^o) = 0.9523\ lagging$

(c) Load: $500\angle -5^o\Omega$

$Z_{eq} = 1k//(500\angle -5^o) = 333.6\angle -3.33^o\Omega$

$V = Z_{eq}I_s = (333.6\angle -3.33^o)(0.275\angle 20^o) = 91.74\angle 16.67^o\ V$

$PF_{souce} = \cos(16.67^o - 20^o) = \cos(-3.33^o) = 0.9983\ leading$

38.

(a) $PF_{souce} = 0.95\ leading \Rightarrow Z_{eq} = 1k//Z_{load}\ is\ capacitive.$

$\angle Z_{eq} = -\cos^{-1}(PF_{souce}) = -\cos^{-1}(0.95) = -18.195^o$

The combined load may be realized by the 1 kΩ resistor in parallel with capacitor C

Then, $Z_{eq} = 1k//\frac{1}{j\omega C} = \frac{\frac{1k}{j\omega C}}{1k+\frac{1}{j\omega C}} = \frac{1k}{1+j\omega kC} = \frac{1k-jk^2\omega C}{1+(k\omega C)^2}$

Then, $\angle Z_{eq} = tan^{-1}\left(\frac{-k^2\omega C}{1k}\right) = -tan^{-1}(\omega kC) = -18.195^o \Rightarrow \omega kC = \tan(18.195^o) = 0.3287$

$\therefore C = \frac{328.6\times10^{-6}}{\omega}\ F$

For ω = 40 rad/s, the desired load may be realized with an 8.22 μF capacitor

(b) $PF_{souce} = 1$

∴ Desired load must be a resistor with non-zero resistance

(c) $PF_{souce} = 0.45\ lagging \Rightarrow Z_{eq} = 1k//Z_{load}\ is\ inductive.$

$\angle Z_{eq} = \cos^{-1}(PF_{souce}) = \cos^{-1}(0.45) = 63.26^o$

The combined load may be realized by the 1 kΩ resistor in parallel with an inductor L

Then, $Z_{eq} = 1k//j\omega L = \frac{j\omega kL}{1k+j\omega L} = \frac{j\omega kL(1k+j\omega L)}{(1k)^2+(\omega L)^2} = \frac{\omega^2 kL^2+j\omega k^2 L}{(1k)^2+(\omega L)^2}$

Then, $\angle Z_{eq} = tan^{-1}\left(\frac{\omega k^2 L}{\omega^2 kL^2}\right) = tan^{-1}\left(\frac{1k}{\omega L}\right) = 63.26^o \Rightarrow \frac{1k}{\omega L} = \tan(63.26^o) = 1.9845$

$\therefore L = \frac{1}{1.9845\times10^{-3}\omega}\ H$

For ω = 40 rad/s, the desired load may be realized with a 12.6 H inductor

39.

(a) Mesh equations:

$$\left.\begin{array}{r} -200\angle 0^o + Z_A I_1 + Z_B(I_1 - I_2) = 0 \\ Z_B(I_2 - I_1) + Z_C I_2 + Z_D I_2 = 0 \end{array}\right\} \Rightarrow \begin{bmatrix} Z_A + Z_B & -Z_B \\ -Z_B & Z_B + Z_C + Z_D \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 200\angle 0^o \\ 0 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 25.14\angle 12.2^o \\ 3.27\angle -42.5^o \end{bmatrix} A\ rms$$

$V_A = 135.4\angle -9.6^o\ V\ rms,\ \ V_B = 70.2\angle 18.7^o\ V\ rms$

$V_C = 29.3\angle -16^o\ V\ rms,\quad V_D = 49\angle 38.6^o\ V\ rms$

So,

$AP_A = 3.4\ kVA,\qquad AP_B = 1.64\ kVA,\qquad AP_C = 95.8\ VA,\qquad AP_D = 160.6\ VA$

$PF_{souce} = \cos(\angle V_2 - \angle I_s) = \cos(0^o - 12.2^o) \Rightarrow PF_{souce} = 0.9774\ leading$

(b) Mesh analysis as in (a):

$$\Rightarrow \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 147\angle 118^o \\ 21.8\angle 77^o \end{bmatrix} A\ rms$$

$V_A = 294\angle -21^o\ V\ rms,\ \ V_B = 131\angle 124^o\ V\ rms$

$V_C = 49\angle 103^o\ V\ rms,\quad V_D = 87\angle 135^o\ V\ rms$

So,

$AP_A = 43.3\ kVA,\qquad AP_B = 17.3\ kVA,\qquad AP_C = 1.07\ kVA,\qquad AP_D = 1.91\ kVA$

$PF_{souce} = \cos(\angle V_2 - \angle I_s) = \cos(0^o - 118^o) \Rightarrow PF_{souce} = 0.465\ leading$

40.

(a) $S = AP\angle cos^{-1}(PF) = \frac{P}{PF}\angle cos^{-1}(PF) = \frac{100}{0.75}\angle cos^{-1}(0.75) = \boxed{133.3\angle 41.41^o\ VA}$

(b) $S = V_{eff}I_{eff}\angle\theta - \varphi = (120)(10.3)\angle 32^o - 29^o = \boxed{1.236\angle 3^o\ kVA}$

(c) $S = P + jQ = 1000 + j10 = \boxed{1000.05\angle -0.57^o\ VA}$

(d) $S = AP\angle cos^{-1}(PF) = \boxed{450\angle 49.5^o\ VA}$

41.

(a) $AP = |S| = 1.118\ KVA$
$PF = \cos\left(tan^{-1}\left({}^{Q}/_{P}\right)\right) = \cos\left(tan^{-1}(0.5)\right) = \cos(26.56^o) = 0.894\quad lagging$
$Q = |S|\sin(26.56^o) = 500\ VAR$

(b) $AP = 400\ VA$
$PF = 1$
$Q = 0\ VAR$

(c) $AP = 150\ VA$
$PF = \cos(-21^o) = 0.93\ \ leading$
$Q = 150\sin(-21^o) = -53.75\ VAR$

(d) $AP = 75\ VA$
$PF = \cos(25^o) = 0.906\ \ lagging$
$Q = 75\sin(25^o) = 31.7\ VAR$

42.

(a) $S = |3 + j1.5|\angle tan^{-1}\left({}^{1.5}/_{3}\right) = 3.354\angle 26.56^{o}\ \ VA$

$PF = \cos(26.56^{o}) = 0.894\ \ \ lagging$

(b) $S = |1 + j4|\angle tan^{-1}\left({}^{1}/_{4}\right) = 4.123\ \angle 14^{o}\ \ kVA$

$PF = \cos(14^{o}) = 0.97\ \ \ lagging$

43.

(a) $PF = \cos(24^o) = 0.913 \ \ lagging$

(b) Current drawn by corrective device is:

$$I_c = \left(\frac{S_c}{V}\right)^* = \left(\frac{j(Q_{new} - Q_{old})}{V}\right)^* = -j\frac{P}{V}\left(\tan(cos^{-1}(PF_{new})) - \tan(cos^{-1}(PF_{old}))\right)$$

$$\Rightarrow I_c = -j\frac{P}{V}\left(\tan(cos^{-1}(0.98) - \tan(cos^{-1}(0.913)\right) = j118.9 = 118.9\angle 90^0 \ A\,rms$$

$$\therefore Z_c = \frac{V}{I_c} = \frac{230}{118.9\angle 90^0} = -j1.934\ \Omega$$

(c) Yes. Selecting the impedance of the corrective device to be small enough can switch to a leading PF.

In this case, this can be achieved by setting

$$Z_c \leq -j\frac{V^2}{P\left(\tan(cos^{-1}(PF_{old}))\right)} = -j1.41$$

or, for operating frequency of 60 Hz by using a corrective capacitor value of

$$C \geq \frac{P\left(\tan(cos^{-1}(PF_{old}))\right)}{\omega V^2} = \frac{50 \times 10^3\left(\tan(cos^{-1}(0.8))\right)}{377(230)^2} = 1.88\ mF$$

44.

$$Z_{eq} = \left(\frac{1}{18+j10} + \frac{1}{-j5} + \frac{1}{1000}\right)^{-1} = 5.5\angle{-76^o}\,\Omega$$

$$I_s = \frac{V_s}{18+Z_{eq}} = \frac{240\angle 45^o}{18+Z_{eq}} = 12\angle 60.5^o\ A\ rms$$

$$V_1 = \frac{Z_{eq}}{18+Z_{eq}} V_s = 66\angle{-16^o}\ V\ rms$$

$$S_{18\,\Omega,1} = I_s I_s^* 18\angle 0^o = \boxed{2.58\angle 0^o\ kVA}$$

$$I_2 = \frac{V_1}{18+j10} = 3.2\angle{-44.7^o}\ A\ rms$$

$$S_{18\,\Omega,2} = I_2 I_2^* 18\angle 0^o = \boxed{184.4\angle 0^o\ VA}$$

$$V_{j10\,\Omega} = j10 I_2 = 32\angle 45.2^o\ V\ rms$$

$$S_{j10\,\Omega} = V_{j10} I_2^* = \boxed{102.45\angle 90^o\ \ VA}$$

$$I_{-j5\,\Omega} = \frac{V_1}{-j10} = 13.2\angle 74.3^o\ A\ rms$$

$$S_{-j5\,\Omega} = V_1 I_{-j5\,\Omega}^* = \boxed{869\angle-90^o\ \ VA}$$

$$S_{1000\,\Omega} = \frac{V_1 V_1^*}{1000}\angle 0^o = \boxed{4.34\angle 0^o\ VA}$$

Also, $S_{source} = V_s I_s^* = (240\angle 45^o)(12\angle{-60.5^o}) = 2.874\angle{-15.46^o}\ \ kVA$

(Note: the sum of the complex power absorbed by the passive elements equals the complex power provided of the source.)

$$PF_{source} = \cos(-15.46^o) = \boxed{0.9638\ \ leading}$$

45.

For the existing circuit,

$Z_{in} = -j10 + (20//(j20 + 10)) = 11.435\angle -19.65^0\ \Omega$

$PF_{source} = \cos(19.65^0\ ) = 0.94\ leading$ leading

Let the required capacitor impedance be: $-jZ_C$. Then:

$Z_{in,new} = -j10 + (20//(j20 + (10//(-jZ_C))))$, or

$$Z_{in,new} = \frac{(2\times 10^3 + 100Z_C) + j(2\times 10^3 - 400Z_C)}{(200 + 20Z_C) + j(200 - 30Z_C)}$$

It is required that: $\angle Z_{in,new} = -cos^{-1}(0.95) \Rightarrow$

$$tan^{-1}\left(\frac{(2\times 10^3 - 400Z_C)(200 + 20Z_C) - (2\times 10^3 + 100Z_C)(200 - 30Z_C)}{(2\times 10^3 + 100Z_C)(200 + 20Z_C) + (2\times 10^3 - 400Z_C)(200 - 30Z_C)}\right) =$$

$$\frac{-5Z_C}{14Z_c^2 - 80Z_C + 800} = \tan\left(-cos^{-1}(0.95)\right) = A \Rightarrow (5 + 14A)Z_c^2 - 80AZ_C + 800A = 0$$

Solving the quadratic provides two values: $Z_C = 8.821\ \Omega\ \ and\ Z_C = -74.82\ \Omega$

The positive value yields a capacitive correction, as required, so that:

$$Z_C = \frac{1}{\omega C} = 8.821\ \Rightarrow C = \frac{1}{8.821(2\pi)50} = \boxed{360.85\ \mu F}$$

46.

(a) Benchmark reactive power value: 0.7(P) = 0.7(175) = 122.5 KVAR
Reactive power subject to penalty: 205 - 122.5 = 82.5 KVAR
Annual cost in penalties: 12(82.5)($0.15) = $148.5

(b) Using a 100 KVAR capacitor compensation the total reactive power is reduced to:
205 – 100 = 105 kVAR, which is now below the penalty benchmark. For compensation at $75/KVAR the savings are:
For the first year: $148.5 - $75 = $73.5
For the second year (and subsequently): $148.5 – 0 = $148.5

47.

$$Z_{eq} = \left(\frac{1}{10} + \frac{1}{15 - j25}\right)^{-1} = 8.25\angle{-14^o}\,\Omega$$

$$I_s = \frac{V_s}{j30 + Z_{eq}} = \frac{50\angle{-17^o}}{j30 + Z_{eq}} = 1.72\angle{-91^o}\ A\,rms$$

$$V_{j30\,\Omega} = j30 I_s = 51.5\angle{-1^o}\ V\,rms$$

$$S_{j30\,\Omega} = V_{j30\,\Omega} I_s^* = \boxed{88.4\angle 90^o\ VA}$$

$$V_1 = \frac{Z_{eq}}{j30 + Z_{eq}} V_s = 14.12\angle{-105.1^o}\ V\,rms$$

$$S_{10\,\Omega} = \frac{V_1 V_1^*}{1000} = \boxed{20\angle 0^o\ VA}$$

$$I_2 = \frac{V_1}{-j25 + 15} = 0.48\angle{-46^o}\ A\,rms$$

$$S_{15\,\Omega} = I_2 I_2^* 15 = \boxed{3.54\angle 0^o\ VA}$$

$$V_{j-25\,\Omega} = -j25 I_2 = 12.1\angle{-136^o}\ V\,rms$$

$$S_{-j25\,\Omega} = V_{-j25\,\Omega} I_2^* = \boxed{5.9\angle -90^o\ VA}$$

Also, $S_{source} = V_s I_s^* = (50\angle{-17^o})(1.72\angle{-91^o}) = 85.85\angle 74.05^o\ \ kVA$

(Note: the sum of the complex power absorbed by the passive elements equals the complex power provided of the source.)

$$PF_{source} = \cos(74.05^o) = \boxed{0.275\ \ leading}$$

48.

(a) $200\ mH \rightarrow j2\Omega$

$V_s = 50\angle-17^o\ V\ rms$

Mesh analysis:

$$\left.\begin{aligned}-V_s + j30I_1 + j2(I_1 - I_2) = 0\\ j2(I_2 - I_2) - j25I_2 + 15I_2 = 0\end{aligned}\right\} \Rightarrow \begin{bmatrix} j32 & -j2 \\ -j2 & 15 - j23 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_s \\ 0 \end{bmatrix} \Rightarrow \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$$= \begin{bmatrix} 1.56\angle-107^o \\ 0.11\angle40^o \end{bmatrix}\ A\ rms$$

$$PF_{source} = \cos(-17^o + 107^o) = 0$$

(b) $AP_{source} = |V_s||I_1| = 78\ VA$

(d) $Q_{source} = |V_s||I_1|\sin(-17^o + 107^o) = 78\ VAR$

49.

(a) $V_s = 50\angle{-17^o}\ V\ rms$

Mesh analysis:

$$\left.\begin{array}{l} -V_s + j30I_1 + 10(I_1 - I_2) = 0 \\ 10(I_2 - I_2) + j30I_2 + 15I_2 = 0 \end{array}\right\} \Rightarrow \begin{bmatrix} 10 + j30 & -10 \\ -10 & 25 + j30 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_s \\ 0 \end{bmatrix} \Rightarrow$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 1.5132\angle{-92.3^o} \\ 0.3875\angle - 142.5^o \end{bmatrix} A\ rms$$

$S_{10\ \Omega} = (I_1 - I_2)(I_1 - I_2)^* 10 = \boxed{16.89\ VA}$

$S_{15\ \Omega} = I_2 {I_2}^* 15 = \boxed{2.25\ VA}$

$S_{j30,1\ \Omega} = j30 I_1 {I_1}^* = \boxed{68.7\angle 90^o\ VA}$

$S_{j30,2\ \Omega} = j30 I_2 {I_2}^* = \boxed{4.5\angle 90^o\ VA}$

(b) $S_{source} = V_s {I_1}^* = \boxed{75.66\angle 75.34^o\ \ VA}$

Note that the sum of the complex power absorbed by the passive elements equals the complex power supplied of the source.

(c) $PF_{source} = \cos(75.34^o) = \boxed{0.253\ \ lagging}$

50. Let $S_{old} = P_{old} + jQ_{old}$ be the complex power associated with the original load conditions. Adding a capacitor in parallel results in total complex power: $S_{old} = P_{old} + jQ_{old}$.

Then, the capacitor reactive power is:
$S_c = jQ_c = S_{new} - S_{old} = P_{new} + jQ_{new} - P_{old} - jQ_{old}$
Since the load average power requirements remain unchanged: $P_{new} = P_{old}$, and so

$$S_c = jQ_c = jQ_{new} - jQ_{old} = jP(tan\theta_{new} - tan\theta_{old}) = VI_C^*$$

$$I_C = \left(\frac{S_c}{V}\right)^* = \frac{[jP(tan\theta_{new} - tan\theta_{old})]^*}{V} = \frac{jP(tan\theta_{old} - tan\theta_{new})}{V}$$

Since, $Z_C = \frac{V}{I_C} = \frac{1}{j\omega C} \Rightarrow \boxed{C = \frac{P(tan\theta_{old} - tan\theta_{new})}{\omega V^2}}$

51.

(a) $V_m = 1200\sqrt{2} = \boxed{1697\ V}$

(b) $(1\ ms) = 1200\sqrt{2}\cos(2\pi 50 \times 10^{-3})\ 10\sqrt{2}\cos\left(2\pi 50 \times 10^{-3} + cos^{-1}(0.9)\right) = \boxed{16.46\ kW}$

(c) $AP_s = 1200(10) = \boxed{12\ kVA}$

(d) $Q = 1200(20)sin^{-1}(0.9) = \boxed{9.4\ kVAR}$

(e) $Z_L = \frac{1200}{10}\angle cos^{-1}(0.9) = \boxed{120\angle 25.84^0\ \Omega}$

(f) $S = 1200(20)\angle cos^{-1}(0.9) = \boxed{12\angle 25.84^0\ \ kVA}$

52.

(a) $V_{50\Omega} = 50I_s = 250\angle 0^0\ V$

$I_{80\Omega} = \dfrac{j60}{80 + j60} I_s = 3\angle 53.1^0\ A$

$V_{ab} = 80I_{80\Omega} = 240\angle 53.1^0\ V$

$V_s = V_{ab} + V_{50} = 438.3\angle 26^0\ V$

$PF_S = \cos(0 - 26) = 0.9\ lagging$

(b) $I_{j60\Omega} = I_s - I_{80\Omega} = 4\angle{-37^0}\ A$

$AP_{50\Omega} = 250(5) = 1250\ VA$

$AP_{80\Omega} = 240(3) = 720\ VA$

$AP_{j60\Omega} = 240(4) = 960\ VA$

(c) $P_s = \frac{438.29*(5)}{2}\cos(26^0) = 985\ W$

(d) $V_{TH} = V_{ab} = 240\angle 53.1^0\ V$

$Z_{TH} = 80//j60 = 48\angle 53.1^0\ \Omega$

$$P_{100\Omega} = \frac{|V_{100\Omega}|^2}{2(100)} = \frac{\left|\frac{100}{100 + Z_{TH}} V_{TH}\right|^2}{200} = 159.43\ W$$

53.

(a) The load is resistive (100 Ω) and so $PF_{load} = 1$

(b) KCL:

$$\frac{V_s}{j60} - 5 + \frac{V_s}{80} + \frac{V_s}{100} = 0 \Rightarrow V_s = 178.6\angle 36.5^o\ V$$

$$P_s = \frac{1}{2} V_s I_s \cos(36.5^o - 0^o) = 358.7\ W$$

(c) $I_{j60\,\Omega} = \frac{V_s}{j60} = 2.98\angle{-53.5^o}\ A$

$$p_{j60\,\Omega}(t) = v_{j60\,\Omega}(t) i_{j60\,\Omega}(t) = |V_s|\cos(2\pi 50t + \angle V_s)|I_{j60\,\Omega}|cos(2\pi 50t + \angle I_{j60\,\Omega})$$

$$p_{j60\,\Omega}(t) = 178.6\cos(2\pi 50t + 36.5^o) 2.98 cos(2\pi 50t - 53.5^o)$$

$For\ t = 2\ ms, \quad p_{j60\,\Omega}(t) = 152.2\ W$

(d)

In unaltered circuit, $Z = \frac{V_s}{I_s} = \frac{178.6\angle 36.5^o}{5\angle 0^o} = 35.7\angle 36.5^o = A + jB = 28.7 + j21.3\ \Omega$

Including a capacitor C, with impedance X_c = -j/ωC, in parallel with 100 Ω load results in:

$$Z_{new} = Z // -jX_c$$

$$Z_{new} = \frac{-jX_c Z}{Z - jX_c} = \frac{-jX_c(A + jB)}{(A + jB) - jX_c} = \frac{AX_C^2 + j(-A^2 X_c + BX_C^2 - B^2 X_c)}{A^2 + (B - X_c)^2}$$

It is required that $\angle Z_{new} = tan^{-1}\left(\frac{-A^2 X_c + BX_C^2 - B^2 X_c}{AX_C^2}\right) = cos^{-1}(0.95) \Rightarrow$

$$\frac{-A^2 - B^2 + BX_c}{AX_c} = \tan\left(cos^{-1}(0.95)\right) \Rightarrow X_c = \frac{A^2 + B^2}{B - \text{Atan}\left(cos^{-1}(0.95)\right)} = 107.86\ \Omega$$

and $C = \frac{1}{\omega X_c} \Rightarrow C = 185.4\ \mu F$

54. 20 mH → j0.64 Ω

(a) $I_S = \frac{V_S}{5+j0.64} = 8.93\angle{-97.3^0}\ A$

$$Q_S = \frac{|V_S||I_S|}{2}\sin(\theta-\varphi) = \frac{45(8.93)}{2}\sin(-90^o + 97.3^0) = \boxed{0.315\ VAR}$$

(b) $AP_{5\Omega} = \frac{I_S(I_S)^*5}{2} = \boxed{199.24\ VA}$

$$AP_s = -\frac{|V_s||I_S|}{2} = \boxed{-200.86\ VA}\quad (i.e., supplied)$$

$$V_{20\ mH} = j0.64 I_S = 5.713\angle{-73^0}\ V$$

$$AP_{20\ mH} = \frac{|V_{20\ mH}||I_S|}{2} = \boxed{25.5\ VA}$$

(c) $S_s = V_s(I_S)^* = \boxed{-200.86\angle 7.3^0\ VA}\quad (i.e., supplied)$

$$S_{5\Omega} = AP_{5\Omega}\angle 0^0 = \boxed{199.24\angle 0^0\ VA}$$

$$S_{20\ mH} = V_{20\ mH}(I_S)^* = \boxed{25.5\angle 90^0\ VA}$$

(d) $PF_s = \cos(-90^o + 97.3^0) = \boxed{0.992\ \ lagging}$

55.

(a) $Z_{in} = jX_1 + (R//jX_2)$

$$Z_{in} = jX_1 + \left(\frac{1}{R} + \frac{1}{jX_2}\right)^{-1} = jX_1 + \frac{jRX_2}{R + jX_2} = \frac{jRX_2 + jX_1(R + jX_2)}{R + jX_2}$$

$$Z_{in} = \frac{RX_2^2 + j(X_1X_2^2 + R^2X_1 + R^2X_2)}{R^2 + X_2^2}.$$

$$S = V_{s,rms}I_{s,rms}^* = V_{s,rms}\left(\frac{V_{s,rms}}{Z_{in}}\right)^* = \frac{V_{s,rms}V_{s,rms}^*}{Z_{in}^*} = \frac{\left(\frac{208}{\sqrt{2}}\right)^2}{|Z_{in}|}\angle Z_{in}$$

where

$$|Z_{in}| = \frac{\sqrt{(RX_2^2)^2 + (X_1X_2^2 + R^2X_1 + R^2X_2)^2}}{R^2 + X_2^2}$$

and

$$\angle Z_{in} = tan^{-1}\left(\frac{X_1X_2^2 + R^2X_1 + R^2X_2}{RX_2^2}\right)$$

(b) For ω = 40 rad/s, 14 mH → jX_1 = j0.56 Ω and 28 mH → jX_2 = j1.12 Ω

Adding capacitor with impedance $Z_c = -jX_c = -j/\omega C$, in parallel to 28 mH inductor:

$Z_{in} = jX_1 + (R//jX_2//-jX_C)$

$$Z_{in} = jX_1 + \left(\frac{1}{R} + \frac{1}{jX_2} + \frac{1}{-jX_C}\right)^{-1} = jX_1 + \frac{RX_2X_C}{X_2X_C - jRX_C + jRX_2}$$

$$Z_{in} = \frac{RX_2X_C + jX_1(X_2X_C - jRX_C + jRX_2)}{X_2X_C - jRX_C + jRX_2}$$

$$Z_{in} = \frac{((RX_2X_C) - RX_1(X_2 - X_C) + jX_1X_2X_C)(X_2X_C - jR(X_2 - X_C))}{(X_2X_C)^2 + (R(X_2 - X_C))^2}$$

Z_{in} must be real for unity PF. Setting its imaginary part to zero we obtain a quadratic equation with X_c as the unknown:

$$(X_1X_2^2 + R^2X_2 + R^2X_1)X_C^2 - R^2(X_2 + 2X_1X_2)\,X_C + R^2X_1X_2^2 = 0$$

Positive valued solutions for X_c satisfy the requirements and the necessary capacitance is:

$$C = \frac{1}{\omega X_C}$$

For example, for R =2 Ω, we obtain $X_C = \{0.956,\ 0.396\}\ \Omega$ or two capacitance values $C = \frac{1}{\omega X_C} = \{26.1,\ 63.1\}\ mF$, which provide unity PF.

Chapter 12

Ebrahim Forati
6/1/2012

1)

a)

$$V_{cb} = -V_{ec} + V_{eb} = 8.35 \text{ V}$$

b)

$$V_{be} = 0.65 \text{ V}$$
$$\text{I}_b = 1 \ \mu\text{A}$$
$$P = 0.65 \ \mu\text{W}$$

2)

a)

$$V_{gs} = -0.2 \text{ V}$$
$$\text{V}_{dg} = 3.2 \text{ V}$$

b)

$$P_{gs} = V_{gs} I_g = -20 \text{ PW}$$

If current is going into the gate, 20 pW is generating in the junction.

3)

a)

$$V_{cn} = 400\measuredangle 273$$

b)

$$V_{an} - V_{bn} = 400\measuredangle 33 - 400\measuredangle 153 = 692.8\measuredangle 3 \text{ V}$$

c)

$$V_{ax} = V_{an} + V_{nc} + V_{cx} = 639.4\measuredangle 31.12 \ \ \text{V}$$

d)

$$V_{bx} = V_{ba} + V_{ax} = 327.7\measuredangle 116.15 \ \ \text{V}$$

4)

A power source having more than two terminals with different phases(amplitude or phase) between terminals is called a polyphase source.

Economically they are more efficient for long distance power transmission.

For balanced sources, amplitudes of voltages between any two terminals are the same and they have

120 degrees phase difference.

5)

$$V_{21} = -V_{12} = -9\measuredangle 30$$
$$V_{13} = V_{12} - V_{32} = 9.97\measuredangle 12.76$$
$$V_{34} = V_{31} + V_{14} = -9.97\measuredangle 12.76 + 2\measuredangle 10 = 7.97\measuredangle -166$$
$$V_{24} = V_{21} + V_{14} = -9\measuredangle 30 + 2\measuredangle 10 = 7.15\measuredangle -144$$

6)

$$V_{12} = V_{14} + V_{24} = 9 - j - (3 + 3j) = 6 - 4j = 7.2\measuredangle - 33.7 \ \text{V}$$

$$V_{32} = V_{34} - V_{24} = 8 - (3 + 3j) = 5 - 3j = 5.8\measuredangle - 30.9 \ \text{V}$$

$$V_{13} = V_{14} - V_{34} = 9 - j - (8) = 1 - j = 1.4\measuredangle - 45 \ \text{V}$$

7)

a)

$$I_{ab} = 9 \text{ A}$$
$$I_{cd} = 8 \text{ A}$$
$$I_{de} = 9 \text{ A}$$
$$I_{fe} = -10 \text{ A}$$
$$I_{be} = 1 \text{ A}$$

b)

$$R = \frac{125}{9}$$

8)

a)

$$I_{gh} = -5 \text{ A}$$
$$I_{cd} = 5 \text{ A}$$
$$I_{dh} = 1 \text{ A}$$

$$I_{ed} = -4 \text{ A}$$
$$I_{ei} = 3 \text{ A}$$
$$I_{jf} = -1 \text{ A}$$

c)

Left mesh: 5 A

Middle mesh: 4 A

Right mesh: 1 A

9)

a) All of voltages

b) all except de and fj

10) they need higher power. If they don’t increase voltage, they will need higher current and therefore thicker wires which is not economic.

11)

a)

$$V_{an} = 110\measuredangle 0$$
$$V_{bn} = -110\measuredangle 0$$

b)

$$V_{z3} = 220\measuredangle 0$$

c)

$$P_{z_1} = \frac{V_{an}{}^2}{\mathrm{Re}(z_1)} = \frac{110^2}{50} = 242 \text{ W}$$
$$P_{z_2} = \frac{V_{an}{}^2}{\mathrm{Re}(z_2)} = \frac{110^2}{100} = 121 \text{ W}$$
$$P_{z_3} = \frac{V_{an}{}^2}{\mathrm{Re}(z_3)} = \frac{220^2}{100} = 484 \text{ W}$$
$$\mathrm{P}_{V_{an}} = -\left[242 + 484/2\right] = -484 \text{ W}$$
$$\mathrm{P}_{V_{an}} = -\left[121 + 484/2\right] = -363 \text{ W}$$

d)

resistor and capacitor

R=100 ohm

$$\frac{1}{\omega C} = 90 \Rightarrow C = \frac{1}{2\pi \times 60 \times 90} = 29.47\ \mu\text{F}$$

12)

$$I_1 = 1.8\measuredangle -128.4\ \ \text{A}$$
$$I_2 = 0.58\measuredangle 179.2\ \ \text{A}$$
$$I_1 = 1.68\measuredangle -0.24\ \ \text{A}$$

a)

$$P_1 = 3.47\ \ \text{Watts}$$
$$P_2 = 0.33\ \ \text{Watts}$$

b)

$$P_{200\Omega} = 488.55\ \ \text{Watts}$$
$$P_{50\Omega} = 256.8\ \ \text{Watts}$$
$$P_{10\Omega} = 3.37\ \ \text{Watts}$$

c)

$$P_{total} = 748.72\ \ \text{Watts}$$
$$\text{Q=}500 \times \text{I}_2^2 = 168.68$$
$$\cos\varphi = \frac{748.72}{\sqrt{748.72^2 + 168.68^2}} = 0.9755$$

13)

a)

$$\cos(\varphi) = 0.9806$$

b)

$$C = 3.2 \ \ mF$$

14)

a) I=0 A

b)

$$z = 155 + 25j \ \ \Omega$$
or
$$z=250-67j \ \ \Omega$$

15)

a)

$$400\measuredangle 33 + 400\measuredangle -87 + 400\measuredangle -207 = \ 335 + 217j + 21 - 399j - 356 + 181j = 0$$

b)

positive sequence. Because,

$$\measuredangle V_{bn} = \measuredangle V_{an} - 120$$

16)

$$I_a = \frac{240}{50 + 2\pi \times 50 \times 0.5i} = 1.45\measuredangle -72.3 \ \ \text{A}$$

$$I_b = \frac{240\measuredangle -120}{50 + 2\pi \times 50 \times 0.5i} = 1.45\measuredangle -192.3 \ \ \text{A}$$

$$I_c = \frac{240\measuredangle 120}{50 + 2\pi \times 50 \times 0.5i} = 1.45\measuredangle 47.7 \ \ \text{A}$$

b)

$$\cos(\varphi) = 0.3$$

c)

$$P = 3|V||I|\cos\varphi = 3\times 240\times 1.45\times 0.3 = 313.2 \text{ Watts}$$

17)

a)

$$V_{an} = 208\measuredangle 0 \text{ V}$$
$$V_{bn} = 208\measuredangle -120 \text{ V}$$
$$V_{cn} = 208\measuredangle 120 \text{ V}$$
$$V_{ab} = \sqrt{3}\times 208\measuredangle 30 \text{ V}$$
$$V_{bc} = \sqrt{3}\times 208\measuredangle -90 \text{ V}$$
$$V_{ca} = \sqrt{3}\times 208\measuredangle -210 \text{ V}$$

$$I_{aA} = 208\measuredangle 0 \text{ mA}$$
$$I_{bB} = 208\measuredangle -120 \text{ mA}$$
$$I_{cC} = 208\measuredangle 120 \text{ mA}$$

b)

$$V_{an} = 208\measuredangle 0 \text{ V}$$
$$V_{bn} = 208\measuredangle -120 \text{ V}$$
$$V_{cn} = 208\measuredangle 120 \text{ V}$$
$$V_{ab} = \sqrt{3}\times 208\measuredangle 30 \text{ V}$$
$$V_{bc} = \sqrt{3}\times 208\measuredangle -90 \text{ V}$$
$$V_{ca} = \sqrt{3}\times 208\measuredangle -210 \text{ V}$$

$$I_{aA} = 1.87\measuredangle -25.8 \text{ A}$$
$$I_{bB} = 1.87\measuredangle -145.8 \text{ A}$$
$$I_{cC} = 1.87\measuredangle 94.2 \text{ A}$$

C)

$$V_{an} = 208\measuredangle 0 \ \ \text{V}$$
$$V_{bn} = 208\measuredangle -120 \ \ \text{V}$$
$$V_{cn} = 208\measuredangle 120 \ \ \text{V}$$
$$V_{ab} = \sqrt{3}\times 208\measuredangle 30 \ \ \text{V}$$
$$V_{bc} = \sqrt{3}\times 208\measuredangle -90 \ \ \text{V}$$
$$V_{ca} = \sqrt{3}\times 208\measuredangle -210 \ \ \text{V}$$

$$I_{aA} = 1.87\measuredangle 25.8 \ \ \text{A}$$
$$I_{bB} = 1.87\measuredangle -94.2 \ \ \text{A}$$
$$I_{cC} = 1.87\measuredangle 145.8 \ \ \text{A}$$

18)

a)

$$V_{an} = 208\measuredangle 0 \ \ \text{V}$$
$$V_{bn} = 208\measuredangle -120 \ \ \text{V}$$
$$V_{cn} = 208\measuredangle 120 \ \ \text{V}$$
$$V_{ab} = \sqrt{3}\times 208\measuredangle 30 \ \ \text{V}$$
$$V_{bc} = \sqrt{3}\times 208\measuredangle -90 \ \ \text{V}$$
$$V_{ca} = \sqrt{3}\times 208\measuredangle -210 \ \ \text{V}$$

$$I_{aA} = 205.9\measuredangle 0 \ \ \text{mA}$$
$$I_{bB} = 205.9\measuredangle -120 \ \ \text{mA}$$
$$I_{cC} = 205.9\measuredangle 120 \ \ \text{mA}$$

b)

$$V_{an} = 208\measuredangle 0 \text{ V}$$
$$V_{bn} = 208\measuredangle -120 \text{ V}$$
$$V_{cn} = 208\measuredangle 120 \text{ V}$$
$$V_{ab} = \sqrt{3}\times 208\measuredangle 30 \text{ V}$$
$$V_{bc} = \sqrt{3}\times 208\measuredangle -90 \text{ V}$$
$$V_{ca} = \sqrt{3}\times 208\measuredangle -210 \text{ V}$$

$$I_{aA} = 1.73\measuredangle -23.57 \text{ A}$$
$$I_{bB} = 1.73\measuredangle -143.57 \text{ A}$$
$$I_{cC} = 1.73\measuredangle 96.43 \text{ A}$$

c)

$$V_{an} = 208\measuredangle 0 \text{ V}$$
$$V_{bn} = 208\measuredangle -120 \text{ V}$$
$$V_{cn} = 208\measuredangle 120 \text{ V}$$
$$V_{ab} = \sqrt{3}\times 208\measuredangle 30 \text{ V}$$
$$V_{bc} = \sqrt{3}\times 208\measuredangle -90 \text{ V}$$
$$V_{ca} = \sqrt{3}\times 208\measuredangle -210 \text{ V}$$

$$I_{aA} = 1.73\measuredangle 23.57 \text{ A}$$
$$I_{bB} = 1.73\measuredangle -96.43 \text{ A}$$
$$I_{cC} = 1.73\measuredangle 143.57 \text{ A}$$

19)

a)

$$Z_p = 0.926 - 0.261j$$
$$V_{an} = \frac{208}{\sqrt{3}}\measuredangle -30 \text{ V}$$
$$V_{bn} = \frac{208}{\sqrt{3}}\measuredangle -150 \text{ V}$$
$$V_{cn} = \frac{208}{\sqrt{3}}\measuredangle 90 \text{ V}$$

b)

$$V_{ab} = 208\measuredangle 0 \text{ V}$$
$$V_{an} = 208\measuredangle -120 \text{ V}$$
$$V_{an} = 208\measuredangle 120 \text{ V}$$

c)

$$I_{aA} = \frac{208}{0.926 - 0.261j} = 216.19\measuredangle 15.7 \text{ A}$$
$$\text{I}_{bB} = 216.19\measuredangle -104.3 \text{ A}$$
$$I_{cC} = 216.19\measuredangle 135.7 \text{ A}$$

d)

$$P = 3R|I|^2 = 3\times 0.926\times 216.19^2 = 129.84 \text{ kW}$$

20)

a)

$$I = 6.8 \text{ A}$$
$$z_p = 8.5\measuredangle 31.8 \ \Omega$$

b)

$$I = 5.64 \text{ A}$$
$$z_p = 10.22\measuredangle -23.07 \ \Omega$$

21)

a)

$$\cos(\varphi) = 0.9688$$

b)

$$P = 22.76 \text{ kW}$$

c)

$$\cos\varphi = 0.9803$$
$$P = 18.36 \text{ kW}$$

22)

a)

$$V_L = 184.4 \text{ V}$$

b)

$$V_p = 106.4 \text{ V}$$

23)

a)

$$P = \frac{210}{\sqrt{3}} |I| \times 0.75 \Rightarrow \quad |I| = 1.43 \text{ A}$$

P=390 W

b)

$$z = \frac{\frac{210}{\sqrt{3}}}{1.43} \measuredangle -41.4 = 63.6 - 56j$$

$$z_{new} = \frac{1}{\frac{1}{63.6-56j} + 1} \simeq 1$$

$$I \simeq V = \frac{210}{\sqrt{3}}$$

$$P = \left(\frac{210}{\sqrt{3}}\right)^2 \times 3 = 44.1 \text{ kW}$$

24)

a)

$$P_c = 3VI = 3\frac{300}{\sqrt{3}} \times \frac{300}{\sqrt{3}z_{total}}$$

$$P_c = 3VI = 3\frac{300}{\sqrt{3}} \times \frac{300}{\sqrt{3}(3.7 - 0.95j)} = 22.76 \text{ kW}$$

b)

$$P_c = 3VI = 3\frac{300}{\sqrt{3}} \times \frac{300}{\sqrt{3}(4.7 - 0.95j)} = 18.36 \text{ kW}$$

25)

$$z = 0.774 \text{ -27.8j } \Omega$$

$$I = \frac{115}{\sqrt{3}} / z = \text{ 0.0664 + 2.3856j A}$$

$$|I| = 2.38 \text{ A}$$

$$P = \text{Re}\left(3 \times \frac{V^2}{z}\right) = 13.22 \text{ W}$$

26)

a)

$$\cos(\varphi) = 0.7$$

$$V_L = 208\sqrt{3}$$

$$I_P = 13.22 \text{ A}$$

$$\text{I}_L = 22.9 \text{ A}$$

b)

$$z_p = \frac{208\sqrt{3}}{13.22}\measuredangle -45.6 = 27.25\measuredangle -45.6$$

$$z_{new} = 9.44 - 9.44j \quad \Omega$$

$$\cos(\varphi_{new}) = 0.707$$

$$I_L = 15.58 \quad \text{A}$$

$$P = \sqrt{3}\times 208 \times I_L \times 0.707 = 3.97 \text{ kW}$$

27)

a)

$$z_p = 0.0002 - 0.318j \quad \Omega$$

$$\text{I}_p = \frac{400\sqrt{3}}{|z_p|} = 2.17 \text{ KA}$$

b)

$$\text{I}_L = \sqrt{3}\text{I}_p = \frac{4003}{|z_p|} = 3.77 \text{ KA}$$

c)

$$V_L = 400\sqrt{3}$$

d)

$$\cos(\varphi) = 6.7\times 10^{-4}$$

e)

$$P = \sqrt{3}V_L I_L \cos(\varphi) = 3 \text{ kW}$$

28)

$$z_p = 94.2 + 195.5j$$

$$I_L = \frac{400}{|z_p|} = 1.82 \text{ A}$$

$$V_L = 400\sqrt{3} \text{ V}$$

$$I_P = I_L = 1.84 \text{ A}$$

$$\cos(\varphi) = 0.4341$$

b)

$$V_L = V_P = 400\sqrt{3}$$

$$I_P = \frac{400\sqrt{3}}{|z_p|} = 3.19 \text{ A}$$

$$I_L = \sqrt{3} I_P = 5.53 \text{ A}$$

$$\cos(\varphi) = 0.4341$$

29)

Y connection:

$$P = 948 \text{ W}$$

Delta connection:

$$P = 2.88 \text{ kW}$$

30)

a)

$$3I_{p1}=\frac{10\text{ k}}{400}=25\text{ A}$$
$$3I_{p2}=\frac{25\text{ k}}{400}=62.5\text{ A}$$
$$|z_1|=48\ \ \Omega$$
$$|z_2|=19.2\ \ \Omega$$
$$\text{z}_1=36+31.75j\ \ \Omega$$
$$\text{z}_2=15.36-11.52\ \ \Omega$$
$$z_1\,||\,z_2=15.97-4.87j\ \ \Omega$$
$$\cos(\varphi)\text{=0.956 lead}$$

b)

$$\sqrt{3}\times400\times\sqrt{3}\times\frac{400}{|z_1\,||\,z_2|}\times0.956=27.5\text{ kW}$$

C)

$$I_{p_1}=\frac{400}{|z_1|}=8.33\text{ A}$$
$$I_{p2}=\frac{400}{|z_2|}=20.83\text{ A}$$

31)

$$V_LI_L=8.34\ \ \text{KVA}$$
$$\text{V}_L=400-RI_L$$
$$RI_L{}^2=100$$
$$\Rightarrow I=21.12\ \ \text{A}$$
$$\text{R=224 m}\Omega$$

32)

$$V_{an} = \frac{160}{\sqrt{3}} \measuredangle 240 \ \text{V}$$
$$I_{bB} = 36.08 \measuredangle 95.54 \ \text{A}$$

33)

34)

35)

36)

a) 1.54 KW up scaled

b) 2.154 kW up scaled

c) 614 W up scaled

37) P=170.6 Watts

38)P=-184.54 Watts

39)

$$P_A = 850 \text{ Watts}$$
$$\text{P}_B = -225 \text{ Watts}$$

Yes, sum of them is the total power.

40)

$$P_1 = P_2 = P_3 = 861.26 \ \text{Watts}$$

41)

There is no need to neutral line. If one of loads fails to open, phases remain correct without any need to neutral ground.

42)

a)

$$V_{AB} = 208\sqrt{3}\measuredangle 30 = 360\measuredangle 30 \ \ \text{V}$$
$$V_{BC} = 360\measuredangle -90 \ \ \text{V}$$
$$V_{CA} = 360\measuredangle 150 \ \text{V}$$

$$\text{I}_A = 2.8\measuredangle -90 \ \ \text{A}$$
$$\text{I}_B = 2.8\measuredangle -210 \ \ \text{A}$$
$$\text{I}_C = 2.8\measuredangle 30 \ \ \text{A}$$

b)

$$V_{AB} = 208\sqrt{3}\measuredangle 30 = 360\measuredangle 30 \ \ \text{V}$$
$$V_{BC} = 360\measuredangle -90 \ \ \text{V}$$
$$V_{CA} = 360\measuredangle 150 \ \text{V}$$

$$\text{I}_A = 0.95\measuredangle -90 \ \ \text{A}$$
$$\text{I}_B = 0.95\measuredangle -210 \ \ \text{A}$$
$$\text{I}_C = 0.95\measuredangle 30 \ \ \text{A}$$

43)

a) Yes, it is a delta connected load.

b)

$$V_{an} = 120\measuredangle 0 \;\; \text{V}$$
$$V_{bn} = 120\measuredangle 180 \;\; \text{V}$$
$$V_{ab} = 240\measuredangle 0 \; \text{V}$$

$$\text{I}_{Z_{AB}} = 96 - 48j \;\; \text{A}$$
$$\text{I}_{Z_{AN}} = 2.4 + 16.8j \;\; \text{A}$$
$$\text{I}_{Z_{BN}} = -37 + 15j \;\; \text{A}$$
$$\text{I}_{a} = 98.4 - 31.2j \;\; \text{A}$$
$$\text{I}_{b} = -133 + 63j \;\; \text{A}$$
$$\text{I}_{n} = 34.6 - 31.8j \;\; \text{A}$$

c) if $I_{AN} \neq I_{NB}$.

44)

We can connect computer equipments as a Y load to the available three phase power.

$$V_p = \frac{208}{\sqrt{3}} = 120 \;\; \text{V}$$

Chapter 13

1)

a) $$V_1 = L_1 \frac{di_1}{dt} + M\frac{di_2}{dt} = -0.04\sin(8t) \quad \text{V}$$

b) $$V_2 = L_2 \frac{di_2}{dt} + M\frac{di_1}{dt} = 0.3\cos(100t) \quad \text{V}$$

c) $$V_2 = L_2 \frac{di_2}{dt} + M\frac{di_1}{dt} = 0.1\cos(8t)\text{-}0.04\sin(8t - 40^o) \quad \text{V}$$

2)

$$\begin{cases} V_1 = L_1 \frac{di_1}{dt} - M\frac{di_2}{dt} \\ V_2 = L_2 \frac{di_2}{dt} - M\frac{di_1}{dt} \end{cases}$$

a)

$$V_1 = 0.8\sin(40t) \quad \text{V}$$

b)

$$V_2 = 2\sin(40t + 15^o) \quad \text{V}$$

c)

$$\begin{cases} V_1 = 24\sin(40t) \quad \text{V} \\ V_2 = 60\sin(40t + 15^o) \quad \text{V} \end{cases}$$

3)

a) $$V_1 = 10.7\sin(70t) \ \ \text{nV}$$

b)

$$V_2 = 41.25\sin\left(5t - 30^o\right) \quad \mu\text{V}$$

c)

$$V_2 = 25.5\cos\left(5t\right) \quad \mu\text{V}$$

4)

$$\begin{cases} V_1 = -L_1 \dfrac{di_1}{dt} + M \dfrac{di_2}{dt} \\ V_2 = -L_2 \dfrac{di_2}{dt} + M \dfrac{di_1}{dt} \end{cases}$$

a)

$$V_2 = -4.25\sqrt{2}e^{-t} \quad \mu\text{V}$$

b)

$$V_2 = 40\sin\left(10t\right) \quad \mu\text{V}$$

c)

$$V_2 = \ \ 489.63\sin\left(70t\right) \quad \mu\text{V}$$

5)

a) 1 and 4, 2 and 3

b) 3 and 1, 4 and 2

c) 1 and 3, 2 and 4

6)

$$M = 0.5 \text{ H}$$

7)

$$i_1 = -\frac{800}{1.5}\sin(5t) \quad \text{A}$$

8)

a)

$$V_1 = -200\cos(40t) - 100\sin(40t) \quad \mu\text{V}$$
$$V_2 = -600\cos(40t) - 100\cos(40t) \quad \mu\text{V}$$

b)

$$V_1 = -200\cos(40t) - 100\sin(40t) \quad \mu\text{V}$$
$$V_2 = 600\cos(40t) + 100\cos(40t) \quad \mu\text{V}$$

9)

a)

$$V_1 = -6\sin(2000t + 13^o) + 0.4\cos(400t) \quad \mu\text{V}$$
$$V_2 = 6\cos(400t) - 1.2\sin(2000t + 13^o) \quad \mu\text{V}$$

b)

$$V_1 = -6\sin(2000t + 13^o) - 0.4\cos(400t) \quad \mu\text{V}$$
$$V_2 = 6\cos(400t) + 1.2\sin(2000t + 13^o) \quad \mu\text{V}$$

10)

$$I_1 = 7.24 - 2.69i \quad \text{mA}$$

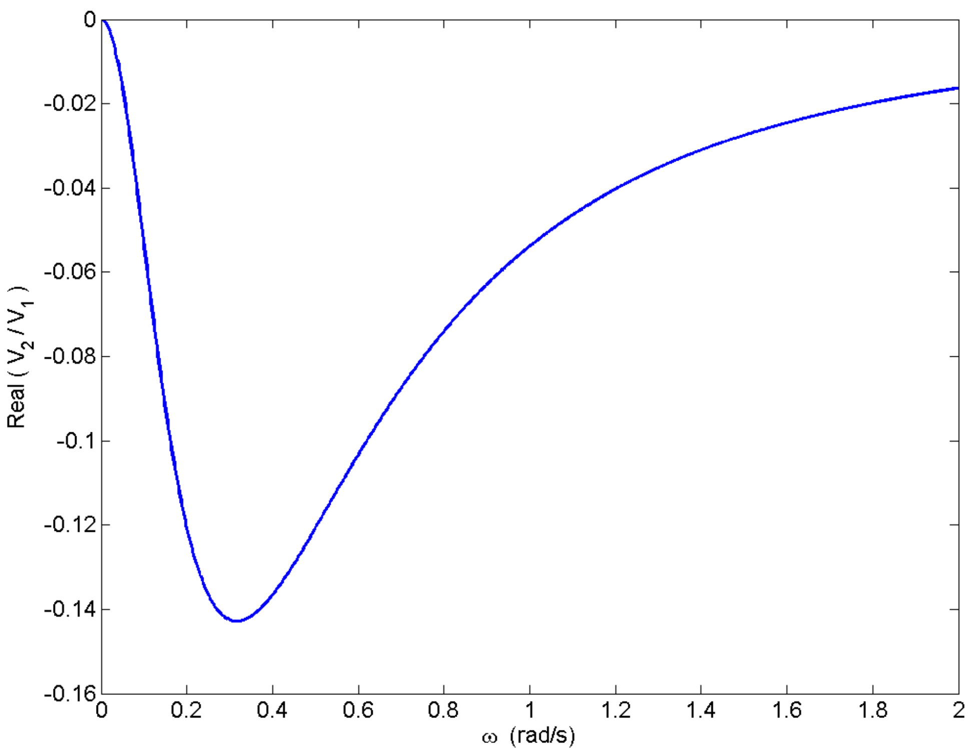
$$I_2 = -2.45 - 0.74i \quad \text{mA}$$

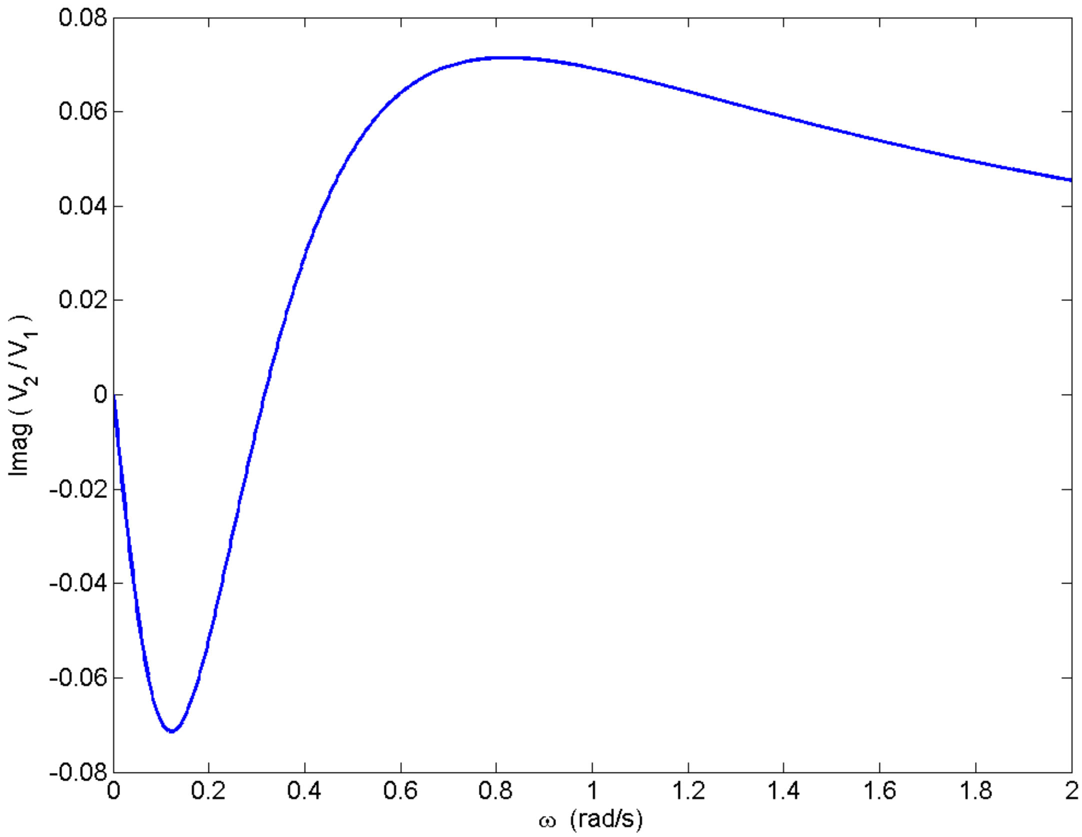
$$\frac{V_2}{V_1} = \frac{0.870(-2.45 - 0.74i)}{40} = (-53.3 - 16.2i) \times 10^{-3}$$

$$\frac{I_2}{I_1} = -0.26 + 0.2i$$

11)

$$\frac{V_2}{V_1} = \frac{-2i\omega}{4\omega^2 + (2+6i\omega)(1+4i\omega)}$$

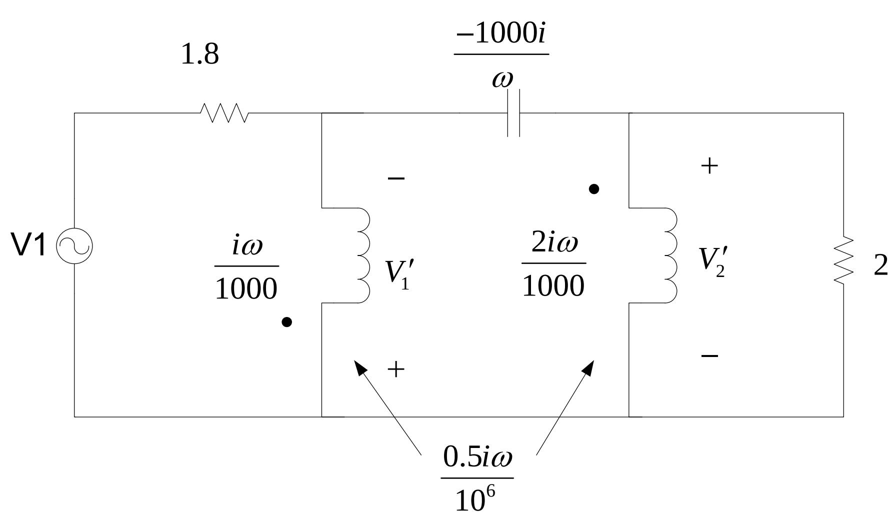




0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
Imag (V2 / V1)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
ω (rad/s)

12)

a)



1.8
−1000i / ω
V1
iω / 1000
V1′
2iω / 1000
V2′
2
0.5iω / 10^6

b)

$$\begin{cases} -V_1 + 1.8I_1 - V_1' = 0 \\ -V_2' + 2I_3 = 0 \\ V_1' + V_2' - \dfrac{1000i}{\omega} I_2 = 0 \\ V_2' = \dfrac{2i\omega}{1000}\left(I_2 - I_3\right) + \dfrac{0.5i\omega}{10^6}\left(I_2 - I_1\right) \\ V_1' = \dfrac{i\omega}{1000}\left(I_2 - I_1\right) + \dfrac{0.5i\omega}{10^6}\left(I_2 - I_3\right) \end{cases}$$

c)

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ V_1' \\ V_2' \end{bmatrix} = \begin{bmatrix} \text{3.15 - 0.58i} \\ \text{1.69 + 2.63i} \\ \text{-0.67 + 1.70i} \\ \text{-2.31 - 1.05i} \\ \text{-1.34 + 3.40i} \end{bmatrix}$$

13)

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ V_1' \\ V_2' \end{bmatrix} = \begin{bmatrix} \text{3.60 - 2.08i} \\ \text{3.18 + 1.55i} \\ \text{0.48 + 2.15i} \\ \text{-2.90 - 0.33i} \\ \text{0.97 + 4.31i} \end{bmatrix}$$

14)

a)

$$P_s = -0.5 \times 2 \times 9.2 = -9.2 \quad \text{mW}$$

b)

$$P_{10\Omega} = 0.5 \times 10 \times \left|9.2 - 40.7i \quad \text{mA}\right|^2 = 8.7 \quad \text{mW}$$
$$P_{5\Omega} = 0.5 \times 5 \times \left|-5.2 + 12.7i \quad \text{mA}\right|^2 = 47 \quad \mu\text{W}$$

c)

$$P = 0$$

d)

$$P = 0$$

15)

$$M = 4 \quad \text{mH}$$

16) I think the question is wrong. Three inductors cannot be coupled with those mutual inductances. (spice simulation confirms that). One of the mutual inductances is the maximum possible while the other one is not zero. But, with the given values, the answer is:

$$V_{AG} = 20i \times I_{s1} = 40i \Rightarrow$$
$$V_{AG}(t) = 40\cos(t + 90^o)$$

17)

$$V_{GC} = 14 + 32i$$
$$V_{BC} = 42 + 24i$$
$$V_{AG} = 21 + 320i$$
$$V_{AB} = V_{AG} + V_{GC} + V_{CB} = -7 + 328i$$

18)

inductors don't have dot!

19)

$$i_c = \frac{30\times10^{-6} t u(t)}{\left(t^2+0.01\right)^2} \quad \text{A} \qquad \text{for } t>0$$

20)

a)

$$\begin{cases} v_A = 0.5\ \cos 10t \\ v_B = 2\ \cos 10t \end{cases}$$

b)

$$\begin{cases} v_A = -2\ \sin(20t)\ -0.4\sin(20t-100^o) \\ v_B = -1.6\ \sin(20t-100^o)\ -3\sin(20t) \end{cases}$$

c)

$$\begin{cases} V_1 = \left(L_1+M\right)\frac{dI_A}{dt} + M\frac{dI_B}{dt} \\ V_2 = \left(L_2+M\right)\frac{dI_A}{dt} + L_2\frac{dI_B}{dt} \end{cases}$$

21)

a)

$$\begin{cases} \left(4-5i\omega\right)I_1 - 4i\omega I_3 = 0 \\ \left(6+5i\omega\right)I_1 - 2i\omega I_2 - 6I_3 = 0 \\ -6I_1 - 4i\omega I_2 + \left(11+6i\omega\right)I_3 = 0 \end{cases}$$

b)

$$I_3 = \frac{\begin{vmatrix} 4-5i\omega & 0 & 0 \\ 6+5i\omega & -2i\omega & 100 \\ -6 & -4i\omega & 0 \end{vmatrix}}{\begin{vmatrix} 4-5i\omega & 0 & -4i\omega \\ 6+5i\omega & -2i\omega & -6 \\ -6 & -4i\omega & 11+6i\omega \end{vmatrix}} =$$

$$\frac{400i\omega(4-5i\omega)}{(4-5i\omega)\{(-2i\omega)(11+6i\omega)-24i\omega\}-4i\omega\{-4i\omega(6+5i\omega)-12i\omega\}} = -3.88 + 1.97i$$

22)

a)

$$\begin{cases} V_1 = i\omega L_1 I_1 - i\omega M I_2 + R_1 I_1 \\ V_2 = i\omega L_2 I_2 - i\omega M I_1 + R_2 I_2 \end{cases}$$

b)

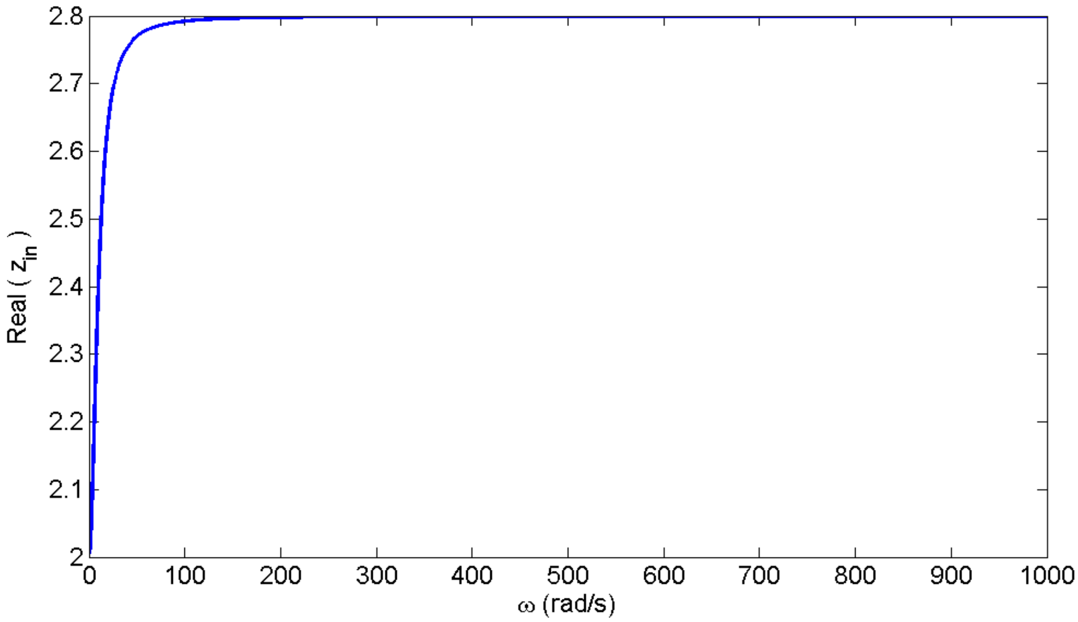
$$\begin{cases} V_1 = i\omega L_1 I_1 + i\omega M I_2 + R_1 I_1 \\ V_2 = -i\omega L_2 I_2 - i\omega M I_1 - R_2 I_2 \end{cases}$$

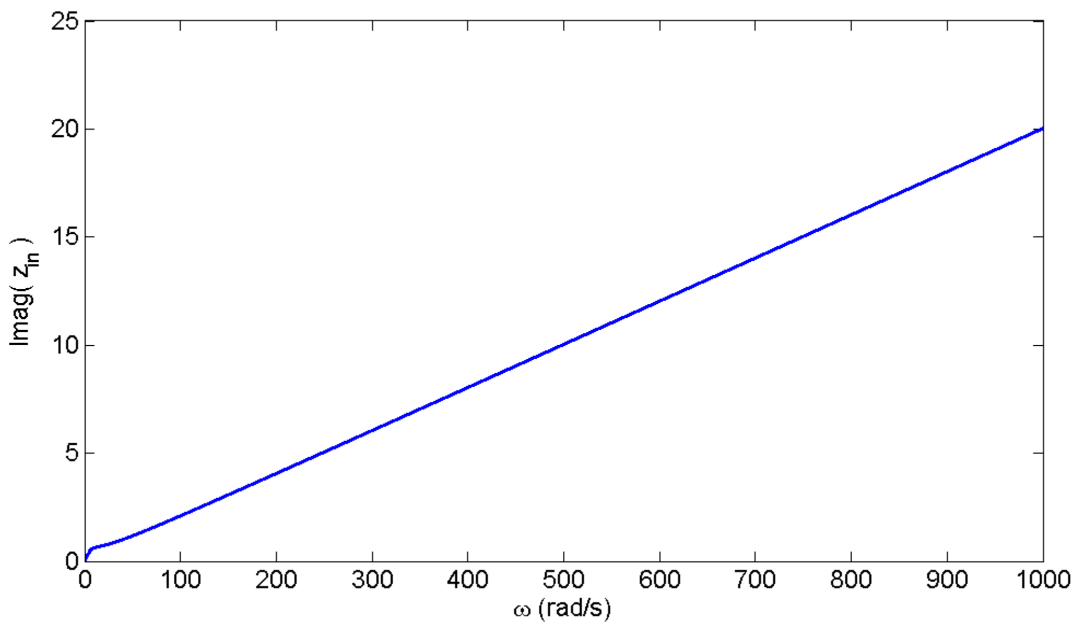
23)

a)

$$z_{in} = \frac{10 - 0.01\omega^2 + 1.5i\omega}{5 + 0.5i\omega}$$

b)





c)

$$z_{in}\left(\omega = 50\right) = 2.76 + 1.15i$$

24)

a) k=1

b) w=349.78 [μJ]

25)

a) M=5.3 [mH]

b) w= 0.32 [μJ]

c) w= 17.64 [μJ]

26)

In order to solve this question, we need to have the value of the resistance, which is in series with the voltage source (v1).

27) Z=0.057+j0.879.

28)

a) w=0.0525 [μJ] (t=0); w=0.0153 [μJ] (t=5ms);

b) w=0.044 [μJ] (t=0); w=0.0128 [μJ] (t=5ms);

29)

$$V_1 = 0.46\measuredangle 118^o \quad \text{V}$$
$$V_2 = 1.12\measuredangle 128^o \quad \text{V}$$

The average powers [Watt]:

P_{v1} =0.1058

$P_{v2} = 0.3136$

30)

A=10+j*2e-5

B=10+j2e-5;

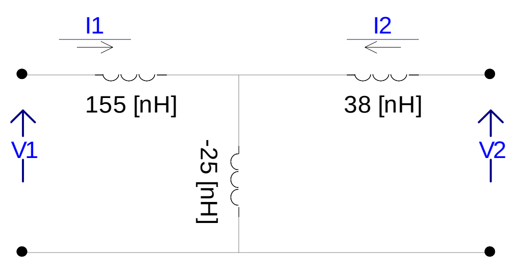
C=10+j1.99e-5;

D=10+j2e-5

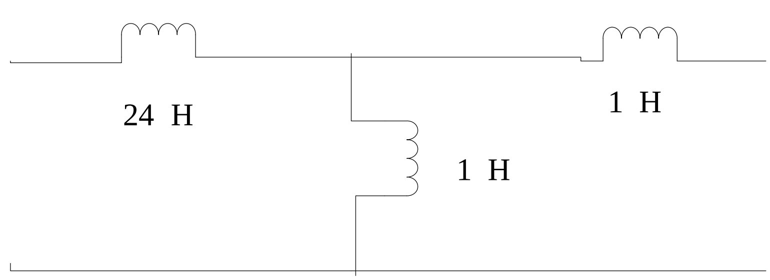
**In this question because the value of the mutual inductance is too small, the impedance seen form the left-hand-side of the circuit will be approximately equal to the R1+jwL1.

This is because two winding are loosely connected, and also the value of the w (frequency) is too small.

31)



32)

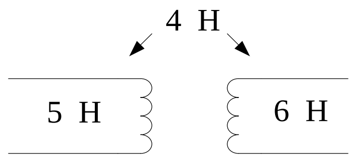


b)

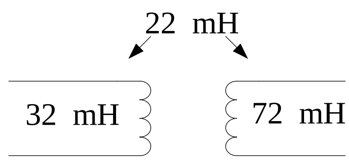
$$V_{CD} = \frac{1}{5}\sin(45t)$$

33)

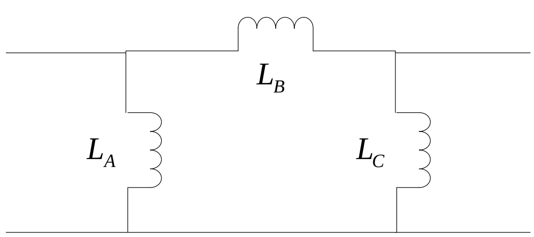
a)



b)



34)



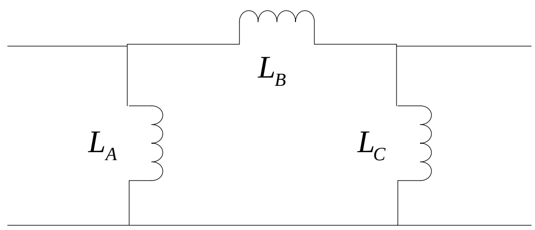
$$L_A = \frac{1065}{38} \quad \text{nH}$$

$$L_B = \frac{1065}{-25} \quad \text{nH}$$

$$L_C = \frac{1065}{155} \quad \text{nH}$$

35)

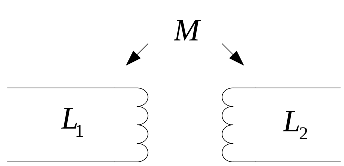
a)



$$L_A = 49 \quad \text{nH}$$
$$L_B = 49 \quad \text{nH}$$
$$L_C = \frac{49}{24} \quad \text{nH}$$

36)

a)



$$M = \frac{4}{7}$$
$$L_1 = \frac{6}{7}$$
$$L_2 = \frac{12}{7}$$

b)

$$M = \frac{110}{41} \quad \text{mH}$$
$$L_1 = \frac{360}{41} \quad \text{mH}$$
$$L_2 = \frac{660}{41} \quad \text{mH}$$

37)

$$\frac{i_l}{V_s} = \frac{2i\omega}{28\omega^2 - 3 - 20i\omega}$$

$$\frac{V_l}{V_s} = \frac{4i\omega}{28\omega^2 - 3 - 20i\omega}$$

38)

$$V_0 = -4.1\cos 1000t - 4.5\sin 1000t$$

39)

$$Z_{in} = \frac{7.85\omega^2 - 2.618i\omega}{1 + 0.384i\omega}$$

40)

a)

$$\begin{cases} V_2 = 6V_1 \\ I_2 = \frac{1}{6} I_1 \end{cases} \Rightarrow V_2 = 24\measuredangle 32^o$$

$$I_2 = \frac{V_2}{Z_L} = \frac{24}{\sqrt{2}} \measuredangle 77^o$$

b)

$$V_2 = 24\measuredangle 32^o$$

$$I_2 = \frac{V_2}{Z_L} = \infty$$

c)

$$V_2 = 12\measuredangle 118^o$$

$$I_2 = \frac{V_2}{Z_L} = \frac{12\measuredangle 118^o}{1.5\measuredangle 10^o} = 8\measuredangle 98^o$$

41)

a)

$$\begin{cases} V_2 = 6V_1 \\ I_2 = \frac{1}{6}I_1 \end{cases} \Rightarrow I_2 = \frac{244}{6} = \frac{122}{3}\measuredangle 0^o \quad \text{mA}$$

$$V_2 = Z_L I_2 = (5-2i)\frac{122}{3}\measuredangle 0^o = 203.3\text{-}81.3\text{i} \quad \text{mV}$$

b)

$$\begin{cases} V_2 = 6V_1 \\ I_2 = \frac{1}{6}I_1 \end{cases} \Rightarrow I_2 = \frac{100}{6}\measuredangle 0^o \quad \text{mA}$$

$$V_2 = Z_L I_2 = (2i)\frac{100}{6}\measuredangle 0^o = 33.3\measuredangle 90^o \quad \text{mV}$$

42)

$$i_1 = \frac{2\measuredangle 0^o}{3+21.4\times 10^{-4}} \simeq \frac{2}{3} \quad \text{A}$$

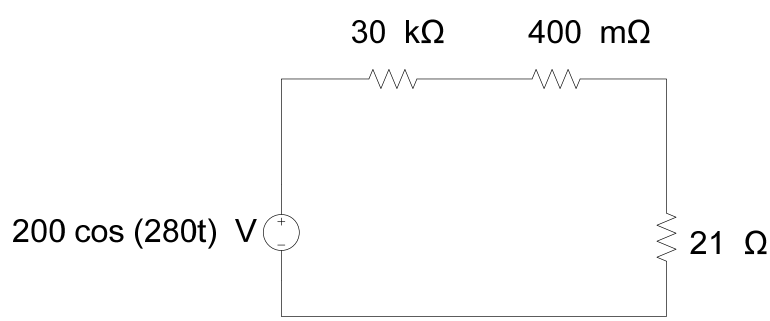
$$i_2 = 0.01 i_1 = \frac{2}{300} \quad \text{A}$$

$$\text{P}_{21\Omega} = 0.5\times 21\times\left(\frac{2}{300}\right)^2 = 467 \quad \mu\text{W}$$

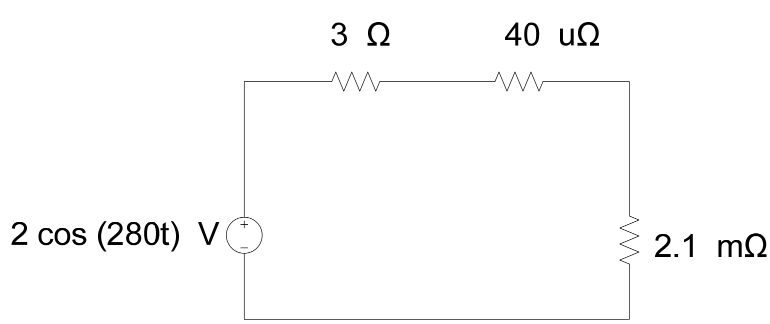
$$\text{P}_{0.4\Omega} = 0.5\times 0.4\times\left(\frac{2}{300}\right)^2 = 8.88 \quad \mu\text{W}$$

43)

a)



b)



44)

$$I_{1.5\Omega} = 5\frac{50+\frac{1}{81}\times\left(38+\frac{1}{16}\times(9)\right)}{1.5+50+\frac{1}{81}\times\left(38+\frac{1}{16}\times(9)\right)} = 4.85 \text{ A}$$

$$I_{50\Omega} = 5-4.85 = 0.15 \text{ A}$$

$$I_{38\Omega} = \frac{1}{9}I_{50\Omega} = \frac{0.15}{9} \quad \text{A}$$

$$I_{9\Omega} = \frac{1}{4}I_{38\Omega} = \frac{0.15}{36} \quad \text{A}$$

$$P_{1.5\Omega} = 0.5\times1.5\times(4.85)^2 = 17.64 \text{ W}$$

$$P_{50\Omega} = 0.5\times1.5\times(0.15)^2 = 169 \text{ mW}$$

$$P_{38\Omega} = 0.5\times1.5\times\left(\frac{0.15}{9}\right)^2 = 208 \ \mu\text{W}$$

$$P_{38\Omega} = 0.5\times1.5\times\left(\frac{0.15}{36}\right)^2 = 13 \ \mu\text{W}$$

45)

a)

$$V_1 = -0.75 \text{ V}$$

$$V_2 = \frac{15}{2}\left(\frac{100\times\frac{4}{225}}{4+\frac{400}{225}}\right)V_1 = -\frac{45}{26} \quad \text{V}$$

b)

$$P_{100\Omega} = 0.5 \times \frac{\left(\frac{45}{26}\right)^2}{100} = 15 \text{ mW}$$

$$P_{4\Omega} = 0.5 \times \frac{\left(V_1 - V_2 \frac{2}{15}\right)^2}{4} = 0.5 \times \frac{\left(0.75 - \frac{3}{13}\right)^2}{4} = 16.9 \text{ mW}$$

$$I_{2\Omega} = 25 \times \frac{27000}{2700 + 2 + 25 \times \left(4 + \frac{400}{225}\right)} = 23.71 \text{ mA}$$

$$P_{2\Omega} = 0.5 \times 2 \times \left(23.71 \times 10^{-3}\right)^2 = 0.562 \text{ mW}$$

$$P_{2.7k\Omega} = 0.5 \times 2.7 \times 10^3 \times \left(1.29 \times 10^{-3}\right)^2 = 2.24 \text{ mW}$$

46)

i_x=5.96 - 3.44i A

V_2= -65.41 +37.76i V

47)

a)

i_x=-10.42 + 6.02i A

V_2= 22.56 -13.02i V

b)

i_x=8.42 - 4.86i A

V_2=27.11-15.65i V

48)

a)

$$V_2 = \frac{4}{4+\frac{1}{900}}\frac{V_s}{30} = 3.89 \quad \text{V}$$

b)

$$V_2 = V_s = 117\measuredangle 0^o \quad \text{V}$$

c)

$$V_2 = 3.96\measuredangle 0^o \quad \text{V}$$

49)

a)

$$V_2 = V_s = 720\measuredangle 0^o \quad \text{V}$$

b)

$$V_2 = 676.73\measuredangle 0^o \quad \text{V}$$

c)

$$V_2 = 664.61\measuredangle 0^o \quad \text{V}$$

50) It is not possible. Maximum power that the source can deliver to such a circuit is less than 2 watts while 200 volts across the load means 20kw!

If we change the question to have 200 mv across the load, the answer is:

$$6.85\left(\frac{a}{b}\right)^2 - 18.5\left(\frac{a}{b}\right) + 9.25 = 0 \Rightarrow \left(\frac{a}{b}\right) = 2, \frac{2}{3}$$

51)

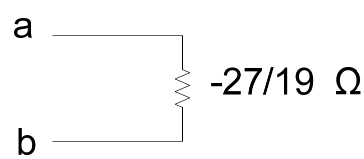
$$V_x = \frac{1.85 \,||\, 0.1}{1.85 \,||\, 0.1 + 314} 2\measuredangle 0^o = 0.63 \quad \text{mV}$$

52)

$$V_x = \frac{1.85 \,||\, (200 \times 16)}{1.85 \,||\, (200 \times 16) + 5.3} 2\measuredangle 0^o = 0.5175$$

$$I_l = -\frac{1}{4}\frac{V_x}{200} = -0.64 \;\; \text{mA}$$

53)



54)

a and b (turn ratios) are not given

55)

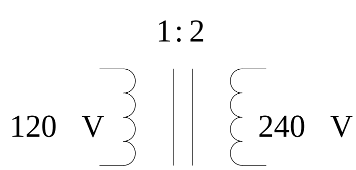
question is wrong. maximum deliverable power is about 5W. to have an answer, we should increase "c". For example, if we consider c=25 s, the answer is b/a=20.3

56)

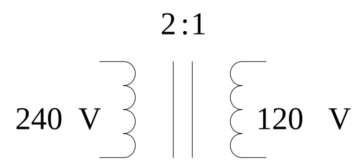
a) $I1 = 9.534 < -24.29$

b) P=1.9 [kW]

57)



58)



Because razors do not consume a lot of energy. The transformer size was probably small and did not let a lot of energy to be converted.

59)

a)

$$\frac{V_2}{V_s} = \frac{-i\omega 4\sqrt{5}}{200 + 6.5i\omega}$$

b)

$$\frac{V_2}{V_s} = \frac{-48.72i\omega}{200\sqrt{5} - 0.182\omega^2 + 57.4\sqrt{5}i\omega}$$

c)

$$\frac{V_2}{V_s} = \frac{-80}{204}$$

60)

a) To couple some energy to his coil without paying for that.

b) somehow. He can use energy only when we are using. The more energy we use, the more energy couples to his coil.

c) False, magnetic field can be propagated even through vaccum.

1. (a) $8+j$
(b) $8e^{-9t}$
(c) 22.5
(d) $4e^{-j9}$
(e) $-2je^{j11}$

2. (a) $(-1)^* = -1$
(b) $\left(\frac{-j}{5\angle 20°}\right)^* = \left(\frac{1\angle -90°}{5\angle 20°}\right)^* = (0.2\angle -110°)^* = 0.2\angle 110°$
(c) $\left(5e^{-j5}+2e^{j3}\right)^* = ((1.4183+j4.7946)+(-1.98+j0.2822))^* = (-0.5617+j5.0769)^* = -0.5617-j5.0769$
(d) $((2+j)(8\angle 30°)e^{j2t})^* = (2.23e^{j26.56°}\times 8e^{j30°}\times e^{j2t})^* = (17.84e^{j(56.56°+2t)})^* = 17.84e^{-j(56.26°+2t)}$

3. (a) $5e^{-j50t}e^{j50t}$
(b) $(2+j)e^{j9t}(2-j)e^{-j9t}$
(c) $(1-j)e^{j78t}(1+j)e^{-j78t}$
(d) $-je^{-5jt}$

4. (a) $\mathbf{s} = \pm j100\ \text{s}^{-1}$
(b) $\mathbf{s} = 0$
(c) $\mathbf{s} = -7 \pm j80\ \text{s}^{-1}$
(d) $\mathbf{s} = 8\text{s}^{-1}$
(e) $\mathbf{s} = -2 \pm j4, -1 \pm j4\ \text{s}^{-1}$

5. (a) $f = 7e^{-9t}\sin(100t+9°) = 3.5[e^{j81}e^{(-j100-9)t} + e^{-j81}e^{(j100-9)t}]$
so $s = -9-j100, s^* = -9-j100$
(b) $f = cos9t$
so $s = 9j, s^* = -9j$
(c) $f = 2\cos(90°-45t)$
so $s = -j45, s^* = j45$

6. (a) $A\,e^{10t}\cos(3t+\emptyset_1)$
(b) $Ae^{0.25t}$
(c) $A+Be^t + C\cos(t+\emptyset_1) + De^t\cos(t+\emptyset_2)$

7. (a) $U = 0.71e^{0.2t}$
for t=0, U=0.71 V, I=0.71/280=2.57 mA
for t=0.1 s, U=0.72 V, I=2.57 mA
for t=0.5 s, U=0.78 V, I=2.8 mA

(b) $U = 0.285e^{-t}\cos(2t-45°)$
for t=0, U=0.202 V, I=0.72 mA
for t=0.1 s, U=0.21 V, I=0.77 mA

for t=0.5 s., U=0.196 V, I=0.6 mA

8. (a) $s = -1 + j200\pi$
The neighbor is approaching nearer to you as the signal is rapidly changing with time.
(b) As the imaginary part of the frequency starts to decrease suddenly, the distance tends to increase.

9. (a) $V_{(t)} = 9(cos4t + jsin4t)$
so, $Re[V_{(t)}] = 9cos4t$;
(b) $V_{(t)} = 12 - 9j$
so $Re[V_{(t)}] = 12$;
(c) $V_{(t)} = 5cos100t - 43jsin100t$
so $Re[V_{(t)}] = 5cos100t$;
(d) $V_{(t)} = (2cos3t - sin3t) + j(2sin3t + cos3t)$
so $Re[V_{(t)}] = 2cos3t - sin3t$

10. (a) The real part is missing.
(b) The complex frequency of the signal is : $\mathbf{s} = -2 + j60\ \mathrm{s}^{-1}$
(c) The fact that Im{ V_x } > Re { V_x } implies that the phase angle is large.
(d) The Re(s) denotes the damping factor and the Im(s) denotes sinusoidal variation. So if Im(s) is larger than the real part, the signal is changing rapidly with time.

11. (a) s=5, $V_{(t)} = Re[19e^{5t+j84}]$
(b) s=0, $V_{(t)} = Re[19e^{j84}]$
(c) s=-4+j, s=5, $V_{(t)} = Re[19e^{j84}e^{(-4+j)t}]$

12. (a) $\mathbf{s} = -1 + j100$; $\mathbf{s}^* = -1 - j100$
(b) **V**=$2.5\angle - 20°$ V;
$v(t) = Re[2.5e^{-j20}e^{(-1+j100)t}] = 2.5e^{-t}\cos(100t - 20°)$
(c) Applying KVL, we obtain,
$$v(t) = Ri + L\frac{di}{dt} + \frac{1}{C}\int idt = 1.5i + 1.8\frac{di}{dt} + 0.25\int idt$$
We construct an s-domain voltage **V(s) =** $2.5\angle - 20°$ with s given above and assume the current of the form $\mathbf{I}e^{st}$
On substituting in the above equation, we get,
$$2.5\angle - 20° e^{st} = 1.5\mathbf{I}e^{st} + 1.8s\mathbf{I}e^{st} + \frac{0.25}{s}\mathbf{I}e^{st}$$
Suppressing the exponential factor, we may write
$$\mathbf{I} = \frac{2.5\angle - 20°}{1.5 + 1.8s + \frac{0.25}{s}} = \frac{2.5\angle - 20°}{180\angle - 90°} = 0.0138\angle - 110°\ \mathrm{A}$$
In time domain, we can write this as

$i(t) = 0.0138\, e^{-t} \cos(100t - 110°)\text{A}$

13. $V(t) = 1.5I + 1.8sI + \frac{0.25}{s} I$
(a) $s = -2 + j2$
we can get: $V(t) = 20.75\angle 151.5° = 20.75e^{-2t}\cos\,(2t + 151.5°)$
(b) $s = -3 + j$
we can get: $V(t) = 21.75\angle 186° = 21.75e^{-3t}\cos\,(t + 186°)$

14. $\mathbf{s} = -200 + j150$
$v_1(t) = i(t).21;\ v_2(t) = 0.1\frac{di(t)}{dt}$
In frequency domain,
$$\mathbf{V}_1 = 21\mathbf{I}_s; \mathbf{V}_2 = 0.1s\mathbf{I}_s;$$
$\frac{\mathbf{V_2}}{\mathbf{V_1}} = \frac{0.1s}{21} = \frac{s}{210} = \frac{250\angle 143.130°}{210} = 1.19\angle 143.130°$

15. $s = -150 + j100, V_2 = 5\angle -25°,$
so $I = \frac{V_2}{Ls} = 0.278\angle -171°, V_1 = IR = 5.84\angle -171°$
we can get: $V = V_1 + V_2 = 6.12\angle -171°,$
and $V_{(t)} = 6.12e^{-150t}\cos\,(100t - 171°)$

16. $\mathbf{s} = -1 + j2; \mathbf{I_s} = 2.3\angle 5°$ A
Applying KCL in the upper node of the given circuit, we obtain,
$i_s = i_R + i_C = \frac{v}{R} + C\frac{dv}{dt}$
We construct an s-domain voltage $\mathbf{I}_s\mathbf{(s)} = 2.3\angle 5°$ A with s given above and assume the voltage of the form $\mathbf{V}e^{st}$
On substituting in the above equation, we get,
$2.3\angle 5° e^{st} = 0.5\mathbf{V}e^{st} + 0.25s\mathbf{V}e^{st}$
Suppressing the exponential factor, we may write
$\mathbf{V} = \frac{2.3\angle 5°}{0.5+0.25s} = \frac{2.3\angle 5°}{0.559\angle 63.435°} = 4.114\angle -58.435°$ V
In time domain, we can write this as
$v(t) = 4.114\, e^{-t}\cos(2t - 58.435°)\text{V}$

17. $I_1 = \frac{V(t)}{R} = 0.9\angle 75°, I_2 = \frac{V(t)}{0.25/s} = 0.72\angle 218.5°$
so $I = I_1 + I_2 = 0.52\angle 129.4°,$
and $i(t) = 0.52e^{-2t}\cos\,(1.5t + 129.4°)$

18. $v_s = 10\cos 5t$
(a) $\mathbf{s} = j5$
(b) $\mathbf{V}_s = 10$ V
(c) $Z_{R1} = 1\,; Z_c = \frac{1}{sC} = \frac{10}{0.4*j5} = -j0.5\,;$
$Z_L = sL = (j5)*1.5 = j7.5\,;$
$Z_{R2} = 2.2\,;$

Total impedance of the circuit is given by,

$$Z_{total} = (Z_{R1} \parallel Z_c) + Z_L + Z_{R2}$$
$$= -\frac{j0.5}{1-j0.5} + 2.2 + j7.5$$
$$= \frac{5.95+j5.9}{1-j0.5} = 2.4 + j7.1$$
$$\therefore \mathbf{I}x = \frac{\mathbf{V}_s}{Z_{total}} = \frac{10}{2.4+j7.1} = 1.334\angle -71.322°\ \text{A}$$

(d) $i_x(t) = 1.334\ \cos(5t - 71.322°)\ \text{A}$

19. $Z_{eq} = 2.2 + 1.5s + \frac{0.4/s}{1+0.4/s} = 0.3 + 0.42j$, $U = I_x Z_{eq} = 1.032\angle 64.5°$
so, $U_x = 1.032e^{-t}\cos(0.5 + 64.5°)$

20. $i_{s1} = 20e^{-3t}\cos 4t$ A; $i_{s2} = 30e^{-3t}\sin 4t$ A
(a) $\mathbf{I}s_1 = 20$; $\mathbf{I}s_2 = 30\angle -90° = -j30$; $\mathbf{s} = -3 + j4$
$Z_R = 5$;
$$Z_c = \frac{1}{sC} = \frac{10}{-3+j4} = -1.2 - j1.6\ ;$$
$Z_L = sL = (-3 + j4) * 2 = -6 + j8$;
Applying principle of superposition in the given circuit, we obtain,

$$\mathbf{V}_x = \mathbf{I}s_1 \frac{((Z_c+Z_L)\parallel Z_R)}{Z_c+Z_L} Z_L + \mathbf{I}s_2 \frac{((Z_c+Z_R)\parallel Z_L)}{Z_L} Z_L$$
$$= 20\frac{5(-7.2+j6.4)}{-2.2+j6.4}\frac{-6+j8}{-7.2+j6.4} - j30\frac{(-6+j8)(3.8-j1.6)}{-2.2+j6.4}$$
$$= \frac{-600+j800-j30(-22.8+12.8+j30.4+j9.6)}{-2.2+j6.4}$$
$$= \frac{600+j1100}{-2.2+j6.4} = \frac{1253\angle 61.389}{6.76\angle 108.97} = 185.35\angle -47.58°$$

(b)In time domain, we can write this as
$v_x(t) = 185.35\ e^{-3t}\cos(4t - 47.58°)\ \text{V}$

21. (a) $F(x) = \int_0^\infty 2.1U(t)dt = \frac{2.1}{s}$
(b) $F(x) = \int_0^\infty e^{-st}2U(t-1)dt = \frac{2}{s}e^{-2s}$
(c) $F(x) = \int_0^\infty e^{-st}[5U(t-2) - 2U(t)]dt = \frac{5}{s}e^{-2s} - \frac{2}{s}$
(c) $F(x) = \int_0^\infty e^{-st}3U(t-b)dt = \frac{3}{s}e^{-bs}$

22. (a) $F(s) = \int_{0-}^\infty 5u(t-6)e^{-st}dt = 5\int_6^\infty e^{-st}dt = 5\left.\frac{e^{-st}}{-s}\right|_6^\infty = \frac{5}{s}e^{-6s}$
(b) $F(s) = \int_{0-}^\infty 2e^{-t}u(t)e^{-st}dt = 2\int_0^\infty e^{-(s+1)t}dt = 2\left.\frac{e^{-(s+1)t}}{-(s+1)}\right|_0^\infty = \frac{2}{s+1}$
(c) $F(s) = \int_{0-}^\infty 2e^{-t}u(t-1)e^{-st}dt = 2\int_1^\infty e^{-(s+1)t}dt = 2\left.\frac{e^{-(s+1)t}}{-(s+1)}\right|_1^\infty =$
$\frac{2}{s+1}e^{-(s+1)}$

(d) $F(s) = \int_{0-}^{\infty} e^{-2t}\sin 5t\, u(t)e^{-st}dt = \int_{0}^{\infty} e^{-2t}\frac{1}{j2}(e^{j5t} - e^{-j5t})e^{-st}dt = \frac{1}{j2}\left[\frac{e^{-(s+2-j5)t}}{-(s+2-j5)}\bigg|_0^{\infty} - \frac{e^{-(s+2+j5)t}}{-(s+2+j5)}\bigg|_0^{\infty}\right] = \frac{1}{j2}\left(\frac{1}{s+2-j5} - \frac{1}{s+2+j5}\right) = \frac{5}{(s+2)^2+25}$

23. (a) $F(s) = \frac{1}{s^2}e^{-s}$

(b) $F(s) = \frac{2}{s^2}$

(c) $F(s) = \frac{12}{s^2+4}$

(d) $F(s) = \frac{s}{s^2+10000}$

24. (a) On employing Eq.[14] and evaluating by integration by parts, we obtain,

$F(s) = \int_{0-}^{\infty} tu(t)e^{-st}dt = \int_{0}^{\infty} te^{-st}dt = \left[\frac{te^{-st}}{-s}\right]_0^{\infty} + \frac{1}{s}\int_0^{\infty} e^{-st}dt = \frac{1}{s^2}$

Also it is given that,

$\mathcal{L}(tf(t)) = -\frac{d}{d\mathbf{s}}\mathbf{F(s)}$, assuming $\mathcal{L}\{f(t)\} = \mathbf{F(s)}$

Here, let $f(t) = u(t), F(s) = \frac{1}{s}$

Therefore,

$\mathcal{L}(tf(t)) = -\frac{d}{ds}\left(\frac{1}{s}\right) = \frac{1}{s^2}$ which is the same as what we found by employing Eq.[14].

(b) On employing Eq.[14] and evaluating by integration by parts, we obtain,

$F(s) = \int_{0-}^{\infty} t^2u(t)e^{-st}dt = \int_{0}^{\infty} t^2e^{-st}dt = \left[\frac{t^2e^{-st}}{-s}\right]_0^{\infty} + \frac{2}{s}\left[\left[\frac{te^{-st}}{-s}\right]_0^{\infty} + \frac{1}{s}\int_0^{\infty} e^{-st}dt\right] = \frac{2}{s^3}$

Also it is given that,

$\mathcal{L}(tf(t)) = -\frac{d}{d\mathbf{s}}\mathbf{F(s)}$, assuming $\mathcal{L}\{f(t)\} = \mathbf{F(s)}$

Here, let $f(t) = tu(t), F(s) = \frac{1}{s^2}$ using the results from part (a)

Therefore,

$\mathcal{L}(tf(t)) = -\frac{d}{ds}\left(\frac{1}{s^2}\right) = \frac{2}{s^3}$ which is the same as what we found by employing Eq.[14].

(c) On employing Eq.[14] and evaluating by integration by parts, we obtain,

$F(s) = \int_{0-}^{\infty} t^3u(t)e^{-st}dt = \int_{0}^{\infty} t^3e^{-st}dt = \left[\frac{t^3e^{-st}}{-s}\right]_0^{\infty} + \frac{3}{s}\int_0^{\infty} t^2e^{-st}dt = \frac{6}{s^4}$

Also it is given that,

$\mathcal{L}\left(tf(t)\right) = -\frac{d}{d\mathbf{s}}\mathbf{F}(\mathbf{s})$, assuming $\mathcal{L}\{f(t)\} = \mathbf{F}(\mathbf{s})$

Here, let $f(t) = t^2u(t), F(s) = \frac{2}{s^3}$

Therefore,

$\mathcal{L}\left(tf(t)\right) = -\frac{d}{ds}\left(\frac{2}{s^3}\right) = \frac{6}{s^4}$ which is the same as what we found by employing Eq.[14].

(d) On employing Eq.[14] and evaluating by integration by parts, we obtain,

$F(s) =$

$\int_{0-}^{\infty} te^{-t}u(t)e^{-st}dt = \int_{0}^{\infty} te^{-(s+1)t}dt = \left[\frac{te^{-(s+1)t}}{-(s+1)}\right]_0^{\infty} + \frac{1}{s+1}\int_0^{\infty} e^{-(s+1)t}dt = \frac{1}{(s+1)^2}$

Also it is given that,

$\mathcal{L}\left(tf(t)\right) = -\frac{d}{d\mathbf{s}}\mathbf{F}(\mathbf{s})$, assuming $\mathcal{L}\{f(t)\} = \mathbf{F}(\mathbf{s})$

Here, let $f(t) = e^{-t}u(t), F(s) = \frac{1}{s+1}$

Therefore,

$\mathcal{L}\left(tf(t)\right) = -\frac{d}{ds}\left(\frac{1}{s+1}\right) = \frac{1}{(s+1)^2}$ which is the same as what we found by employing Eq.[14].

25. (a) $t + 4, s > 0$
    (b) $(t + 1)(t + 2), s > 0$
    (c) $e^{-0.5t}U(t), s > -0.5$
    (d) $sin10t \cdot U(t + 1),\ s > -1$

26. $\mathcal{L}\{f(t) + g(t) + h(t)\} = \int_{0-}^{\infty}\left(f(t) + g(t) + h(t)\right) e^{-st}dt$

$= \int_{0-}^{\infty} f(t)e^{-st}dt + \int_{0-}^{\infty} g(t)e^{-st}dt + \int_{0-}^{\infty} h(t)e^{-st}dt$

$= \mathcal{L}\{f(t)\} + \mathcal{L}\{g(t)\} + \mathcal{L}\{h(t)\}$

27. (a) $F(s) = \frac{3}{s}e^{-2s}$
    (b) $F(s) = \frac{3}{s+2} + \frac{5}{s}$
    (c) $F(s) = 1 + \frac{1}{s} - \frac{1}{s^2}$
    (d) $F(s) = 5$

28. (a) $g(t) = [5u(t)]^2 - u(t)$

$\therefore\ G(s) = \int_0^{\infty}[5]^2e^{-st}dt - \int_0^{\infty} u(t)e^{-st}dt = 25\left.\frac{e^{-st}}{-s}\right|_0^{\infty} - \left.\frac{e^{-st}}{-s}\right|_0^{\infty} = \frac{24}{s}$

(b) $g(t) = 2u(t) - 2u(t-2)$

$\therefore\ G(s) = 2\int_0^{\infty} e^{-st}dt - 2\int_2^{\infty} e^{-st}dt\ = 2\left.\frac{e^{-st}}{-s}\right|_0^{\infty} - 2\left.\frac{e^{-st}}{-s}\right|_2^{\infty} =$
$\frac{2}{s}(1 - e^{-2s})$

(c) $g(t) = tu(2t)$

$\therefore\ G(s) = \int_0^{\infty} te^{-st}dt = \left[\frac{te^{-st}}{-s}\right]_0^{\infty} + \frac{1}{s}\int_0^{\infty} e^{-st}dt = \frac{1}{s^2}$

(d) $g(t) = 2e^{-t}u(t) + 3u(t)$

$\therefore\ G(s) = 2\int_0^{\infty} e^{-(s+1)t}dt + 3\int_0^{\infty} e^{-st}dt = 2\left.\frac{e^{-(s+1)t}}{-(s+1)}\right|_0^{\infty} + 3\left.\frac{e^{-st}}{-s}\right|_0^{\infty} =$
$\frac{2}{s+1} + \frac{3}{s}$

29. (a) $f(t) = U(t)$
(b) $f(t) = 1.55\delta(t) - 2U(t)$
(c) $f(t) = e^{-1.5t}U(t)$
(d) $f(t) = 5[tU(t) + U(t) + \delta(t)$

30. (a) $G(s) = \frac{1.5}{(s+9)^2}$
$\therefore\ g(t) = 1.5te^{-9t}u(t)$
(b) $G(s) = \frac{2}{s} - 0$
$\therefore\ g(t) = 2u(t)$
(c) $G(s) = \pi$
$\therefore\ g(t) = \pi\delta(t)$
(d) $G(s) = \frac{a}{(s+1)^2} - a, a > 0$
$\therefore\ g(t) = ae^{-t}tu(t) - a\delta(t)$

31. (a) $\delta(t)|_{t=1} = 0$
(b) $5\delta(t+1) + u(t+1)|_{t=1} = 1$
(c) $\int_{-1}^{2} \delta(t)\,dt = 1$
(d) $3 - 2\int_{-1}^{2} \delta(t)\,dt = 1$

32. (a) $[\delta(2t)]^2|_{t=1} = 0$
(b) $2\delta(t-1) + u(-t+1)|_{t=0} = 1$
(c) $\frac{1}{3}\int_{-0.001}^{0.003} \delta(t)dt = 0$
(d) $\frac{1}{\left[\frac{1}{2}\int_0^2 \delta(t-1)dt\right]^2} = 4$

33. (a) $\int_{-\infty}^{\infty} 2\delta(t-1)dt = 2$
(b) $\frac{1}{1} = 1$
(c) $\frac{\sqrt{3}}{1} - 0 = \sqrt{3}$
(d) 1

34. (a) $\int_{-\infty}^{+\infty} e^{-100}\delta\left(t-\frac{1}{5}\right)dt = e^{-100}$

(b) $\int_{-\infty}^{+\infty} 4t\delta(t-2)\,dt = 8$

(c) $\int_{-\infty}^{+\infty} 4t^2\delta(t-1.5)\,dt = 0$

(d) $\frac{\int_{-\infty}^{+\infty}(4-t)\delta(t-1)dt}{\int_{-\infty}^{+\infty}(4-t)\delta(t+1)dt} = \frac{3}{5}$

35. (a) $f(t) = 5\delta(t) + 5tU(t) - 5e^{-t}U(t)$

(b) $f(t) = U(t) + 50e^{-40t}U(t)$

(c) $f(t) = 0.5u(t) + 4tu(t) + 4te^{-5t}u(t) + 2\delta(t)$

(d) $f(t) = 4te^{-5t}u(t) + 2e^{-t}u(t) + e^{-3t}u(t)$

36. (a) $G(s) = \frac{3(s+1)}{(s+1)^2} + \frac{2s}{s^2} - \frac{1}{(s+2)^2} = \frac{3}{(s+1)} + \frac{2}{s} - \frac{1}{(s+2)^2}$

$\therefore g(t) = 3e^{-t}u(t) + 2u(t) - te^{-2t}u(t)$

(b) $G(s) = -\frac{10}{(s+3)^3}$

$\therefore g(t) = -10\frac{1}{2}t^2e^{-3t}u(t) = -5t^2e^{-3t}u(t)$

(c) $G(s) = 19 - \frac{8}{(s+3)^2} + \frac{18}{(s^2+6s+9)} = 19 + \frac{10}{(s+3)^2}$

$\therefore g(t) = 19\delta(t) + 10te^{-3t}u(t)$

37. (a) $F(s) = \frac{1}{s+2}$, $f(t) = 2e^{-2t}u\,(t)$

(b) $F(s) = 1$, $f(t) = \delta(t)$

(c) $F(s) = \frac{3}{s+2}$, $f(t) = 3e^{-2t}u(t)$

(d) $= \frac{2s}{s+1.5}$, $f(t) = 2\delta(t) - 3e^{-0.5t}U(t)$

38. (a) $V(s) = \frac{s^2+2}{s} + 1$

$\therefore v(t) = \frac{d\delta(t)}{dt} + 2u(t) + \delta(t)$

(b) $V(s) = \frac{s+8}{s} + \frac{2}{s^2} = 1 + \frac{8}{s} + \frac{2}{s^2}$

$\therefore v(t) = \delta(t) + 8u(t) + 2tu(t)$

(c) $V(s) = \frac{s+1}{s(s+2)} + \frac{2s^2-1}{s^2} = \frac{1}{s+2} + \frac{1}{s(s+2)} + 2 - \frac{1}{s^2}$

$\therefore v(t) = e^{-2t}u(t) + 0.5(1-e^{-2t})u(t) + 2\delta(t) - tu(t)$

(d) $V(s) = \frac{s^2+4s+4}{s} = s + 4 + \frac{4}{s}$

$\therefore v(t) = \frac{d\delta(t)}{dt} + 4\delta(t) + 4u(t)$

39. (a) $F(s) = \frac{17}{3}\frac{1}{s=3} + \frac{1}{3s}$, $f(t) = \frac{(17e^{-3t}+1)}{3}u(t)$

(b) $f(t) = 7\delta(t) + \left[\frac{6\sqrt{5}}{5}\sinh\left(\frac{\sqrt{5}t}{2}\right)e^{-1.5t} - 1\right]U(t)$

(c) $f(t) = 2t + \left[\frac{4}{10}\cosh\left(2\sqrt{10}t\right) - \frac{3\sqrt{10}}{10}\sinh\left(2\sqrt{10}t\right)\right] e^{-8t}U(t) + U(t)$

(d) $f(t) = 2te^{-t}u(t)$

(e) $f(t) = (\frac{14}{9}e^{-4t} - \frac{49}{72}e^{-t} - \frac{7}{8}e^{-5t} + \frac{7}{6}te^{-t})u(t)$

40. (a) $G(s) = \frac{1}{s^2+9s+20} = \frac{1}{(s+4)(s+5)}$

Applying method of residues

$\left.\frac{1}{s+4}\right|_{s=-5} = -1$; $\left.\frac{1}{s+5}\right|_{s=-4} = 1$ so that,

$G(s) = \frac{1}{s+4} - \frac{1}{s+5}$

$\therefore g(t) = e^{-4t}u(t) - e^{-5t}u(t)$

(b) $G(s) = \frac{4}{s^3+18s^2+17s} + \frac{1}{s} = \frac{4}{s(s+1)(s+17)} + \frac{1}{s}$

Applying method of residues to the first term,

$\left.\frac{4}{(s+1)(s+17)}\right|_{s=0} = \frac{4}{17}$; $\left.\frac{4}{s(s+17)}\right|_{s=-1} = -\frac{1}{4}$; $\left.\frac{4}{s(s+1)}\right|_{s=-17} = \frac{1}{68}$

so that,

$G(s) = \frac{4}{17s} - \frac{1}{4(s+1)} + \frac{1}{68(s+17)} + \frac{1}{s}$

$\therefore g(t) = \frac{21}{17}u(t) + \frac{1}{68}e^{-17t}u(t) - \frac{1}{4}e^{-t}u(t)$

(c) $G(s) = 0.25\frac{1}{\left(\frac{s}{2}\right)^2+1.75s+2.5} = \frac{1}{(s+2)(s+5)}$

Applying method of residues

$\left.\frac{1}{s+5}\right|_{s=-2} = \frac{1}{3}$; $\left.\frac{1}{s+2}\right|_{s=-5} = -\frac{1}{3}$ so that,

$G(s) = \frac{1}{3(s+2)} - \frac{1}{3(s+5)}$

$\therefore g(t) = \frac{1}{3}e^{-2t}u(t) - \frac{1}{3}e^{-5t}u(t)$

(d) $G(s) = \frac{3}{s(s+1)(s+4)(s+5)(s+2)}$

Applying method of residues,

$\left.\frac{3}{(s+1)(s+4)(s+5)(s+2)}\right|_{s=0} = \frac{3}{40}$; $\left.\frac{3}{s(s+4)(s+5)(s+2)}\right|_{s=-1} = -\frac{1}{4}$;

$\left.\frac{3}{s(s+1)(s+4)(s+5)}\right|_{s=-2} = \frac{1}{4}$; $\left.\frac{3}{s(s+1)(s+5)(s+2)}\right|_{s=-4} = -\frac{1}{8}$;

$\left.\frac{3}{s(s+1)(s+4)(s+2)}\right|_{s=-5} = \frac{1}{20}$

so that,

$G(s) = \frac{3}{40s} - \frac{1}{4(s+1)} + \frac{1}{4(s+2)} - \frac{1}{8(s+4)} + \frac{1}{20(s+5)}$

$\therefore g(t) = \frac{3}{40}u(t) - \frac{1}{4}e^{-t}u(t) + \frac{1}{4}e^{-2t}u(t) - \frac{1}{8}e^{-4t}u(t) + \frac{1}{20}e^{-5t}u(t)$

(e) MATLAB Verifications:

```
>> syms t s
A = 1/(s^2+9*s+20);
B = 4/(s^3+18*s^2+17*s)+1/s;
C = 0.25* 1/((s/2)^2+1.75*s+2.5);
D = 3/(s*(s+1)*(s+4)*(s+5)*(s+2));
a = ilaplace(A)
b = ilaplace(B)
c = ilaplace(C)
d = ilaplace(D)
 a =1/exp(4*t) - 1/exp(5*t)
 b = 1/(68*exp(17*t)) - 1/(4*exp(t)) + 21/17
c = 1/(3*exp(2*t)) - 1/(3*exp(5*t))
 d = 1/(4*exp(2*t)) - 1/(4*exp(t)) - 1/(8*exp(4*t)) + 1/(20*exp(5*t))
+ 3/40
```

41. (a) $F(s) = -\frac{1}{(s+2)^2} - \frac{1}{s+2} + \frac{1}{s+1}$, $f(t) = (-te^{2t} - e^{-2t} + e^{t})u(t)$

(b) $F(s) = -\frac{2}{(s+2)^3} + \frac{1}{(s+2)^2}$, $f(t) = (t^2 + t)e^{-2t}u(t)$

(c) $F(s) = \frac{\frac{2}{7}}{s+2} - \frac{\frac{2}{3}}{s+6} + \frac{\frac{8}{21}}{s+9}$, $f(t) = (\frac{2}{7}e^{-2t} - \frac{2}{3}e^{-6t} + \frac{8}{21}e^{-9t})u(t)$

42. (a) $G(s) = \frac{1}{3s} - \frac{1}{2s+1} + \frac{3}{s^3+8s^2+16s} - 1 = \frac{1}{3s} - \frac{1}{2(s+0.5)} + \frac{3}{s(s+4)^2} - 1$

Applying method of residues to the third term,

$\left.\frac{3}{(s+4)^2}\right|_{s=0} = \frac{3}{16}$; $\frac{d}{ds}\left[\frac{3}{s}\right]\Big|_{s=-4} = -\frac{3}{16}$; $\left.\frac{3}{s}\right|_{s=-4} = -\frac{3}{4}$ so that

$G(s) = \frac{1}{3s} - \frac{1}{2(s+0.5)} + \frac{3}{16s} - \frac{3}{16(s+4)} - \frac{3}{4(s+4)^2} - 1$

$\therefore g(t) = \frac{25}{48}u(t) - \frac{1}{2}e^{-0.5t}u(t) - \frac{3}{16}e^{-4t}u(t) - \frac{3}{4}te^{-4t}u(t) - \delta(t)$

(b) $G(s) = \frac{1}{3s+5} + \frac{3}{\frac{s^3}{8}+0.25s^2} = \frac{1}{3s+5} + \frac{24}{s^2(s+2)}$

Applying method of residues to the second term,

$\frac{d}{ds}\left[\frac{24}{s+2}\right]\Big|_{s=0} = -6$; $\left.\frac{24}{s+2}\right|_{s=0} = 12$; $\left.\frac{24}{s^2}\right|_{s=-2} = 6$ so that

$G(s) = \frac{1}{3(s+1.667)} - \frac{6}{s} + \frac{12}{s^2} + \frac{6}{s+2}$

$\therefore g(t) = \frac{1}{3}e^{-1.667t}u(t) - 6u(t) + 12tu(t) + 6e^{-2t}u(t)$

(c) $G(s) = \frac{2s}{(s+a)^2} = 2\left[\frac{1}{s+a} - \frac{a}{(s+a)^2}\right]$

$\therefore g(t) = 2e^{-at}u(t) - 2ate^{-at}u(t)$

43. (a) $F(s) = \frac{24}{(s+4)^2} + \frac{6}{s+4} - \frac{6}{s+2}$, $f(t) = (24te^{-4t} + 6e^{-4t} - 6e^{-2t})u(t)$

(b) $F(s) = 3 + \frac{15}{4}\frac{1}{(s+5)^2} - \frac{9}{8}\frac{1}{s+5} - \frac{21}{4}\frac{1}{s+7}$,

$f(t) = 3\delta(t) + (\frac{15}{4}te^{-5t} - \frac{9}{8}e^{-5t} - \frac{21}{4}e^{-7t})u(t)$

(c) $F(s) = 2 - \frac{1}{s+100} + \frac{s}{s^2+100}$, $f(t) = 2\delta(t) - (e^{100t} + \cos(10t))u(t)$

(d) $f(t) = \frac{1}{2}tu(t)$

44. (a) $G(s) = \frac{s}{(s+2)^3} = \frac{1}{(s+2)^2} - \frac{2}{(s+2)^3}$

$\therefore g(t) = te^{-2t}u(t) - t^2e^{-2t}u(t)$

(b) $G(s) = \frac{4}{(s+1)^4(s+1)^2} = \frac{4}{(s+1)^6}$

$\therefore g(t) = \frac{1}{120}t^5e^{-t}u(t)$

(c) $G(s) = \frac{1}{s^2(s+4)^2(s+6)^3} - \frac{2s^2}{s} + 9$

Using Matlab to perform the partial fraction expansion of

$\frac{1}{s^2(s+4)^2(s+6)^3}$

```
>>N = [1];
>>D = poly([0 0 -4 -4 -6 -6 -6]);
>>[r, p, k]=residue(N,D)
r =
    0.0081
    0.0093
    0.0069
   -0.0078
    0.0078
   -0.0003
    0.0003
p =
   -6.0000
   -6.0000
   -6.0000
   -4.0000
   -4.0000
         0
         0
k =
     []
>> rats(r)
ans =
      7/864
      1/108
      1/144
     -1/128
      1/128
     -1/3456
      1/3456
```

$G(s) = \frac{1}{s^2(s+4)^2(s+6)^3} - 2s + 9 = \frac{1}{3456s^2} - \frac{1}{3456s} + \frac{1}{128(s+4)^2} - \frac{1}{128(s+4)} + \frac{1}{144(s+6)^3} + \frac{1}{108(s+6)^2} + \frac{7}{864(s+6)} - 2s + 9$

$\therefore g(t) = \frac{1}{3456}tu(t) - \frac{1}{3456}u(t) + \frac{1}{128}te^{-4t}u(t) - \frac{1}{128}e^{-4t}u(t) + \frac{1}{288}t^2e^{-6t}u(t) + \frac{1}{108}te^{-6t}u(t) + \frac{7}{864}e^{-6t}u(t) - 2\frac{d\delta(t)}{dt} + 9\delta(t)$

(d) MATLAB Verifications

```
>> syms t s
A = s/(s+2)^3;
B = 4/((s+1)^4*(s+1)^2);
C = 1/(s^2*(s+4)^2*(s+6)^3);
a = ilaplace(A)
b = ilaplace(B)
c = ilaplace(C)

a = t/exp(2*t) - t^2/exp(2*t)
b =t^5/(30*exp(t))
 c =t/3456 - 1/(128*exp(4*t)) + 7/(864*exp(6*t)) + t/(128*exp(4*t))
+ t/(108*exp(6*t)) + t^2/(288*exp(6*t)) - 1/3456
```

45. (a) $5(sI(s) - I(0)) - 7\left(s^2I(s) - sI(0) - I'(0)\right) + 9I(s) = \frac{4}{s}$

(b)

$m(s^2P(s) - sP(0) - p'(0)) + \mu_f(sP(s) - P(0) + k\int_{-\infty}^{\infty} e^{-st}P(t)dt = 0$

(c) $s\Delta nP(s) - \Delta nP(0) = \frac{1}{\tau}\int_{-\infty}^{\infty} \Delta npe^{-st}dt + \frac{GL}{s}$

46. $v(0^-) = 1.5$ V; $i_s = 700\, u(t)$ mA

(a)Writing the differential equation from KCL, we obtain,

$i_s = i_R + i_C = \frac{v}{R} + C\frac{dv}{dt}$

$0.7u(t) = 0.5v + \frac{0.5dv}{dt}$

(b)Taking Laplace transform, we obtain,

$\frac{0.7}{s} = 0.5\mathbf{V}(s) + 0.5[\mathbf{sV(s)} - v(0^-)]$

$\frac{0.7}{\mathbf{s}} = 0.5\mathbf{V(s)} + 0.5\mathbf{sV(s)} - 0.75$

(c) $\mathbf{V(s)} = \frac{7}{5s(s+1)} + \frac{3}{2(s+1)}$

Applying method of residues to the first term,

$\left.\frac{7}{5(s+1)}\right|_{s=0} = \frac{7}{5}$; $\left.\frac{7}{5s}\right|_{s=-1} = -\frac{7}{5}$ so that,

$\mathbf{V(s)} = \frac{7}{5s} - \frac{7}{5(s+1)} + \frac{3}{2(s+1)}$

$\therefore v(t) = \frac{7}{5}u(t) + \frac{1}{10}e^{-t}u(t)$ V

47. $Zeq = \frac{1}{4s+1}$,

$V(s) = I(s) * Zeq = \frac{2}{(s+1)^2}$,

$v(t) = 2te^{-t}u(t)$

48. $i(0^-) = 5$ A; $\mathbf{V(s)} = \left(\frac{2}{s} - \frac{1}{s+1}\right)$ V

(a)Writing the differential equation applying KVL, we obtain,

$v(t) = iR + \frac{Ldi}{dt}$

$v(t) = 4i + \frac{0.2di}{dt}$

Taking Laplace transform, we obtain,

$\frac{2}{\mathrm{s}} - \frac{1}{\mathrm{s}+1} = 4\mathbf{I(s)} + 0.2[\mathbf{sI(s)} - i(0^-)]$

$\mathbf{I(s)} = \frac{10}{s(s+20)} - \frac{5}{(s+1)(s+20)} + \frac{5}{s+20}$

Applying method of residues to the first and the second term,

$\left.\frac{10}{s+20}\right|_{s=0} = \frac{1}{2}$; $\left.\frac{10}{s}\right|_{s=-20} = -\frac{1}{2}$

$\left.\frac{5}{s+1}\right|_{s=-20} = -\frac{5}{19}$; $\left.\frac{5}{s+20}\right|_{s=-1} = \frac{5}{19}$

so that,

$\mathbf{I(s)} = \frac{1}{2s} - \frac{1}{2(s+20)} + \frac{5}{19(s+20)} - \frac{5}{19(s+1)} + \frac{5}{s+20}$ A

(b) $\therefore i(t) = \frac{1}{2}u(t) + \frac{181}{38}e^{-20t}u(t) - \frac{5}{19}e^{-t}u(t)$ A

49. $V(t) = 5i(t) + 5\int i(t)\,dt$,

$I(s) = \frac{2}{5}\frac{1}{s+1}$,

$i(t) = \frac{2}{5}e^{-t}u(t)$

50. $v(0^-) = 4.5\,V$; $\mathbf{Vs}(\mathrm{s}) = \frac{2}{s+1}$ V

(a)Writing the differential equation applying KVL, we obtain,

$v_s(t) = \frac{1}{C}\int_{-\infty}^{t} i(t')dt' + i(t)R$

$v_s(t) = 5\int_{-\infty}^{t} i(t')dt' + 5i(t)$

We can write, $5\int_{-\infty}^{t} i(t')dt' = 5\int_{-\infty}^{0-} i(t')dt' + 5\int_{0-}^{t} i(t')dt'$

$$= v(0-) + 5\int_{0-}^{t} i(t')dt'$$

$$2e^{-t}u(t) = v(0-) + 5\int_{0-}^{t} i(t')dt' + 5i(t)$$

(b) Taking Laplace transform, we obtain,

$\frac{2}{s+1} = 5\text{I}(s) + \frac{4.5}{s} + \frac{5}{s}\text{I}(s)$

$\text{I}(s) = 0.4s - \frac{0.9}{s+1}$

$\therefore i(t) = 0.4\frac{d\delta(t)}{dt} - 0.9\, e^{-t}u(t)$ A

51. $Zeq = \frac{1.5s}{1=1.5s}$

$V(s) = \frac{450}{s+0.67}$,

$v(t) = 450e^{-0.67t}u(t)$

52. The function for the plot in Fig. 14.18 is given by

$f(t) = 6u(t-1.6) + 6u(t-3) - 12u(t-4.6)$

$\therefore F(s) = \frac{6}{s}(e^{-1.6s} + e^{-3s} - 2e^{-4.6s})$

53. (a) $D(s) = s^3 + 13s^2 + 47s + 35$

s^3	1	47	0
s^2	13	35	0
s	44.3	0	
1	35		

Stable

(b) $D(s) = s^3 + 13s^2 + s + 35$

s^3	1	1	0
s^2	13	35	0
s	-x	0	
1	35		

Unstable

54. (a) $D(s) = s^2 + 3s + 8$

s^2	1	8	0
s	3	0	
1	8		

There is no sign change. Therefore, the system is Stable.

$D(s) = s^2 + 3s + 8 = \left(s - 1.5 + \frac{j\sqrt{23}}{2}\right)\left(s - 1.5 - \frac{j\sqrt{23}}{2}\right)$

Since the poles lie on the left hand plane, the system is stable.

(b) $D(s) = s^2 + 2s + 1$

s^2	1	1	0
s	2	0	
1	1		

There is no sign change. Therefore, the system is Stable.

$D(s) = s^2 + 2s + 1 = (s+1)^2$

Since the poles lie on the left hand plane, the system is stable.

55. $f(0) = \lim_{s\to\infty}[sF(s)]$
    (a) $f(0) = 2$
    (b) $f(0) = 2$
    (c) $f(0) = 1$
    (d) $f(0) = 1$

56. (a) $f(t) = u(t-3); F(s) = \frac{1}{s}e^{-3s}$
    $f(0) = \lim_{s\to\infty}[sF(s)] = 0$
    (b) $f(t) = 2e^{-(t-2)}u(t-2); F(s) = \frac{2}{s+1}e^{-2s}$
    $f(0) = \lim_{s\to\infty}[sF(s)] = 0$
    (c) $f(t) = \frac{u(t-2)+[u(t)]^2}{2}; F(s) = \frac{1}{2s}e^{-2s} + \frac{1}{2s}$
    $f(0) = \lim_{s\to\infty}[sF(s)] = 0.5$
    (d) $f(t) = \sin 5t\, e^{-t}u(t); F(s) = \frac{5}{(s+2)^2+25}$
    $f(0) = \lim_{s\to\infty}[sF(s)] = 5$

57. (a) $f(\infty) = -2$
    (b) $f(\infty) = 0$
    (c) $f(\infty) = 2$
    (d) $f(\infty) = 0$

58. (a) $\frac{1}{s+18}$
    $f(0+) = \lim_{s\to\infty}[sF(s)] = \lim_{s\to\infty}\left[\frac{s}{s+18}\right] = 1$
    $f(\infty) = \lim_{s\to 0}[sF(s)] = \lim_{s\to 0}\left[\frac{s}{s+18}\right] = 0$
    (b) $10\left(\frac{1}{s^2} + \frac{3}{s}\right)$
    $f(0+) = \lim_{s\to\infty}[sF(s)] = \lim_{s\to\infty}\left[10s\left(\frac{1}{s^2} + \frac{3}{s}\right)\right] = 30$
    $f(\infty) = \lim_{s\to 0}[sF(s)] = \lim_{s\to 0}\left[10s\left(\frac{1}{s^2} + \frac{3}{s}\right)\right] = \infty$
    (c) $\frac{s^2-4}{s^3+8s^2+4s}$
    $f(0+) = \lim_{s\to\infty}[sF(s)] = \lim_{s\to\infty}\left[s\left(\frac{s^2-4}{s^3+8s^2+4s}\right)\right] = 1$
    $f(\infty) = \lim_{s\to 0}[sF(s)] = \lim_{s\to 0}\left[s\left(\frac{s^2-4}{s^3+8s^2+4s}\right)\right] = -1$
    (d) $\frac{s^2+2}{s^3+3s^2+5s}$

$$f(0+) = \lim_{s\to\infty}[sF(s)] = \lim_{s\to\infty}\left[s\left(\frac{s^2+2}{s^3+3s^2+5s}\right)\right] = 1$$

$$f(\infty) = \lim_{s\to 0}[sF(s)] = \lim_{s\to 0}\left[s\left(\frac{s^2+2}{s^3+3s^2+5s}\right)\right] = \frac{2}{5}$$

59. (a) $f(0) = 1$, $f(\infty) = 0$
(b) $f(0) = \infty$, $f(\infty) = NaN$
(c) $f(0) = \infty$, $f(\infty) = 0$

60. (a) $\frac{1}{s-1}$
Here, the pole lies on the right hand plane, so the final value theorem is not applicable.
(b) $\frac{10}{s^2-4s+4} = \frac{10}{(s-2)^2}$
Here, the poles lie on the right hand plane, so the final value theorem is not applicable.
(c) $\frac{13}{s^3-5s^2+8s-6} = \frac{13}{(s-3)(s^2-2s+2)}$
Here, the poles lie on the right hand plane, so the final value theorem is not applicable.
(d) $\frac{3}{2s^3-10s^2+16s-12} = \frac{3}{2(s-3)(s^2-2s+2)}$
Here, the poles lie on the right hand plane, so the final value theorem is not applicable.

61. $V = \frac{8}{s+2}$
(a) $I = \frac{1}{s+2}$, $R = \frac{V}{I} = 8$, resister: 8 Ω
(b) $I = \frac{4}{s(s+2)}$, $R = \frac{V}{I} = 2s$, inductance: 2H

62. (a) $F(s) = \frac{16}{s-1}$
$f(0+) = \lim_{s\to\infty}[sF(s)] = \lim_{s\to\infty}\left[\frac{16s}{s-1}\right] = 16$
Here, the pole lies on the right hand plane, so function has an indeterminate final value.
(b) $\therefore f(t) = 16e^{-t}u(t)$
(c) $i_c(t) = C\frac{dv(t)}{dt} = 2(-16)e^{-t} = -32e^{-t}$ A

63. if only i(s) applies to the circuit, $Zeq = \frac{2s+10}{3s+10}$, $Ic(s)' = \frac{5}{3}\frac{1}{(s+3.33)}$
if only V(s) applies to the circuit, $Zeq = \frac{10}{s} + 3$, $Ic(s)'' = \frac{3s+10}{s}\frac{1}{s+4}$
so $Ic(s) = Ic(s)' - Ic(s)''$,
then $ic(t) = (\frac{5}{3}e^{-3.33} - 3e^{-4} - 2.5 + 25e^{-4t})u(t)$

64. $i_s(t) = 2u(t+2)$ A; $\mathbf{I_s}(s) = \frac{2}{s}$

(a) $v_s(t) = 2u(t)$ V; $\mathbf{V_s}(s) = \frac{2}{s}$
$Z_{R1} = 1$;
$Z_c = \frac{1}{sC} = \frac{10}{s}$;
$Z_{R2} = 2$;
Applying principle of superposition in the given circuit, we obtain,

$$\mathbf{I}_C(s) = I_s \frac{\left((Z_{R2} + Z_c) \parallel Z_{R1}\right)}{Z_{R2} + Z_c} - \frac{V_s(s)}{Z_{R1} + Z_c + Z_{R2}}$$
$$= \frac{2}{s} \frac{\left(2 + \frac{10}{s}\right)}{\left(2 + \frac{10}{s} + 1\right)} \frac{1}{\left(2 + \frac{10}{s}\right)} - \frac{\frac{2}{s}}{2 + \frac{10}{s} + 1}$$
$$= 0$$

$\therefore i_c(t) =$ 0A;

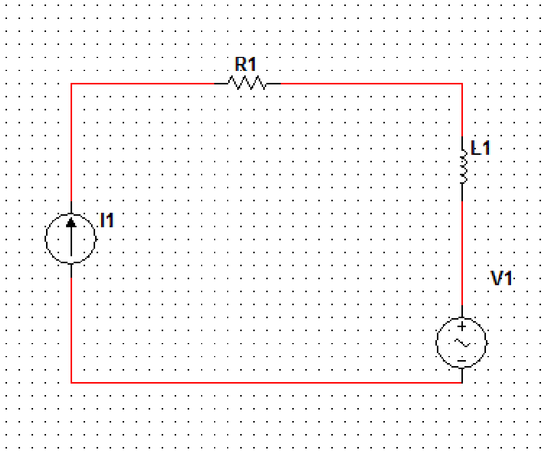
(b) $v_s(t) = te^{-t}u(t)$ V; $V_s = \frac{1}{(s+1)^2}$
Applying principle of superposition in the given circuit, we obtain,

$$\mathbf{I}_C(s) = \mathbf{I_s(s)} \frac{\left((Z_{R2}+Z_c) \| Z_{R1}\right)}{Z_{R2}+Z_c} - \frac{\mathbf{V_s(s)}}{Z_{R1}+Z_c+Z_{R2}}$$
$$= \frac{2}{s} \frac{\left(2+\frac{10}{s}\right)}{\left(2+\frac{10}{s}+1\right)} \frac{1}{\left(2+\frac{10}{s}\right)} - \frac{\frac{1}{(s+1)^2}}{2+\frac{10}{s}+1}$$
$$= \frac{2}{3s+10} - \frac{s}{(s+1)^2(3s+10)}$$
$$= \frac{2}{3s+10} - \frac{1}{(s+1)(3s+10)} + \frac{1}{(s+1)^2(3s+10)}$$
$$= \frac{2}{3s+10} + \frac{3}{7(3s+10)} - \frac{1}{7(s+1)} - \frac{3}{49(s+1)} + \frac{1}{7(s+1)^2} + \frac{9}{49(3s+10)}$$
$$= \frac{128}{147(s+\frac{10}{3})} - \frac{10}{49(s+1)} + \frac{1}{7(s+1)^2}$$

$$\therefore \ i_C(t) = \left(\frac{128}{147} e^{-\frac{10t}{3}} - \frac{10}{49} e^{-t} + \frac{1}{7} te^{-t}\right) u(t) \text{ A}$$

65. (a) $i(0) = \lim_{s\to\infty} sI(s) =$ $5\ A$
(b) $v(\infty) = \lim_{s\to 0} s^2 I(s) =$ 0

1. I1=2A, R1=4, L1=1.5s, V1=-3

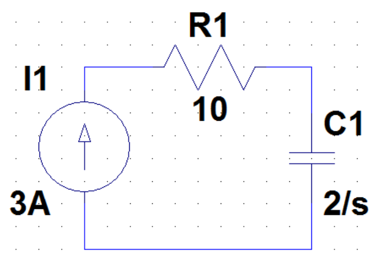


2. $R = 10\Omega, C = 500mF, I_1 = 3A$

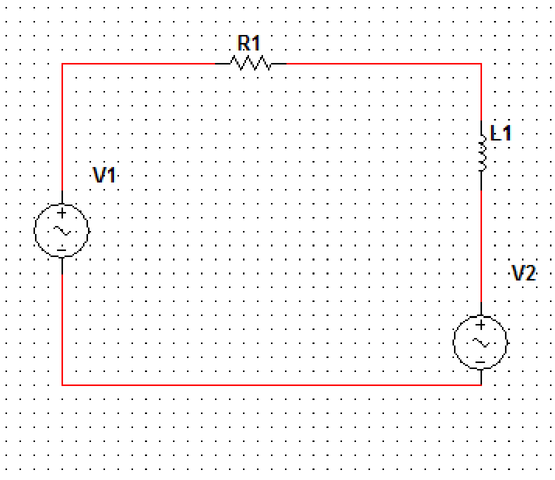
$t = 0^-$

$v_C(0^-) = v_C(0^+) = v_C(0) = 0$

$R = 10\Omega, Z_C = 1/500\times10^{-3}s$



3. $V1 = 3\frac{1.5}{s+1} + \frac{2}{s}, R1 = 2.7, L1 = 1.1s, V2 = -1.1i(0)$



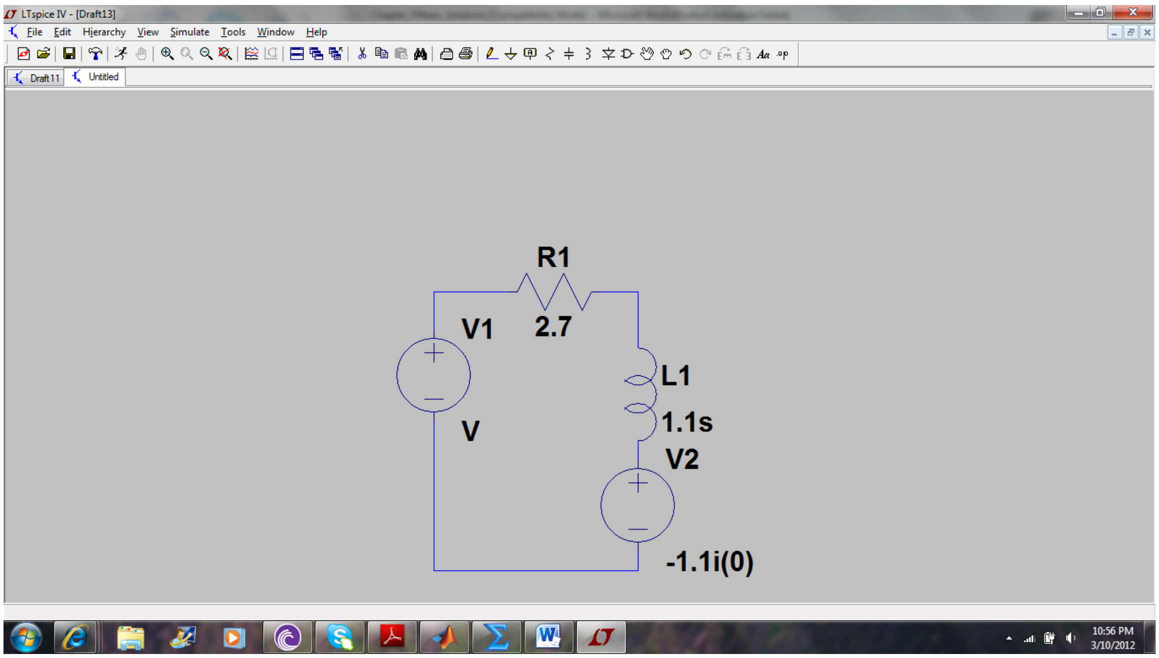
(a) $I(s) = \frac{V1}{2.7+1.1s}, i(t) = (0.94e^{-t} - 1.68e^{-2.46t} + 0.74)u(t)$

(b) $I(s) = \frac{V1-V2}{2.7+1.1s}, i(t) = (0.94e^{-t} - 3.68e^{-2.45t} + 0.74)u(t)$

4. $R = 2.7\Omega, L = 1.1H, v_s = 1.5e^{-t}u(t) + 2u(t)V$

(a) $i(0) = 0$

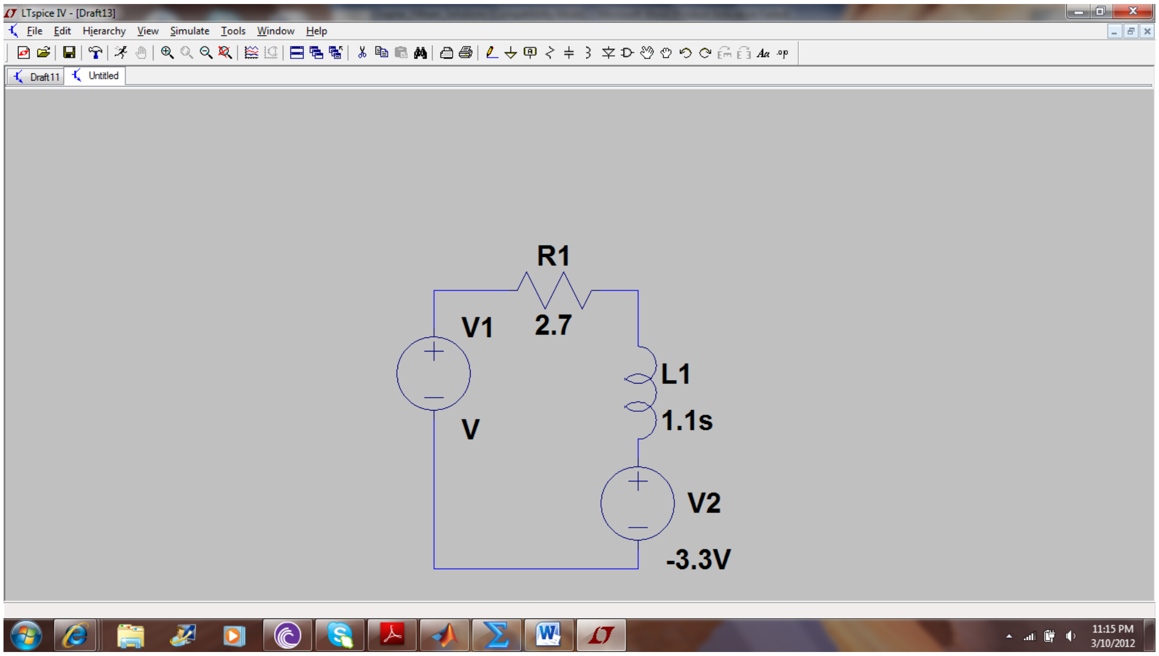
$$V_s(s) = \frac{1.5}{s+1} + \frac{2}{s}$$
$$R_1 = 2.7\Omega, L_1 = 1.1s, V_2 = -1.1i(0^-)$$



$$I(s) = \frac{V_1}{R_1 + sL} = \frac{\frac{1.5}{s+1} + \frac{2}{s}}{2.7 + 1.1s} = \frac{3.5(s+0.57)}{1.1s(s+1)(s+2.45)}$$

$$V(s) = 1.1sI(s) = \frac{3.5(s+0.57)}{(s+1)(s+2.45)} = \frac{A}{(s+1)} + \frac{B}{s+2.45}$$
$$A = \frac{3.5(s+0.57)}{(s+2.45)}\Big|_{s=-1} = -1.0345$$
$$B = \frac{3.5(s+0.57)}{(s+1)}\Big|_{s=-2.45} = 345$$
$$V(s) = \frac{-1.0345}{(s+1)} + \frac{4.5345}{s+2.45}$$
$$v(t) = \left[-1.0345e^{-t} + 4.5345e^{-2.45t}\right]u(t)$$

(b) $i(0) = 3A$



$$I(s) = \frac{V_1 + 3.3}{R_1 + sL} = \frac{\frac{1.5}{s+1} + \frac{2}{s} + 3.3}{2.7 + 1.1s} = \frac{3.3s^2 + 6.8s + 2}{1.1s(s+1)(s+2.45)}$$

$$V(s) = 1.1sI(s) - 3.3 = \frac{-4.585s - 6.085}{(s+1)(s+2.45)} = \frac{A}{(s+1)} + \frac{B}{s+2.45}$$

$$A = \frac{-4.585s - 6.085}{(s+2.45)}\Big|_{s=-1} = -3.551$$

$$B = \frac{-4.585s - 6.085}{(s+1)}\Big|_{s=-2.45} = -1.0345$$

$$V(s) = \frac{-3.551}{(s+1)} + \frac{-1.0345}{s+2.45}$$

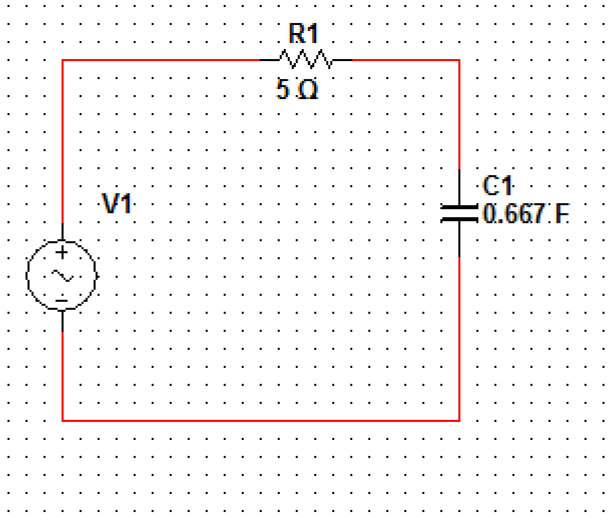
$$\boxed{v(t) = \left[-3.551e^{-t} - 1.0345e^{-2.45t}\right]u(t)}$$

5. $-\frac{sVc}{1.5}+2+\frac{\frac{2}{s}-Vc}{5}=0$

(a) $Vc(s)=\frac{10s+2}{s+3}$

(b) $vc(t)=31.2e^{-31.3t}u(t)+10\delta(t)$

(c) V1=2u(t)

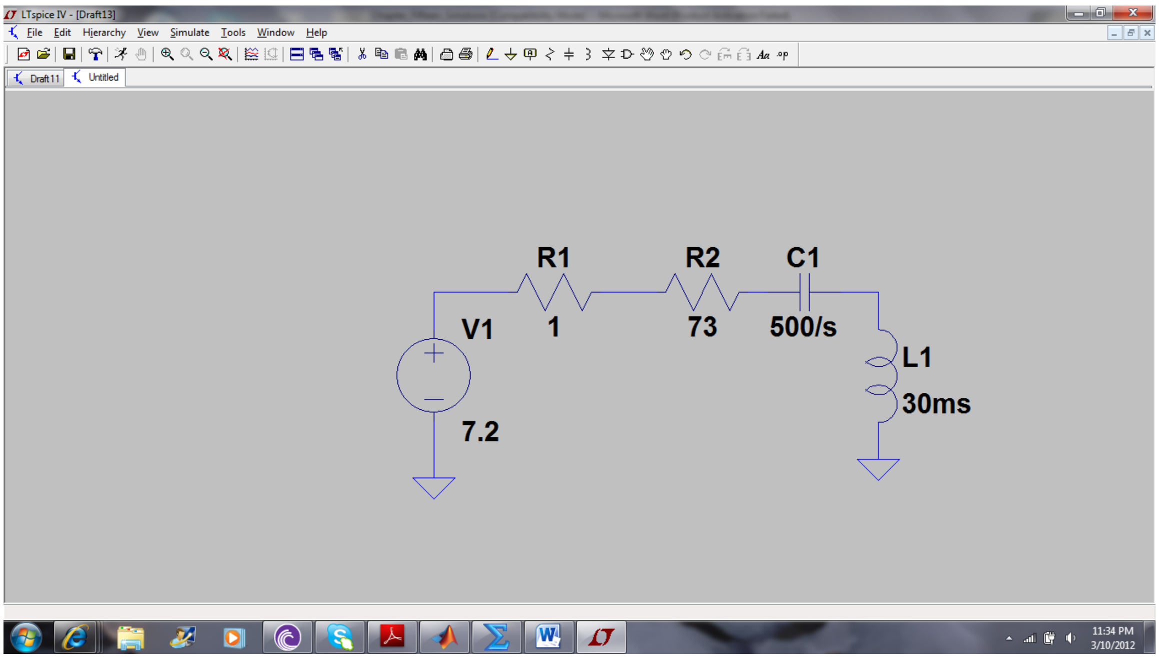


6. $i_L(0^-) = 0, v_C(0^-) = 0$

R_1, R_2 Will remain the same in the s-domain

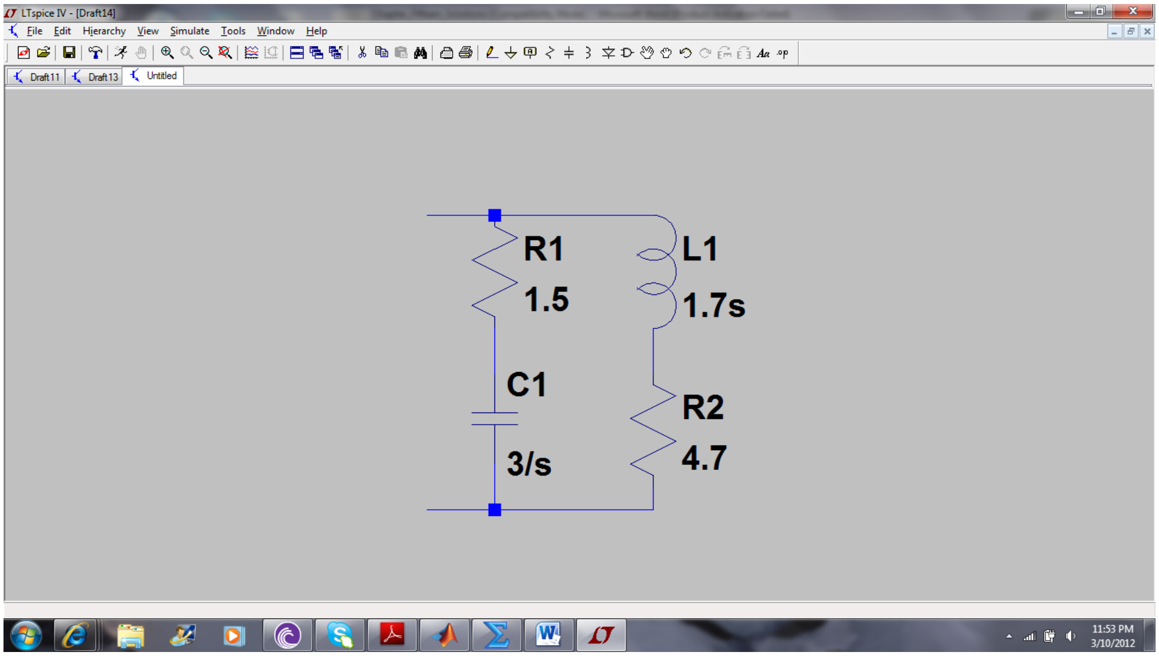
$C \rightarrow 1/Cs = 500/s$

$L \rightarrow sL = 30 \times 10^{-3} s$



7. $Zs = 0.5s + 3.3||\frac{4}{s} = 0.5s + \frac{13.2s}{3.3s+4}$

8. Find input admittance Y(s)



$$Z_{eq} = Z_1 // Z_2$$

$$Z_1 = 4.7 + 1.7s$$

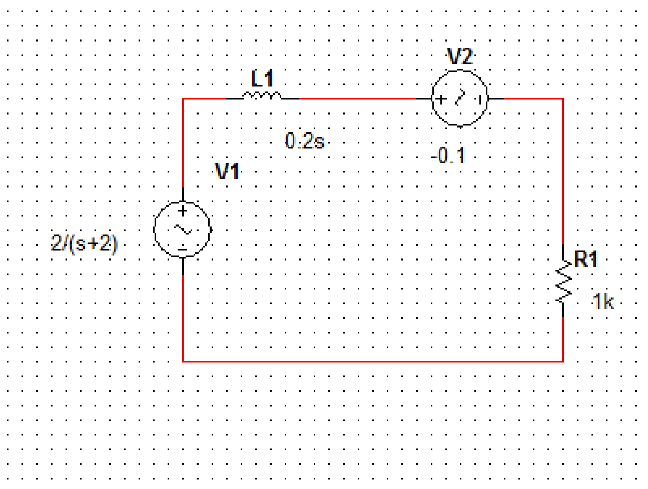
$$Z_2 = 1.5 + 3/s$$

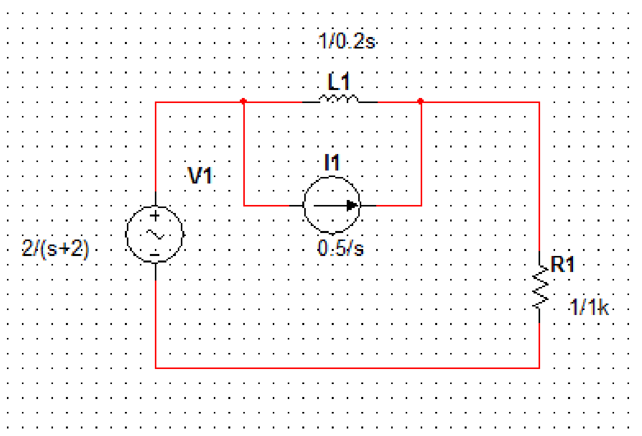
$$Z_{eq} = Z_1 // Z_2 = \frac{Z_1 Z_2}{Z_1 + Z_2} = \frac{(4.7+1.7s)(1.5+3/s)}{(4.7+1.7s)+(1.5+3/s)}$$

$$Z_{eq} = \frac{2.55s^2 + 7.05s + 19.2}{1.7s^2 + 6.2s + 3}$$

$$Y_{eq} = 1/Z_{eq} = \frac{1.7s^2 + 6.2s + 3}{2.55s^2 + 7.05s + 19.2}$$

9. (a)

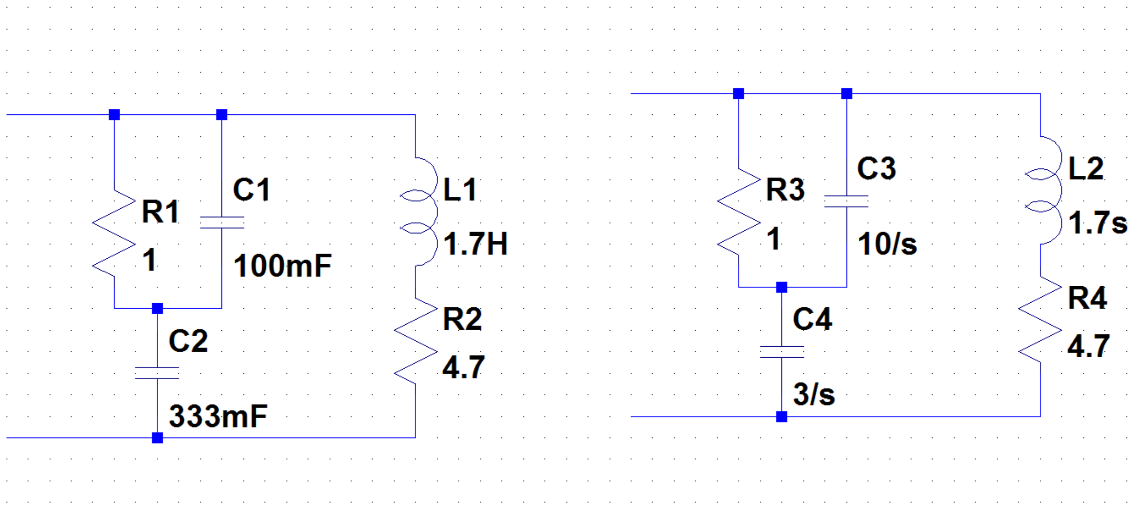




(b) $Is = \frac{\frac{2}{s+2}+0.1}{0.2s+1000}, Vs = Is * 0.2s = \frac{\frac{2}{s+2}+0.1}{0.2s+1000} * 0.2s$

(c) $v(t) = 0.1\delta(t) - (498e^{-5000t} - 0.0008e^{-2t})u(t)$

10.



$$Z_1 = 1\Omega // (10/S) = \frac{10}{S+10}$$

$$Z_2 = Z_1 + \frac{3}{s} = \frac{13s+3}{s(s+1)}$$

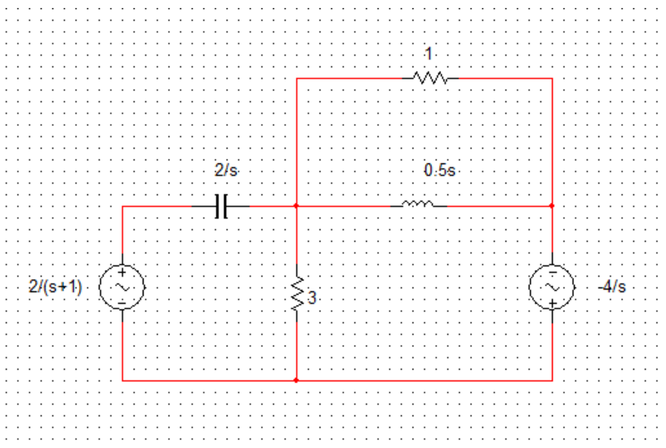
$$Z_3 = 1.7s + 4.7$$

$$Z_{in} = Z_2 // Z_3$$

$$\boxed{Z_{in} = \frac{13(s+3)(1.7s+4.7)}{(13s+3)+s(1.7s+4.7)(s+1)}}$$

11.

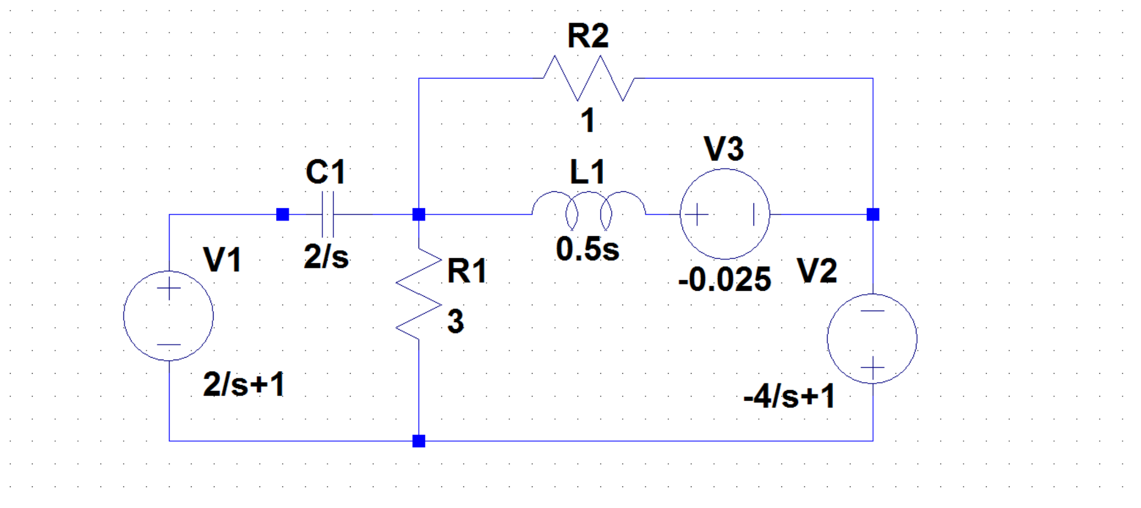
(a)



(c) $\begin{cases} \frac{2}{s+1} + \frac{2}{s} I1 + 3(I1 - I3) = 0 \\ I2 + 0.5s(i2 - i3) = 0 \\ -\frac{4}{3} + 3I3 + 0.5s(I3 - I2) = 0 \end{cases}$

(d) $\begin{cases} i1 = (2.9e^{-0.67t} - 0.6e^{-1.5t} - 2e^{t})u(t) \\ i2 = e^{-1.5t}u(t) \\ i3 = (1.33 - 0.33e^{-1.5t})u(t) \end{cases}$

12.



Mesh 1:

$$\frac{-2}{s+1}+\frac{2}{s}I_1+3\left(I_1-I_2\right)=0$$

Mesh 2:

$$3\left(I_2-I_1\right)+\left[0.5s(I_2-I_3)+(-0.025)\right]-\frac{-4}{s+1}=0$$

Mesh 3:

$$-(-0.025)+0.5s(I_3-I_2)+1(I_3)=0$$

$$I_1=\frac{2\left(3s^2+4s\right)}{\left(s+1\right)\left(3s+2\right)}$$

$$I_2=\frac{0.025(360s^3+963s^2-318)}{(s+1)(2s+3)(3s+2)}$$

$$I_3=\frac{-0.025(-360s^3-231s^2+175s+6)}{(s+1)(2s+3)(3s+2)}$$

$$i_1(t) = 2\delta(t) - 2.67e^{-0.6t} + 2e^{-t}$$

$$i_2(t) = 1.5\delta(t) + 1.4625e^{-1.5t} - 3.2e^{-0.67t} + e^{-t}$$

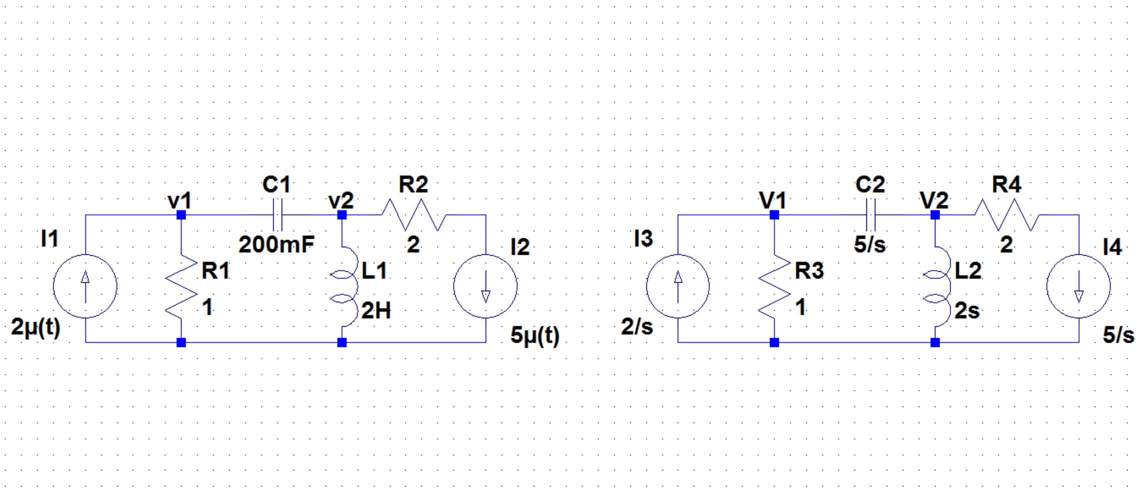
$$i_3(t) = 1.5\delta(t) - 4.3875e^{-1.5t} + 1.6e^{-0.67t} - e^{-t}$$

13. (a) $\frac{Vx}{5} + \frac{Vx+\frac{2}{s}}{0.8s} + \frac{\left(Vx-\frac{3}{s}\right)s}{4} = 0$

(b) $Vx = \frac{15s^2-50}{5s^3+4s^2+25s}$,

$vx(t) = (5(cos2.27 - 0.036sin2.2t)e^{-0.4t} - 2)u(t)$

14.



At node 1:

$$\frac{2}{s}=\frac{V_1}{1}+\frac{(V_1-V_2)}{5/s}\Rightarrow\frac{2}{s}=\frac{V_1}{1}+\frac{(V_1-V_2)s}{5}$$

At node 2:

$$\frac{5}{s}=\frac{V_2}{2s}+\frac{(V_2-V_1)}{5/s}\Rightarrow\frac{5}{s}=\frac{V_2}{2s}+\frac{(V_2-V_1)s}{5}$$

```
>> eqn1='(V1/1)+(V1-V2)/(5/s)=2/s';

eqn2='(V2/2*s)+((V2-V1)*s)/5=5/s';

solution=solve(eqn1,eqn2,'V1','V2');

V1=solution.V1

V1 =

24/(s*(s + 7))

>> v1=ilaplace(V1)

v1 =

24/7 - 24/(7*exp(7*t))

>> V2=solution.V2
```

```
V2 =

(2*(7*s + 25))/(s^2*(s + 7))

>> v2=ilaplace(V2)

v2 =

(50*t)/7 - 48/(49*exp(7*t)) + 48/49
```

$$V_1 = \frac{24}{s(s+7)}$$

$$V_2 = \frac{2(7s+25)}{s^2(s+7)}$$

$$\boxed{v_1(t) = \frac{24}{7} - \frac{24}{7}e^{-7t}}$$

$$\boxed{v_2(t) = \frac{50t}{7} - \frac{48}{49}e^{-7t} + \frac{48}{49}}$$

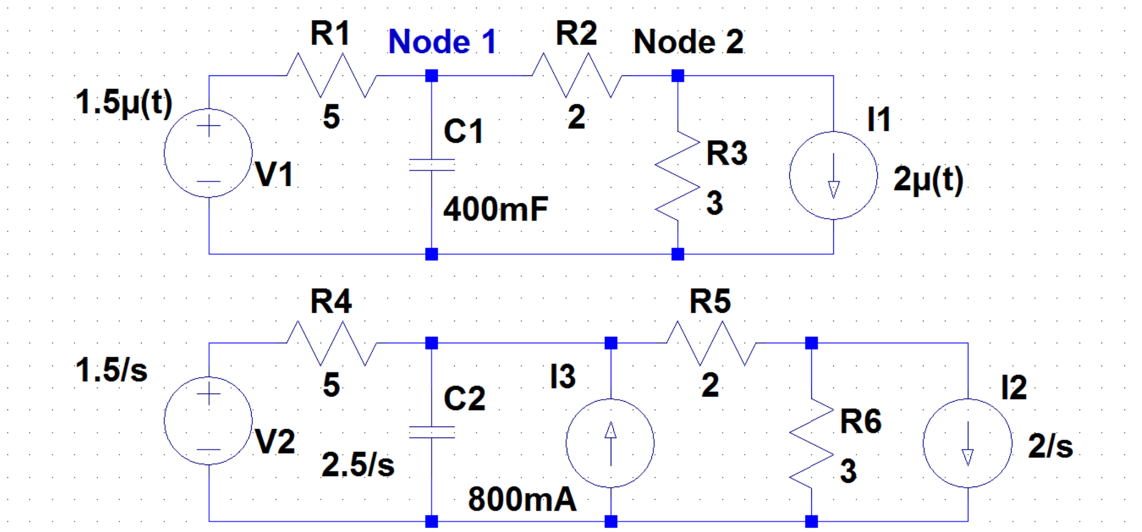
15. $\begin{cases} \frac{4}{s+1} = \frac{V1}{1} + \frac{(V1-V2)s}{5} \\ \frac{V2}{2s} + \frac{(V2-V1)s}{5} = \frac{5}{s} \end{cases}$

so, $\begin{cases} V1 = \frac{18s^2+10s+20}{2s^3+3s^2+6s+5} \\ V2 = \frac{18s^2+60s+50}{2s^3+3s^2+6s+5} \end{cases}$

$$v1(t) = (\frac{14}{3}e^{-t} + \left(\frac{13}{169}\cos\left(\frac{\sqrt{39}t}{4}\right) - \frac{11\sqrt{39}}{169}\sin\left(\frac{\sqrt{39}t}{4}\right)\frac{1}{3}e^{-0.25t}\right)u(t)$$

$$P = \frac{v1(t)^2}{R} = v1(t)^2$$

16.



At node 1:

$$\frac{V_1 - 1.5/s}{5} + 800\times10^{-3} + \frac{V_2 - V_1}{2} + \frac{V_1}{s.5/s} = 0$$

At node 2:

$$\frac{V_2}{3} + \frac{V_2 - V_1}{2} = \frac{2}{s}$$

$$V_1 = \frac{-0.25(8s-15)}{s(s+1)}$$

$$V_2 = \frac{0.15(8s+31)}{s(s+1)}$$

$$v_2(t) = 4.65 - 3.45e^{-t}$$

$$\boxed{P = \frac{v^2{}_2(t)}{R} = \frac{(4.65-3.45e^{-t})^2}{3}}$$

Solving in Matalb:

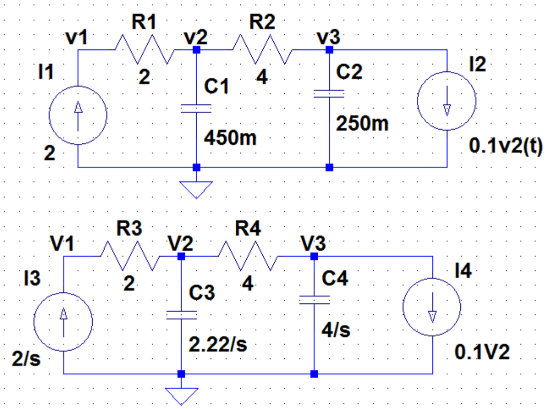
```
>> eqn1='(V1/(2.5/s))+((V1-(1.5/s))/5)+((V1-V2)/2)=-800e-3'

eqn1 =

(V1/(2.5/s))+((V1-(1.5/s))/5)+((V1-V2)/2)=-800e-3

>> eqn2='(V2/3)+((V2-V1)/2)=(2/s)'

eqn2 =

(V2/3)+((V2-V1)/2)=(2/s)

>> solution=solve(eqn1,eqn2,'V1','V2');

>> V1=solution.V1

V1 =

-(0.25*(8.0*s - 15.0))/(s*(s + 1.0))

>> V2=solution.V2

V2 =

(0.15*(8.0*s + 31.0))/(s*(s + 1.0))

>> v2=ilaplace(V2)

v2 =

4.65 - 3.45/exp(1.0*t)
```

17. $\begin{cases} \frac{3}{s} = \frac{V1}{5} + \frac{(V1-V2)s}{10} \\ \frac{10}{s^2+4} = \frac{V2}{2s} + \frac{(V2-V1)s}{10} \end{cases}$, so $\begin{cases} V1 = \frac{30s^4+100s^3+270s^2+600}{2s^5+5s^4+18s^3+20s^2+40s} \\ V2 = \frac{30s^3+100s^2+320s}{2s^4+5s^3+18s^2+20s+40} \end{cases}$

then

$$vx(t) = v2(t) = (\frac{300}{13} cos2t + \frac{289}{13} sin27 - \left(\frac{105}{231}\cos\left(\frac{\sqrt{55}t}{4}\right) + \frac{59\sqrt{55}}{231}\sin\left(\frac{\sqrt{55}t}{4}\right)\right)\frac{1}{13}e^{-1.25t})u(t)$$

18. (a)



(b)

At node 1:

$$\frac{2}{s} = \frac{V_1 - V_2}{2} \Rightarrow V_1 - V_2 = \frac{4}{s} \qquad (1)$$

At node 2:

$$0 = \frac{V_2 - V_1}{2} + \frac{V_2}{2.22/s} + \frac{V_2 - V_3}{4}$$

$$0 = \frac{-V_1}{2} + \left(\frac{3}{4} + \frac{s}{2.22}\right)V_2 - \frac{V_3}{4} \qquad (2)$$

At node 3:

$$-0.1V_2 = \frac{V_3}{4/s} + \frac{V_3 - V_2}{4} \qquad (3)$$

From eq. (1)

$$V_1 = \frac{4}{s} + V_2$$

$$from(3) \Rightarrow V_3 = \frac{0.6}{s+1} V_2$$

$$V_2 = \frac{2/s}{\frac{1}{2} + \frac{s}{2.22} - \frac{0.15}{s+1}}$$

Solving in Matlab:

```
>> syms s;

>> V2=(2/s)/(0.5+(s/2.22)-(0.15/s+1));

>> v2=ilaplace(V2)
```

```
v2 =

(8*2849^(1/2)*exp((111*t)/200)*sinh((3*2849^(1/2)*t)/200))/77
```

```
>> V1=(4/s)+V2

V1 =

4/s - 2/(s*(3/(20*s) - (50*s)/111 + 1/2))

>> v1=ilaplace(V1)
```

```
v1 =

(8*2849^(1/2)*exp((111*t)/200)*sinh((3*2849^(1/2)*t)/200))/77 + 4
```

```
>> V3=(0.6/(s+1))*V2

V3 =

-6/(5*s*(s + 1)*(3/(20*s) - (50*s)/111 + 1/2))

>> v3=ilaplace(V3)
```

```
v3 =

2664/(1777*exp(t)) - (2664*exp((111*t)/200)*(cosh((3*2849^(1/2)*t)/200) -
(311*2849^(1/2)*sinh((3*2849^(1/2)*t)/200))/8547))/1777
```

19. $$\begin{cases} -\frac{6(0.45+0.22s)}{s^2+4}+\frac{1333}{s}(I1-I2)+2(I1-I3)=0 \\ 0.005I1+0.001s(I2-I4)-0.001+\frac{1333}{s}(I2-I1)=0 \\ \frac{1000}{s}(I4-I3)+0.001+0.001s(I4-I2)=0 \\ 2(I3-I1)+\frac{1000}{s}(I3-I4)+\frac{6s}{s^2+4}=0 \end{cases}$$

so, $$\begin{cases} I1=-\frac{936s-540}{s^2+4} \\ I2=\frac{234s^4-10^8s^3-3.1\times10^{10}s^2-6.2\times10^{13}s-3.6\times10^{13}}{1.1\times10^5s^4+3.3\times10^7s^3+6.7\times10^{10}s^2+1.3\times10^8s+2.7\times10^{11}} \end{cases}$$

so, $\boxed{i1(t)=936cos2t-270sin2t}$

20.

$$5V_2 + 3V_2 + \frac{V_1 - 14/s^2}{100 + 1/600\times10^{-6}s} + \frac{V_1 - V_2}{1/500\times10^{-6}s} = 0$$

$$\frac{V_2 - V_1}{1/500\times10^{-6}s} + \frac{V_2}{2\times10^{-3}s} = 5V_2$$

$$V_2 = \frac{140}{s(5\times10^5 s^2 + 18.34\times10^6 s - 4.99\times10^4}$$

$$v_2(t) = 0.0027998e^{0.002726t} + 0.208\times10^{-6}e^{-36.676t} - 0.0028$$

(a)

$$\boxed{v_2(1ms) = 8.14\times10^{-9}}$$

(b)

$$\boxed{v_2(100ms) = 5.686\times10^{-7}}$$

(c)

$$\boxed{v_2(10s) = 7.717\times10^{-5}}$$

21. $Ueq = \frac{12s^2}{(s+1)(s+2)(34s^2+47s+30)}$

$$Zeq = \frac{12(34s+35)}{34s^2+47s+30}$$

22. (a) Z=2Ω

Transform the voltage source and 20Ω into current source

$$I_1 = \frac{s}{20(s+1)(s+2)}$$

$$Z_1 = 20\Omega // 8s = \frac{160s}{20+8s}$$

$$V_2(s) = I_1(s)Z_1 = \frac{8s^2}{(s+1)(s+2)(8s+20)}$$

$$Z_2 = Z_1 + 14 = \frac{160s}{20+8s} + 14$$

$$I_2 = \frac{V_2(s)}{Z_2} = \frac{8s^2}{(272s+280)(s+1)(s+2)}$$

$$Z_3 = Z_2 // (12/s) = \frac{12(272s+280)}{12(8s+20)+s(272s+280)}$$

$$V_3 = I_2 Z_3 = \frac{96s^2}{(s+1)(s+2)[12(8s+20)+s(272s+280)]}$$

$$I(s) = \frac{V_3}{Z+Z_3}, Z = 2\Omega$$

$$I(s) = \frac{96s^2}{(s+1)(s+2)[12(8s+20)+s(272s+280)]} \times \frac{1}{2 + \frac{12(272s+280)}{12(8s+20)+s(272s+280)}}$$

(b)

$$I(s) = \frac{V_3}{Z+Z_3}, Z = 1/2s\Omega$$

$$I(s) = \frac{96s^2}{(s+1)(s+2)[12(8s+20)+s(272s+280)]} \times \frac{1}{\frac{1}{2s} + \frac{12(272s+280)}{12(8s+20)+s(272s+280)}}$$

(c)

$$I(s) = \frac{V_3}{Z+Z_3}, Z = s + \frac{1}{2s} + 3\Omega$$

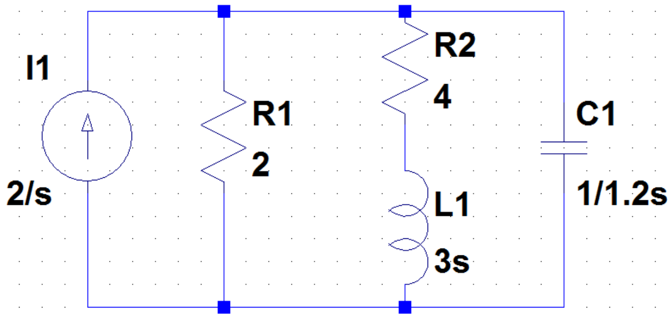
$$I(s) = \frac{96s^2}{(s+1)(s+2)[12(8s+20)+s(272s+280)]} \times \frac{1}{\left(s + \frac{1}{2s} + 3\right) + \frac{12(272s+280)}{12(8s+20)+s(272s+280)}}$$

23. (a) $Ueq = \frac{10(3s+4)}{s(18s^2+24s+5)}$; $Zeq = \frac{5(3s+4)}{18s^2+24s+5}$;

(b) $Ueq = \frac{2(15s+46)}{5s+12}$; $Zeq = \frac{s(15s+46)}{5s+12}$

(c) $Ueq = \frac{2(6s+8)}{s(3s+6)}$; $Zeq = \frac{6s+8}{3s+6}$

24.



$$\frac{-4}{s}+2(I+I_C)+(4+3s)(I-I_C)=0$$

$$(4+\frac{3}{s})(I_C-I)+I_C\times\frac{1}{1.2s}=0$$

$$I=\frac{4\left(4\times10^{33}s+3.83\times10^{33}\right)}{s(1.85\times10^{34}s+1.7\times10^{34})}$$

$$I=\frac{4\left(4\times10^{33}s+3\times10^{33}\right)}{s(1.85\times10^{34}s+1.7\times10^{34})}$$

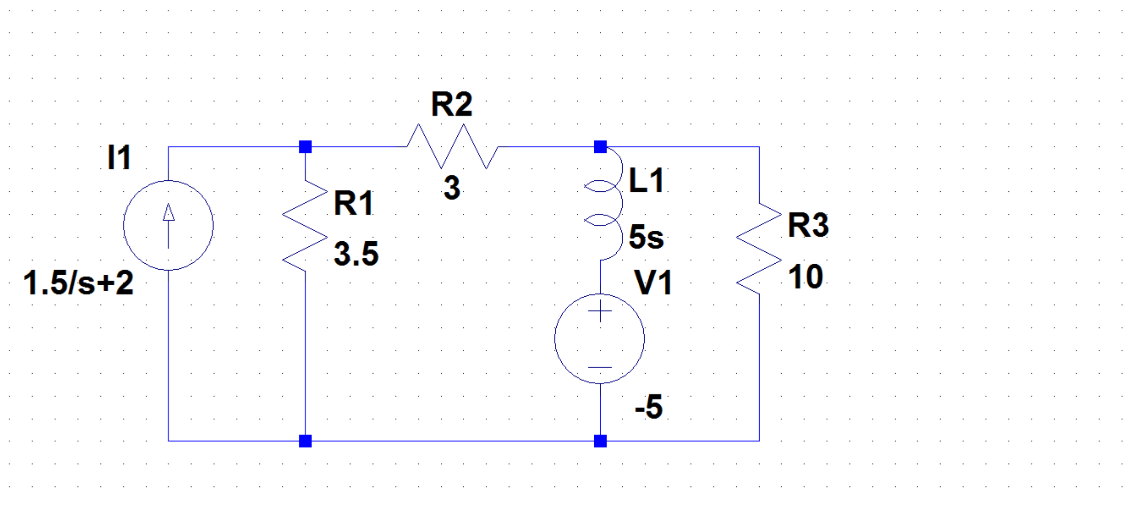
$$\boxed{i_C(t)=0.15898e^{-0.9189t}+0.706}$$

$$\boxed{i(t)=0.902-0.037e^{-0.9189t}}$$

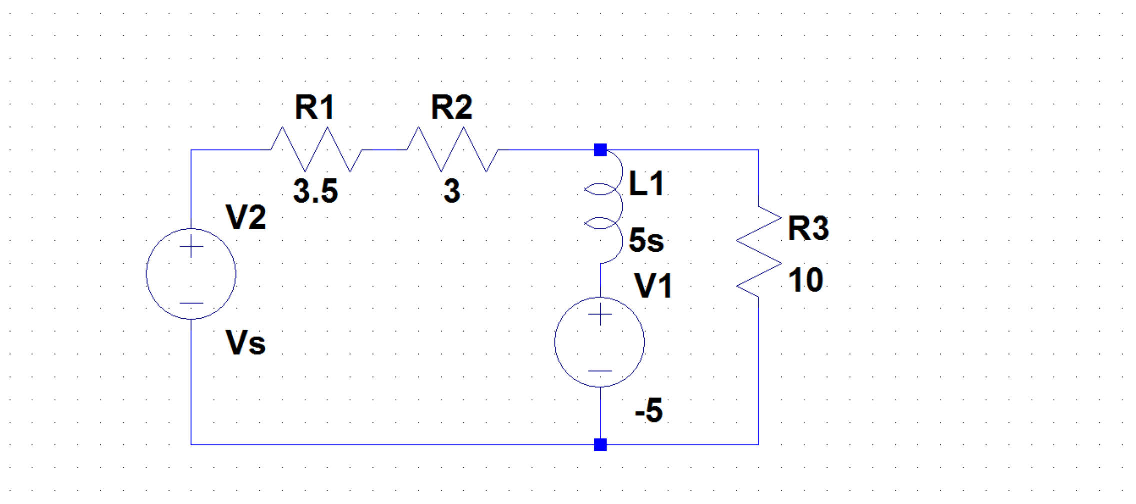
25. (a) $Ueq = \frac{17.5}{1.3+s}; \ Zeq = \frac{6.5s}{1.3+s}$

(b) $Is = \frac{350}{33s\left(5s+\frac{13}{9}\right)}, i(t) = \frac{1050}{143}u(t)(1 - e^{\frac{13t}{45}})$

26.



$$V_s = 3.5I_s = \frac{5.25}{s+2}$$



$$-V_s + 6.5(I_L + I_x) + 5sI_L - 5 = 0$$
$$-5 + 5(I_x - I_L) + 10I_x = 0$$
$$I_x = \frac{0.25(20s^2 + 86s + 113)}{(15s + 26)(s + 2)}$$
$$\boxed{i_x(t) = 1.5e^{-1.73t} + 0.33\delta(t) - 1.3125e^{-2t}}$$

31.

	Zero	Pole
(a)	0	-12.5
(b)	0, -1	-5, -3
(c)	-4	-1, -7
(d)	2, -1	0,-7,-1

32.

(a) s+4

Zero at s = -4

Pole at ∞

(b)

$$\frac{2s}{s^2-8s+16}=\frac{2s}{(s-4)(s-4)}$$

$$zero = 0$$
$$ploes = 4,4$$

(c)

$$\frac{4}{s^3+8s+7}$$

$$zero = \infty$$

$$poles$$

$$s = 0.4044 + j2.9139$$
$$s = -0.8089$$
$$s = 0.4044 - j2.9139$$

(d)

$$\frac{s-5}{s^3-7s+6}=\frac{s-5}{(s+3)(s-2)(s-1)}$$

$$zero$$
$$s = 5$$
$$ploes:$$
$$s = -3$$
$$s = 2$$
$$s = 1$$

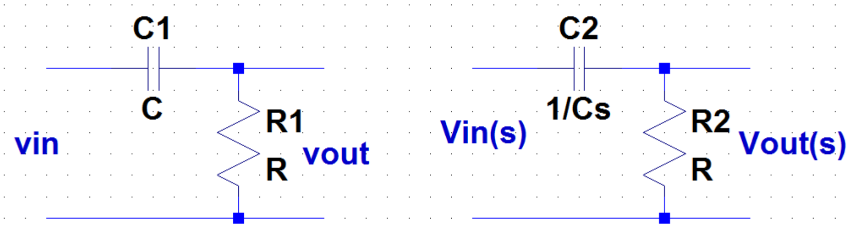
33. (a) s=0. s=-0.2;

(b) s=0, s=-4, s=-1, s=-3, s=-5;

(c) s=2, s=-2;

(d) s=1, s=-1, s=6, s=-6

34.



(a)

$$H(s)=\frac{V_{out}(s)}{V_{in}(s)}$$

$$0=\frac{V_{out}(s)}{R}+\frac{V_{out}-V_{in}}{1/sC}$$

$$0=\frac{V_{out}(s)}{R}+sCV_{out}-sCV_{in}$$

$$sCV_{in}=V_{out}\left(\frac{1}{R}+sC\right)$$

$$\boxed{\frac{V_{out}}{V_{in}}=\frac{RCs}{1+RCs}}$$

(b)

Zero

$$RCs=0$$

$$\boxed{s=0}$$

Poles:

$$\boxed{\begin{gathered}1+\mathrm{RC}s=0\\ s=-1/\mathrm{RC}\end{gathered}}$$

35. (a) for circuit a:

$$\frac{Vout}{R} = \frac{Vin - Vout}{sL}, H = \frac{Vout}{Vin} = \boxed{\frac{1}{\frac{sL}{R} + 1}}$$

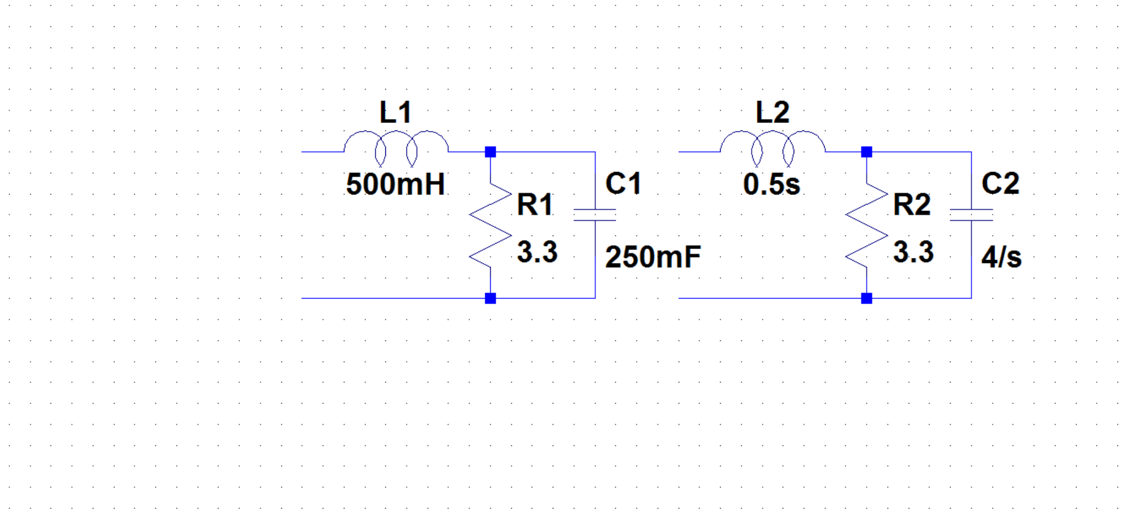
for circuit b:

$$\frac{Vout}{Ls} = \frac{Vin - Vout}{R}, H = \boxed{\frac{1}{1 + \frac{R}{sL}}}$$

(b)

	Zero	Pole
(a)	∞	-R/L
(b)	0,	-R/L

36.



$$Z_{in}(s) = 0.5s + 3.3//(4/s)$$

$$Z_{in}(s) = 0.5s + \frac{3.3\times(4/s)}{3.3+(4/s)}$$

$$Z_{in}(s) = \frac{1.65s^2 + 2s + 13.2}{3.3s + 4}$$

Critical frequencies are the poles and the zeros

$$\begin{array}{l} poles \\ s = -4/3.3 \\ Zeros: \\ s_1 = -0.6061 + j2.7627 \\ s_2 = -0.6061 - j2.7627 \end{array}$$

37. $Y(s) = \frac{2650s+120}{(17s+47)(333s+200)} + \frac{1}{5}$

zeros: s=-0.3285, -5.3774

poles: s=-47/17, -200/333

38. $H(s) = \dfrac{s}{s^2 + 8s + 7}$

(a) $v_{in}(t) = 3u(t)V$

$$V_{out}(s) = H(s)V_{in}(s)$$

$$V_{in}(s) = \frac{3}{s} \Rightarrow V_{out}(s) = \frac{s}{s^2 + 8s + 7} \times \frac{3}{s}$$

$$\therefore V_{out}(s) = \frac{3}{s^2 + 8s + 7}$$

(b) $v_{in}(t) = 25e^{-2t}u(t)$

$$V_{in}(s) = \frac{25}{s+2}$$

$$V_{out}(s) = H(s)V_{in}(s)$$

$$V_{out}(s) = \frac{25s}{(s+2)(s^2 + 8s + 7)}$$

(c) $v_{in}(t) = 4u(t+1)$

$$V_{in}(s) = 4 \times \frac{1}{s} \times e^{s} = \frac{4}{s}e^{s}$$

$$V_{out}(s) = H(s)V_{in}(s)$$

$$V_{out}(s) = \frac{4e^{s}}{(s^2 + 8s + 7)}$$

(d) $v_{in}(t) = 2\sin(5t)u(t)$

$$V_{in}(s) = 2 \times \frac{5}{s^2 + 25} = \frac{10}{s^2 + 25}$$

$$V_{out}(s) = H(s)V_{in}(s)$$

$$V_{out}(s) = \frac{10s}{(s^2 + 25)(s^2 + 8s + 7)}$$

39. $H(s) = s + \frac{1}{s^2+23s+60}$

(a) $Vin = \frac{2}{s} + 4, Vout = H(s) * Vin = \frac{2(s^3+23s^2+60s+1)(2s+1)}{s(s+20)(s+3)}$

s=0, s=-20, s=-3; s=-0.5

(b)$Vin = -\frac{5}{s+1}, Vout = \frac{5(s^3+23s^2+60s+1)}{(s+20)(s+3)(s+1)}$

s=-20, s=-3, s=-1

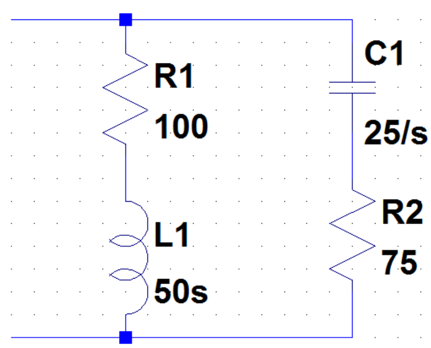
(c)$Vin = \frac{4}{(s+2)^2}, Vout = H(s) * Vin = \frac{4(s^3+23s^2+60s+1)}{(s+20)(s+3)(s+2)^2}$

s=-20, s=-3, s=-2

$(d)\ Vin = 5\sqrt{10}\frac{s+1}{(s+10)^2+25},$

s=-20, s=-3, s=-5, s=-15, s=-10

40.



$$Z_1 = 75 + \frac{25}{s}$$

$$Z_2 = 100 + 50s$$

$$Z_{in} = Z_1 // Z_2 = \frac{(100+50s)\left(75+\frac{25}{s}\right)}{100+50s+75+\frac{25}{s}}$$

$$Z_{in} = \frac{(100+50s)(75s+25)}{225s+25}$$

Zeros :

$$s_1 = -100/50 = -2$$
$$s_2 = -25/75 = -0.333$$

Poles :

$$s = -25/225 = -0.111$$

41. x(t)=u(t), y(t)=u(t-1);

So, $x(t) * y(t) = \int_{-\infty}^{t} u(t)u(t-z-1)\,dz$

When t<1, x(t)*y(t)=0; when t>1, x(t)*y(t)=t-1

42. (a) $x(t) * x(t)$

$$y(t) = x(t) * h(t) = \int_{-\infty}^{t} x(z)h(t-z)dz$$ Equation (11)

$t < 0$

$x(t) * x(t) = 0$

$t > 0$

$$x(t) * x(t) = \int_{0}^{t} (1 \times 1) dz = t$$

To check in frequency domain:

$$x(t) * x(t) = X(s) \times X(s) = \frac{1}{s^2}$$

$$\ell^{-1}\{X^2(s)\} = \ell^{-1}\left\{\frac{1}{s^2}\right\} = t$$

(b) $y(t) * \delta(t)$

$$y(t) = 3u(t-1)$$

$$y(t) * \delta(t) = \int_{-\infty}^{t} \delta(z)y(t-z)dz$$

43. $f(t) = \begin{cases} 0, \ t < 0 \\ 10t, \ 0 \leq t < 2 \\ 20, \ 2 \leq t < 4 \\ 10t - 20, \ 4 \leq t < 6 \\ 40, \ t \geq 6 \end{cases}$

44.

$$h(t) = 2e^{-3t}u(t)$$
$$x(t) = u(t) - \delta(t)$$
$$y(t) = h(t) * x(t)$$

(a) convolution in the time domain

$$h(t) * x(t) = \int_{-\infty}^{t} x(z)h(t-z)dz$$
$$t < 0 \Rightarrow y(t) = 0$$
$$t > 0$$
$$y(t) = \int_{-\infty}^{t} [u(z) - \delta(z)](2e^{-3(t-z)}dz$$
$$y(t) = \left[\frac{2}{3} - \frac{8}{3}e^{-3t}\right]u(t)$$

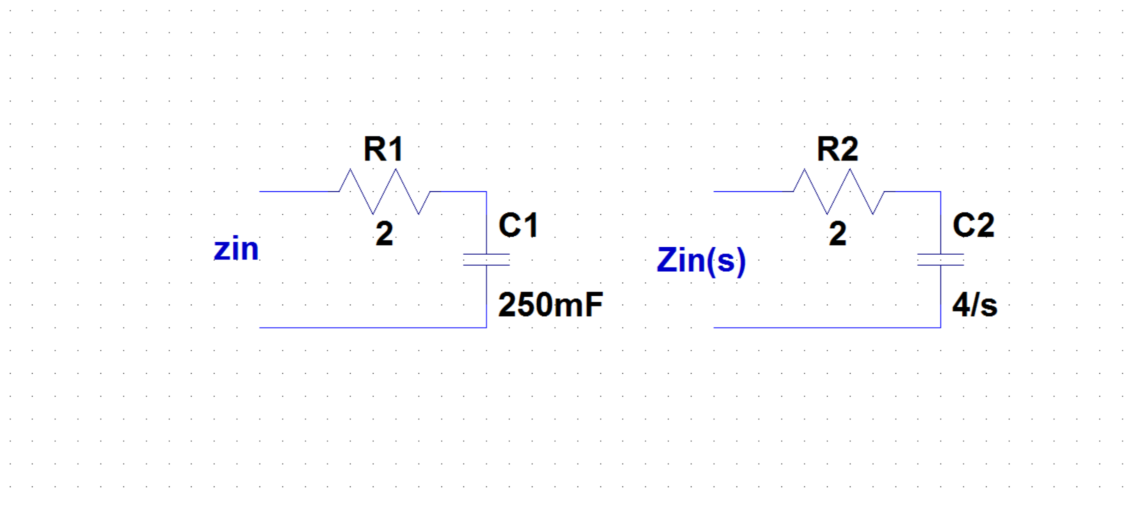
(b) $y(t) = \ell^{-1}\{X(s)H(s)\}$

$$H(s) = \frac{2}{s+3}$$
$$X(s) = \ell\{u(t) - \delta(t)\} = \frac{1}{s} - 1 = \frac{1-s}{s}$$
$$Y(s) = X(s)H(s) = \frac{1-s}{s} \times \frac{2}{s+3} = \frac{2(1-s)}{s(s+3)} = \frac{A}{s} + \frac{B}{s+3}$$
$$A = \frac{2}{3}, B = \frac{-8}{3}$$
$$Y(s) = \frac{2/3}{s} + \frac{-8/3}{s+3}$$

$$\boxed{y(t) = \ell^{-1}\{Y(s)\} = \left[\frac{2}{3} - \frac{8}{3}e^{-3t}\right]u(t)}$$

45. $Z = \frac{5s+20}{s+9}$, $Vin = Vout$

46.



$$Z_{in} = R + \frac{1}{Cs} = \frac{RCs+1}{RCs}$$

$$Z_{in} = 2 + \frac{4}{s} = \frac{2s+4}{s}$$

$$s = \sigma + j\omega$$

$$Z_{in} = \frac{2(\sigma + j\omega)+4}{\sigma + j\omega}$$

$$|Z_{in}| = \frac{\sqrt{(2\sigma+4)^2 + 4\omega^2}}{\sqrt{\sigma^2+\omega^2}}$$

$$s = \sigma \Rightarrow |Z_{in}| = \frac{(2\sigma+4)}{\sigma}$$

$$s = j\omega \Rightarrow |Z_{in}| = \frac{\sqrt{16+4\omega^2}}{\omega}$$

47. (a) $\boxed{Z(\sigma) = \sigma^2 + \sigma}$

(b) $Z(\omega) = -\omega^2 + j\omega$, $\boxed{|Z| = \omega\sqrt{\omega^2 + 1}}$

(c) $Z = (\sigma^2 + \sigma - \omega^2) + 2j\sigma\omega$, $\boxed{|Z| = \sqrt{(\sigma^2 + \sigma - \omega^2)^2 + (2\sigma\omega)^2}}$

48.

(a) $\dfrac{s(s+4)}{(s+5)(s+2)}$

$$Zeros: s = 0, s = -4$$
$$Poles: s = -5, s = -2$$

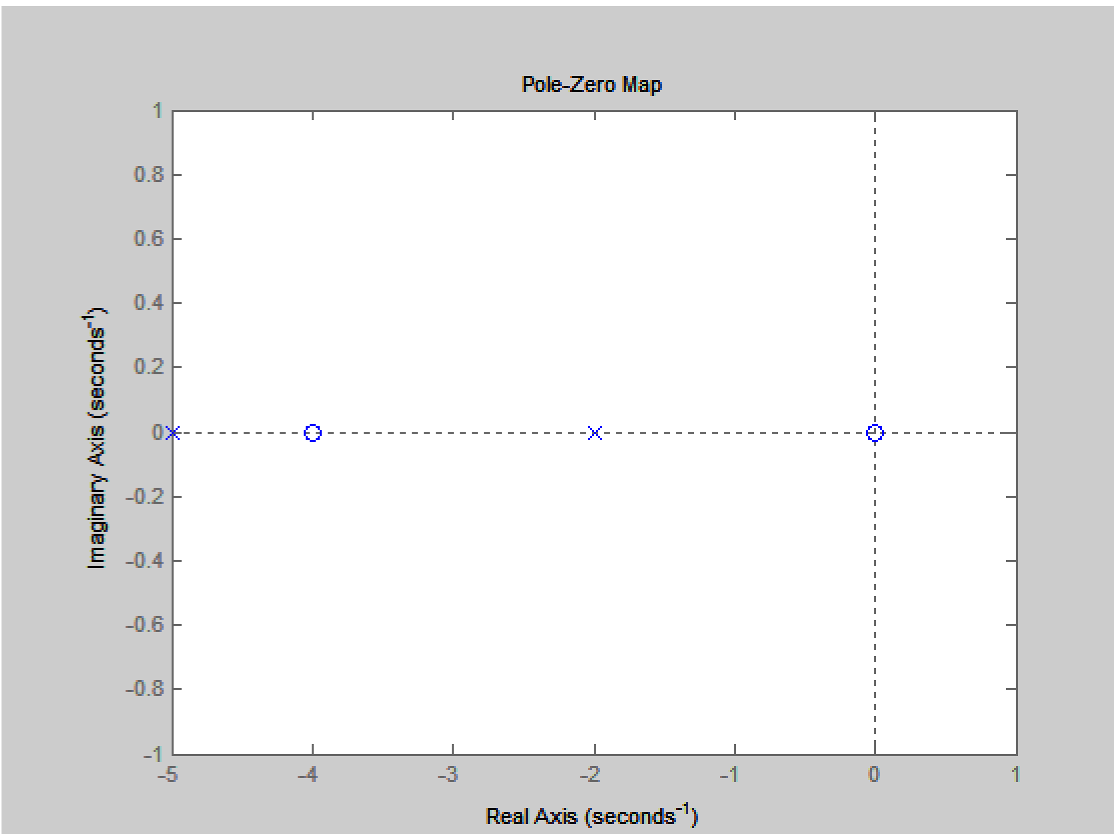
```
H = tf([1 4 0],[1 7 10])
sgrid
pzmap(H)
```

Transfer function:

s^2 + 4 s

----

s^2 + 7 s + 10



(b) $\frac{s-1}{s^2+8s+7}$

$Zeros: s=1$

$Poles: s=-1, s=-7$

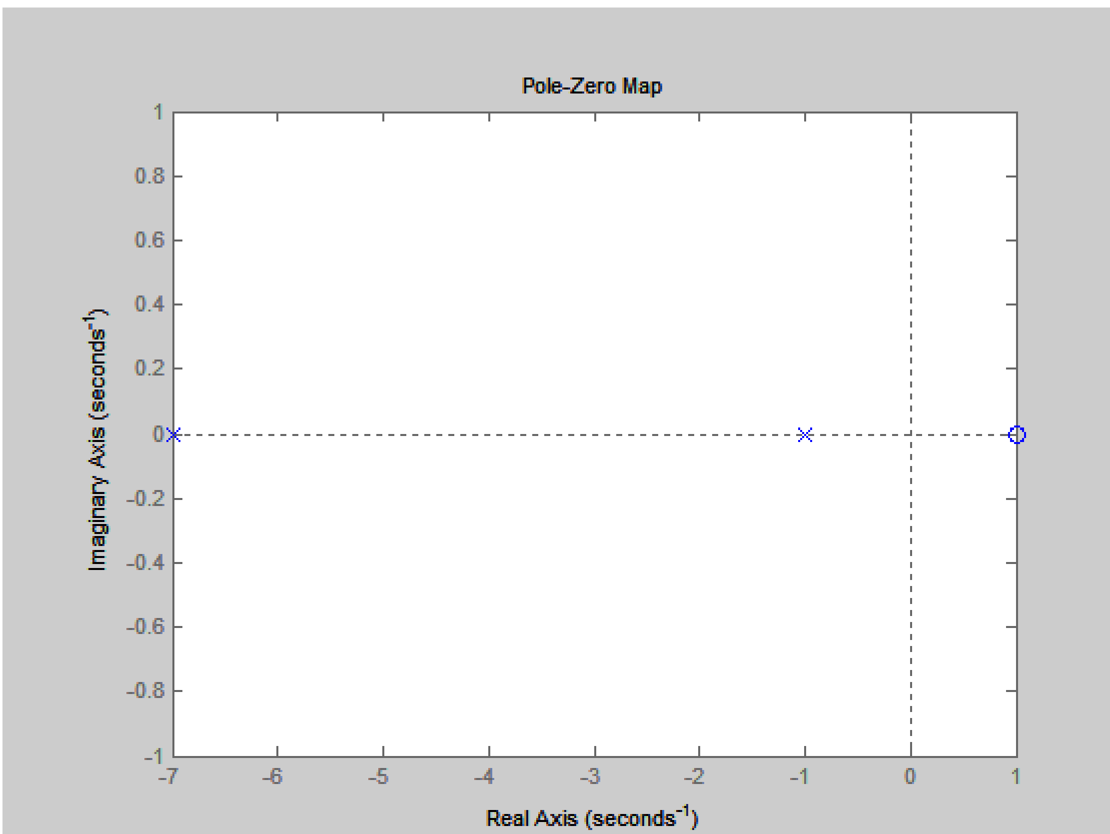
```
H = tf([1 -1],[1 8 7])
sgrid
pzmap(H)
```

Transfer function:

s - 1

----

s^2 + 8 s + 7



(c) $\dfrac{s^2+1}{s(s^2+10s+16)}$

$$Zeros: s = \pm\sqrt{-1} = \pm j$$
$$Poles: s = 0, s = -2, s = -8$$

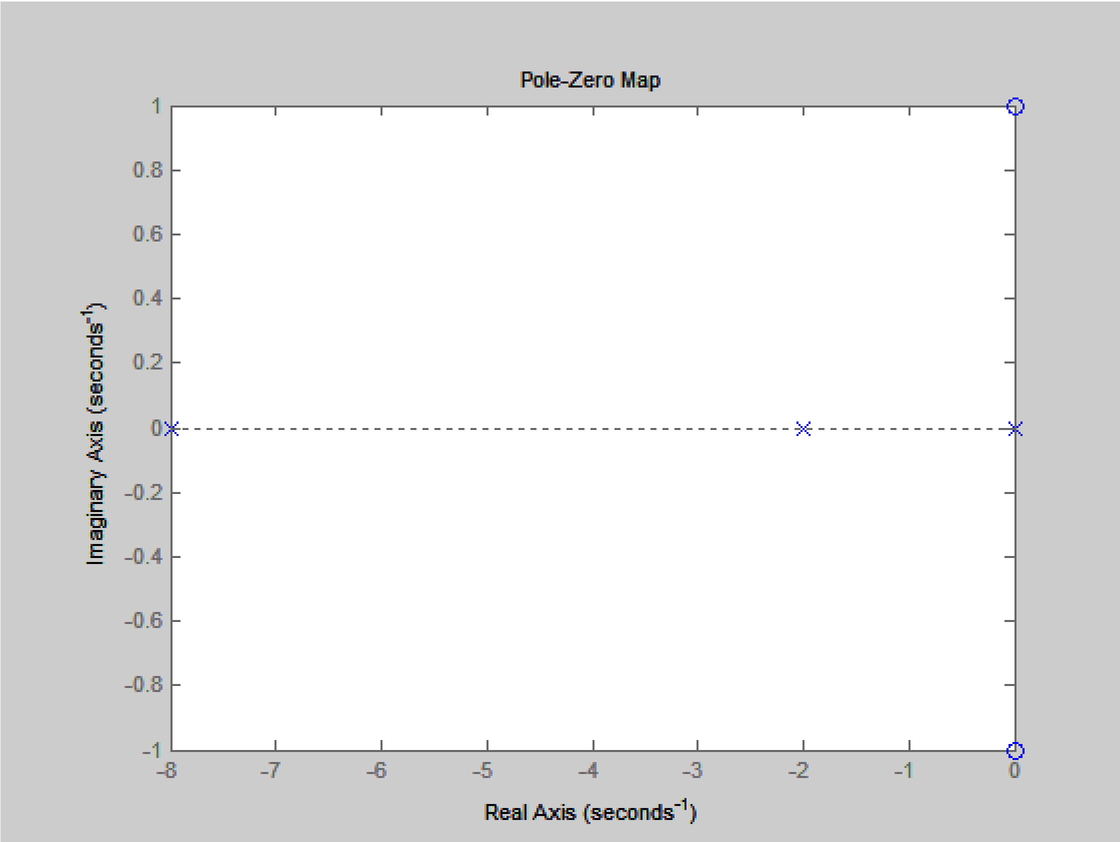
```
H = tf([1 0 1],[1 10 16 0])
sgrid
pzmap(H)
```

Transfer function:

s^2 + 1

----

s^3 + 10 s^2 + 16 s



(d) $\dfrac{5}{s^2+2s+5}$

$$Zeros: s = \infty$$
$$Poles: s = -1+2j, s = -1-2j$$

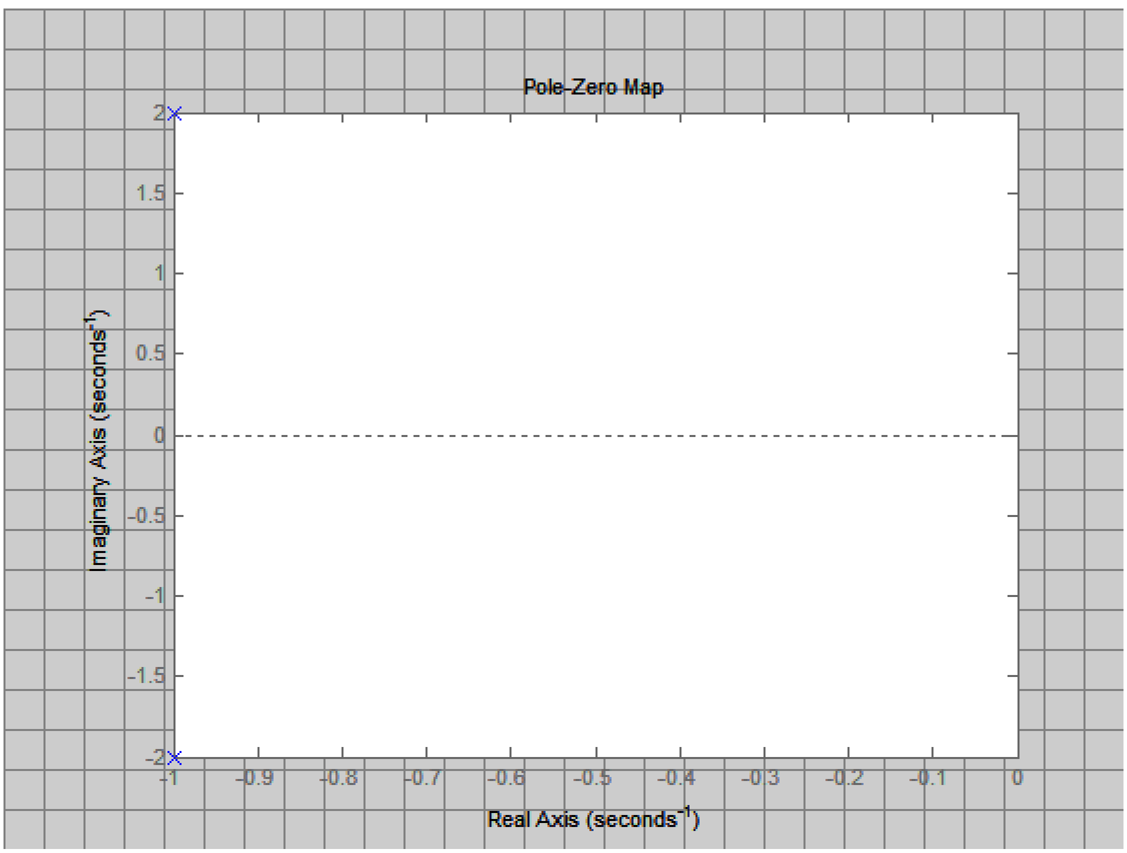
```
H = tf([5],[1 2 5])
sgrid
pzmap(H)
```

Transfer function:

5

----

s^2 + 2 s + 5

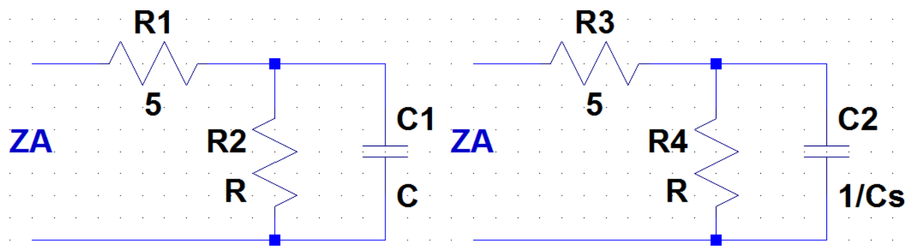


49. $H(s) = \frac{k(s+2)}{s^2+2s+5}$

(a) $H(0) = 1$, $H(s) = \frac{5}{2}\frac{s+2}{s^2+2s+5}$

(b) $H(0) = -5$, $H(s) = -\frac{25}{2}\frac{s+2}{s^2+2s+5}$

50.



$$Z_A = \left(R // \tfrac{1}{Cs}\right) + 5 = \frac{(R+5)+5RCs}{RCs+1}$$

$$Zero:(R+5)+5RCs = 0$$

$$s = \frac{-(R+5)}{5RC} = -10$$

$$20 + Z_A = 20 + \frac{(R+5)+5RCs}{RCs+1}$$

$$= \frac{25RCs+R+25}{RCs+1}$$

$$s_{zero} = \frac{-(R+25)}{25RC}$$

$$\boxed{R = 20\Omega}$$

$$\boxed{C = 0.25F}$$

51.

(a) $H(s) = 100\frac{s+2}{s^2+2s+5}$

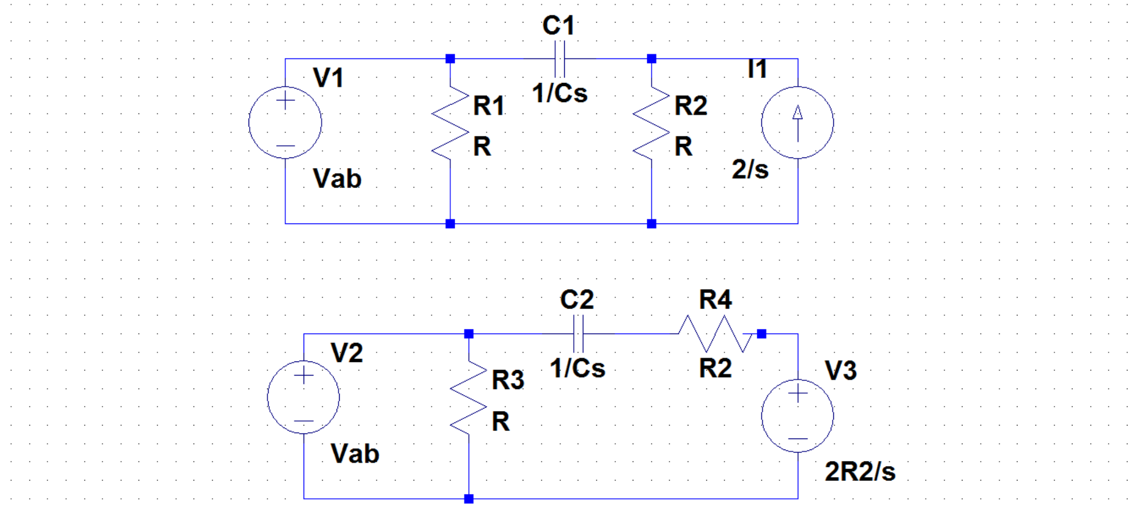
(b) $H(j\omega) = 100\frac{j\omega+2}{-\omega^2+2j\omega+5}, |H(j\omega)| = 100\sqrt{\frac{\omega^2+4}{\omega^4+14\omega^2+25}}$

(e) $\omega_{max} = -1.67$

53. $\begin{cases} \left(4+\frac{2}{s}\right)I1 + 2s(I1 - I2) - 2 = 0 \\ 2I2 + 2s(I2 - I1) + 2 = 0 \end{cases}$

So, $\begin{cases} I1 = \frac{s}{3s^2+3s+1} \\ I2 = -\frac{2s+1}{3s^2+3s+1} \end{cases}$, and $\boxed{i2(t) = -\frac{2}{3}\cos\left(\frac{\sqrt{3}t}{6}\right)e^{-0.5t}}$

54.



$$Z_1 = R_2 + 1/Cs$$

$$V_{ab} = \frac{2R_2}{s} \times \frac{R_1}{R_1 + Z_1}$$

$$V_{ab} = \frac{2R_1R_2C}{1 + (CR_1 + CR_2)s}$$

Natural frequency in Vab:

$$\boxed{s = \frac{-1}{(CR_1 + CR_2)}}$$

55. $Iin = \frac{2s^2+16s+16}{2s^3+13s^2+12s}$

(a) $\begin{cases} I2(s) = \frac{1}{2s^2+13s+12} \\ I1(s) = Iin - I2(s) = \frac{2s^2+15s=16}{2s^3+13s^2+12s} \end{cases}$

So $i2(t) = 0.12e^{-1.11t} - 0.12e^{-5.39t}$

56. $H(s) = V_{out}/V_{in}$

(a) $5(s+1)$

Zero at s=-1

Fig. 15.43 (b)

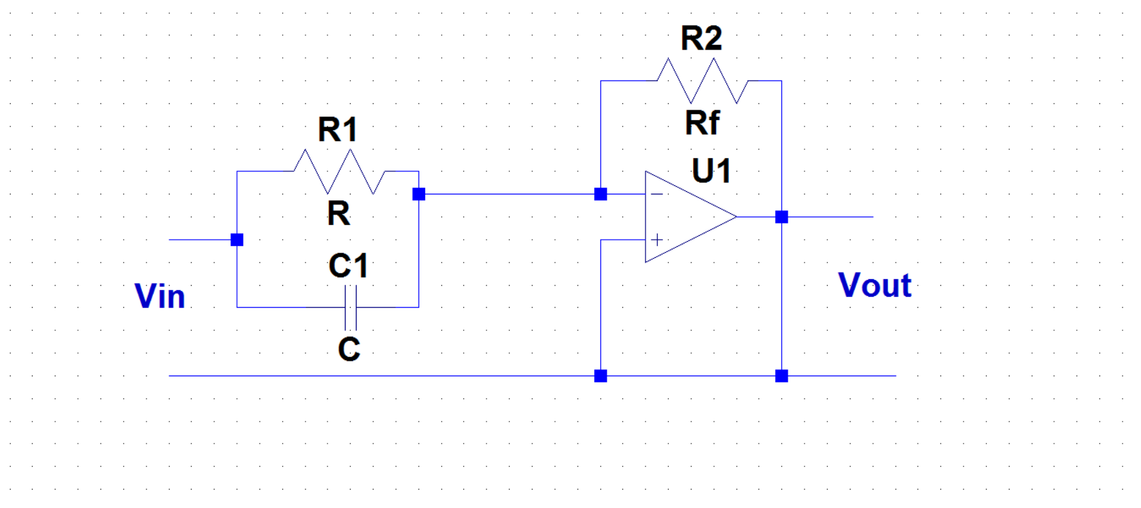
$$H(s) = -R_f C_1 (s + \frac{1}{R_1 C_1})$$

$$zero : s = \frac{-1}{R_1 C_1} = -1$$

$$\boxed{R_1 = 100k\Omega} \Rightarrow \boxed{C_1 = 10\mu F}$$

$$H(s) = -R_f C_1 (s+1) = -R_f 10\times 10^{-6} (s+1) = 5(s+1)$$

$$-R_f 10\times 10^{-6} = 5 \Rightarrow \boxed{R_f = 50k\Omega}$$



56. (b)

$$H(s) = \frac{5}{s+1}$$

$$pole: s = -1$$

$$Fig15.43(a)$$

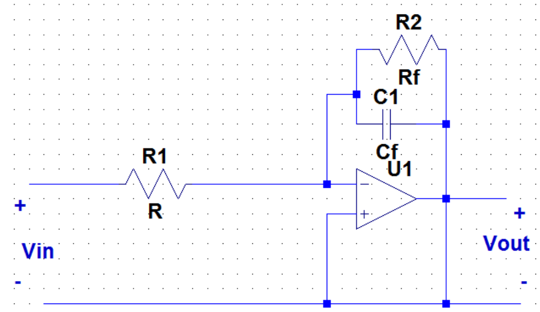
$$H(s) = -\frac{1/R_1C_f}{s + \left(1/R_fC_f\right)}$$

$$pole = -1/R_fC_f = -1$$

$$\boxed{R_f = 100k\Omega}$$

$$C_f = \frac{1}{R_f} \Rightarrow \boxed{C_f = 10\mu F}$$

$$\frac{1}{R_1C_f} = 5 \Rightarrow \boxed{R_1 = 20k\Omega}$$



56. (c)

$$H(s) = 5\frac{s+1}{s+2}$$

$$Pole: s = -2$$

$$\frac{1}{R_{fA}C_{fA}} = 2$$

$$\boxed{R_{fA} = 100k\Omega}$$

$$C_{fA} = \frac{1}{2\times 100\times 10^3} \Rightarrow \boxed{C_{fA} = 5\mu F}$$

$$H_A(s) = -\frac{\frac{1}{R_{1A}C_{fA}}}{s + \left(\frac{1}{R_{fA}C_{fA}}\right)} = -\frac{2\times 10^5 / R_{1A}}{s+2}$$

$$Zero: s = -1$$

$$\frac{1}{R_{1B}C_{1B}} = 1 \Rightarrow \boxed{R_{1B} = 100k\Omega}$$

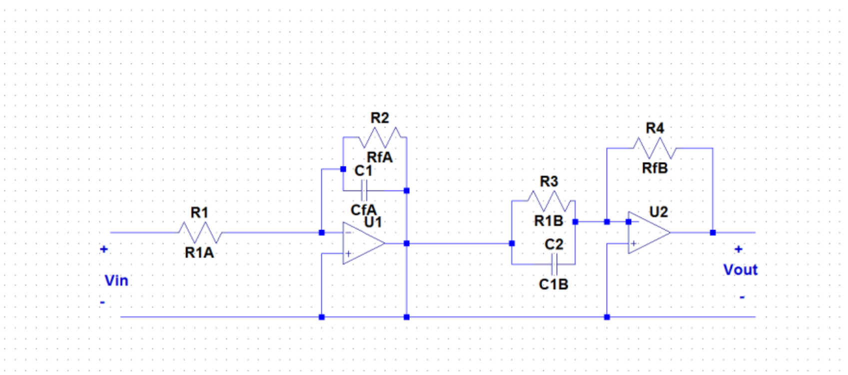
$$C_{1B} = \frac{1}{R_{1B}} \Rightarrow \boxed{C_{1B} = 10\mu F}$$

$$H_B(s) = -R_{fB}C_{1B}\left(s + \frac{1}{R_{1B}C_{1B}}\right) = -10\times 10^{-6} R_{fB}(s+1)$$

$$H(s) = H_A(s)H_B(s) = 2.\frac{R_{fB}}{R_{1A}}.\frac{(s+1)}{(s+2)}$$

$$2.\frac{R_{fB}}{R_{1A}} = 5 \Rightarrow \boxed{R_{fB} = 100k\Omega}$$

$$\boxed{R_{1A} = \frac{2R_{fB}}{5} = 40k\Omega}$$



57. (a), cascade 2 stage of fig/ 15.43 (b).

We get: $H1 = H2 = -\sqrt{2}(s+1) = -Rf * C1\left(s + \frac{1}{R1*C1}\right)$

So, R1=1 kΩ, C1=1 μF, Rf=1.41 kΩ

(b) two stage of Fig. 15.43 (a)

Stage 1: $H1 = -\frac{\frac{1}{R1*Cf1}}{s+\frac{1}{Rf1*Cf1}} = -\frac{3}{s+500}$,

Then, Cf1=1 μF, R1=333 Ω, Rf1=2 Ω

Stage 2: $H1 = -\frac{\frac{1}{R2*Cf2}}{s+\frac{1}{Rf2*Cf2}} = -\frac{1}{s+100}$

Then, Cf2=1 μF, R2=2 kΩ, Rf1=100 Ω

58. $H(s) = \frac{V_{out}}{V_{in}} = 5\frac{s+10^4}{s+2\times10^5}$

$Pole: s = -2\times10^5$

$1/R_{fA}C_{fA} = 2\times10^5$

$\boxed{R_{fA} = 100k\Omega}$

$C_{fA} = \frac{1}{2\times10^5\times100\times10^3} \Rightarrow \boxed{C_{fA} = 5\times10^{-11}F}$

$H_A(s) = -\frac{1/R_{1A}C_{fA}}{s+\left(1/R_{fA}C_{fA}\right)} = -\frac{2\times10^{10}/R_{1A}}{s+2\times10^5}$

$Zero: s = -10^4$

$1/R_{1B}C_{1B} = 1 \Rightarrow \boxed{R_{1B} = 100k\Omega}$

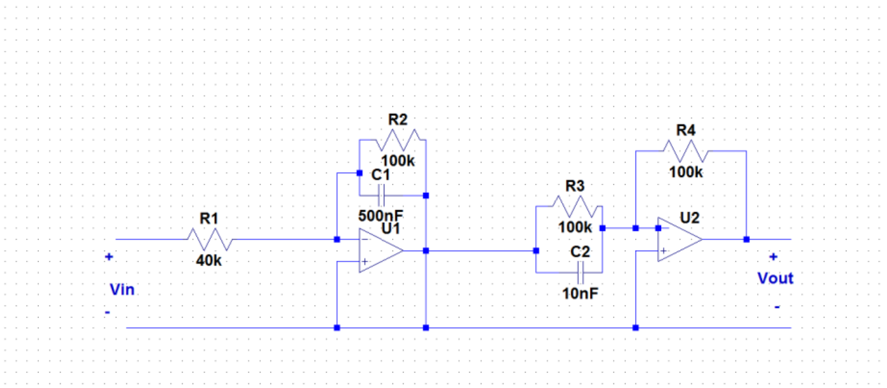
$C_{1B} = 1/10^4 R_{1B} \Rightarrow \boxed{C_{1B} = 10nF}$

$H_B(s) = -R_{fB}C_{1B}\left(s + 1/R_{1B}C_{1B}\right) = -1\times10^{-10}R_{fB}(s+10^4)$

$H(s) = H_A(s)H_B(s) = 2.\frac{R_{fB}}{R_{1A}}.\frac{(s+10^4)}{(s+2\times10^5)}$

$2.\frac{R_{fB}}{R_{1A}} = 5 \Rightarrow \boxed{R_{fB} = 100k\Omega}$

$\boxed{R_{1A} = \frac{2R_{fB}}{5} = 40k\Omega}$



59. 3 stages:

Stage 1: Fig. 15.43(b); stage 2&3: Fig. 15.43(a)

Then, $\begin{cases} C1 = 1\ \mu F \\ Rf1 = 3\ k\Omega \\ R1 = 20\ \Omega \end{cases}$, $\begin{cases} Cf2 = cf3 = 1\ \mu F \\ R2 = R3 = 1\ k\Omega \\ Rf2 = 13.3\ \Omega \end{cases}$

60. $H(s)=\frac{V_{out}}{V_{in}}=-\frac{Z_f}{Z_1}$

(a)

$$Z_1(s)=10^3+(10^8/s), Z_f(s)=500$$

$$H(s)=\frac{-500}{10^3+(10^8/s)}=\frac{-500s}{10^8+10^3s}$$

(b)

$$Z_1(s)=5000, Z_f(s)=10^3+(10^8/s)$$

$$H(s)=\frac{-\left(10^3+(10^8/s)\right)}{5000}=-2\times10^{-4}\left(\frac{10^8+10^3s}{s}\right)$$

(c)

$$Z_1(s)=10^3+(10^8/s), Z_f(s)=10^4+(10^8/s)$$

$$H(s)=\frac{-Z_f}{Z_1}=-\frac{10^4+(10^8/s)}{10^3+(10^8/s)}$$

$$H(s)=-\frac{10^8+10^4s}{10^8+10^3s}$$

1. (a) Q0=100; ξ=0.005;

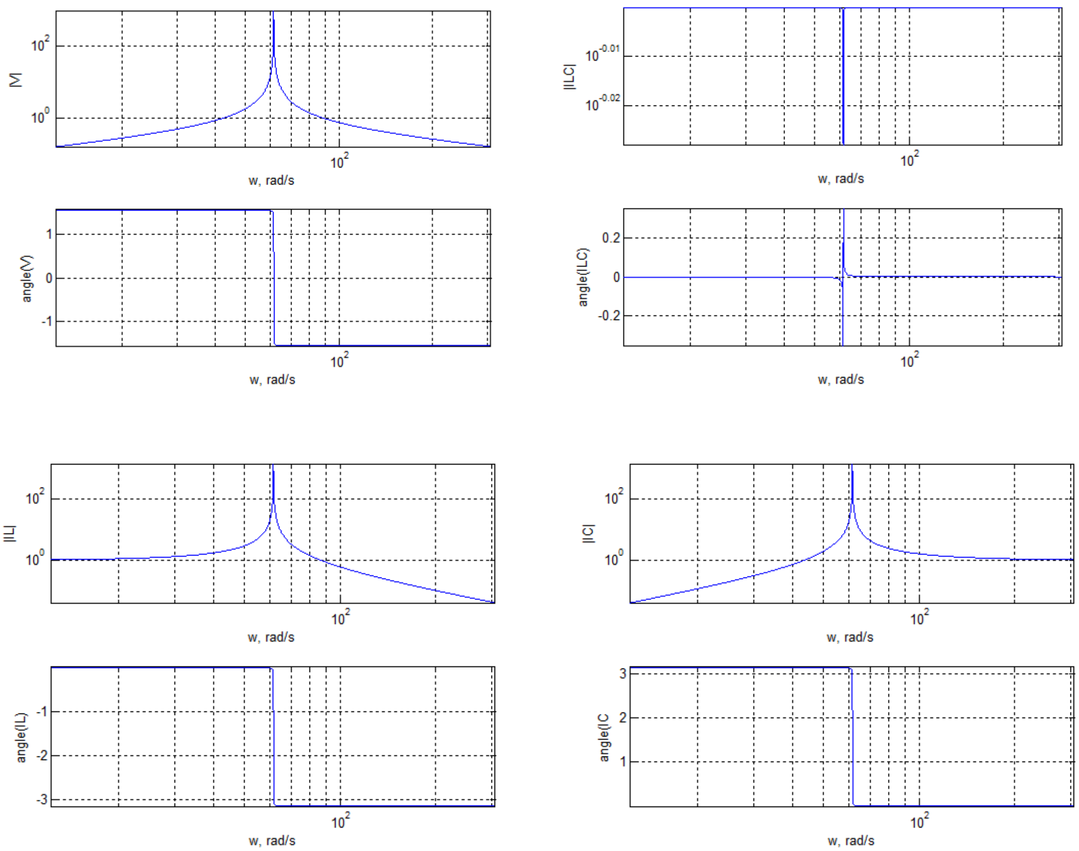
(b) Q0=0.1, ξ=5;

(c) q0=1000, ξ=5e-4;

(d) Q0=1, ξ=0.5

2. (a) α = 22.73e-3; ω_0 = 61.54 rad/s; ζ = 369e-6; f_0 = 9.8 Hz; ω_d = 61.54 rad/s

(b)



Note $\angle V = 0^o$ at ω_0.

(c) $I_L = -I_C$ at ω_0.

3. $|Y| = \sqrt{\frac{1}{R^2} + \left(\omega L - \frac{1}{\omega c}\right)^2}$

So 1/12.3<|Y|<9.93,

Then 0.1<|Z|<12.3

4. (a) $Q_0 = 0.5$

(b) Require |Z(ω)| = 0.9 Zmax = 0.9 R = 0.9(5) = 4.5 or |Y(ω)| = 1/4.5 or

$$|Y(\omega) = \left|\frac{1}{R} + \frac{1}{j\omega L} + j\omega C\right| = \sqrt{\left(\frac{1}{R}\right)^2 + \left(\omega C - \frac{1}{\omega L}\right)^2} = \frac{1}{4.5}$$

Solve quadratic equation to obtain: $\omega_1 = 62.7$ rad/s; $\omega_1 = 159.5$ rad/s

5. Z(ω) = (R1+jωL)//(R2 + (R3//(1/jωC))), where R1 = 1 Ω, R2 = 2 Ω and R3 = 100kΩ then

$$Z(\omega) \approx \frac{100e3 - 0.4\omega^2 + j(200e3)\omega}{100e3 - 0.2\omega^2 + j2.2\omega}$$

At resonance Z(ω) is purely resistive. Set Imag{ Z(ω)} = 0 to obtain ω_0, or

$$40\omega_o^2 - 20e6 = 0 \Rightarrow \omega_o = 707.1\ rad/s$$

6.

$$Z(\omega) = \frac{100e3 - 0.4\omega^2 + j(200e3)\omega}{100e3 - 0.2\omega^2 + j2.2\omega}$$

7. $Y = sC + 10^{-5} + \frac{1}{1+0.2s}$

|Y(ω0)|=6e-5,

(b) When *Im*(Y) = 0, ω0=707 rad/s

(c) Q_max=707

8. (b) At resonance, Z(ω) is real and $Z(\omega_0) = 8054.4\ \Omega$

(a) When *Im*(Z) = 0, ω_0=707.1 rad/s

(c) Let source voltage $V_S = 1\angle 0^o Volt$ be connected at input terminals.

Then, $V_C = \frac{V_S}{1+j0.014} \approx V_S = V_L$

Maximum energy stored at ω_0 is:

$$w_C(t) + w_L(t) = \frac{1}{2}Cv_C^2(t) + \frac{1}{2}Li_C^2(t) = \frac{1}{2}Cv_C^2(t) + \frac{1}{2}L(\int v_L dt)^2 = \frac{cos^2\omega_0 t}{200e3} + \frac{sin^2\omega_0 t}{200e3} = 10^{-5}$$

Total energy lost per period at ω_0 is:

$$(P_{2\Omega} + P_{100K\Omega})T_0 = 44.4 \times 10^{-9}$$

Therefore, $Q_0 = 2\pi \frac{\text{Maximum energy storedat } \omega_0}{\text{Total energy lost per period at } \omega_0}$

$Q_0 = 1414$

9. Q=$\frac{5.06e-3}{\frac{1}{\omega}+(5.97e-14)\,\omega}$,

ω0=4e6,

Q_max=10368.6

10. ω_0 = 3162 rad/s , $R = \frac{Q_0}{\sqrt{\frac{C}{L}}} = 47.43\ \Omega$ and B = ω_0/Q_0 = 210.8 rad/s

(a) Z(3162) = Z(ω_0) = 47.43 Ω

(b) $|Z(\omega)| \approx \frac{R}{\sqrt{1+N^2}}$ and $argZ(\omega) = -tan^{-1}N$. So, $Z(3000) = 25.8\angle 57^o \Omega$

(c) $Z(3200) = 44.7\angle{-20^o}\Omega$

(d) $Z(2000) = 4.3\angle 85^o \Omega$

(d) $Z(3000) = 25.3\angle 58^o \Omega; Z(3200)45\angle - 20^o \Omega; Z(2000) = 3.3\angle 86^o \Omega$

11. $|Y| = \frac{1}{R}\sqrt{1 + Q^2\left(\frac{\omega}{\omega 0} - \frac{\omega 0}{\omega}\right)^2}$

(a) |Y|=0.3016, |Z|=3.3156;

(b) |Y|=0.0551, |Z|=18.15;

(c) |Y|=0.0349, |Z|=28.65;

(d) |Y|=1/32.5, |Z|=32.5

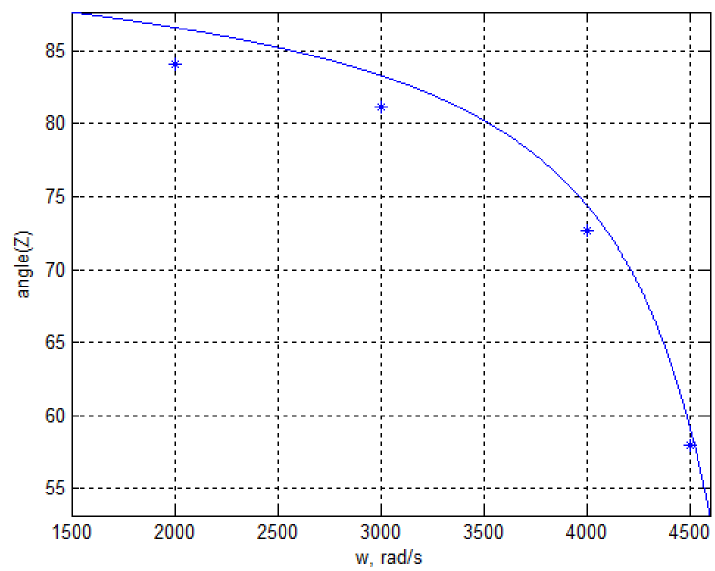
12. C = 200 μF; R = 8 Ω

(a) $arg Z(2000) = \angle 84^o$

(b) $arg Z(3000) = \angle 82^o$

(c) $arg Z(4000) = \angle 73^o$

(d) $arg Z(4500) = \angle 58^o$



(d)

13. (a) B~1 kHz;

(b) B~10 MHz

14.(a) C = 1 F

(b) R = 2.5 Ω

(c) Q = 2.5; w1 = 0.82 rad/s; w2 = 1.22 rad/s; B = 0.4 rad/s

15. $Q0 = \frac{1}{R}\sqrt{\frac{L}{C}} = 7, so\ C = 3\ nF, Z = R + j(\omega L - \frac{1}{\omega C})$

(a) |Z|=500 kΩ

(b) $Is = 10^{-20} cos(4.25 \times 10^{8} t) + 1.7 \times 10^{-6} sin(4.25 \times 10^{8} * t) - 8 \times 10^{-11} * e^{-3\times 10^{-7} * t}$

16. $Q0 = \frac{1}{R}\sqrt{\frac{L}{C}} = 7$; so for Q0 = 5, R = 141.4 Ω

(b) $argZ(90K) = \angle -82.9^o, argZ(100K) = \angle -82.8^o, argZ(110K) = \angle -82.6^o$

(c) $Z = R + j(\omega L - \frac{1}{\omega C})$

$argZ(90K) = \angle -87.7^o, argZ(100K) = \angle -87.5^o, argZ(110K) = \angle -87.2^o$

$error(90K) = 5.4\%, error(100K) = 5.4\%, error(110K) = 5.3\%$

17. (a) $Q0 = R\sqrt{\frac{C}{L}} = 1.11, Y = \frac{1}{R}[1 + jQ0\left(\frac{\omega}{\omega 0} - \frac{\omega 0}{\omega}\right)]$

So, |Y|=0.201, |Z|=4.97 Ω

(b) $Q0 = \frac{1}{R}\sqrt{\frac{L}{C}} = 0.894, Z = R + j(\omega L - \frac{1}{\omega C})$

So, |Z|=4.95 Ω

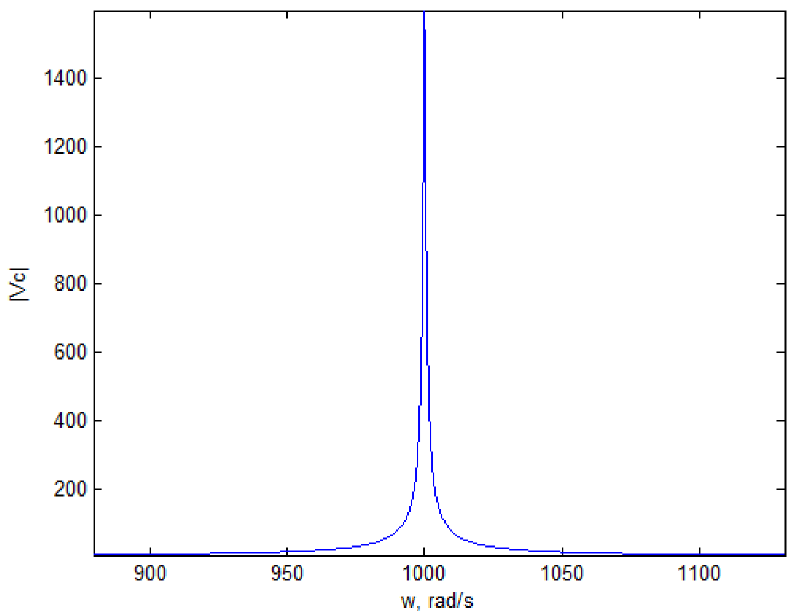
18. Loop current is $I = \frac{1.5\angle 0^o\ V}{Zin}, where\ Zin = 3.75 + j\left(4\omega - \frac{4\times 10^3}{\omega}\right)\ \Omega$

Zin in real at resonance, so $\omega_0 = 1000\ rad/s$

At resonance, $I(\omega_0) = 0.4\ A.$

Vc is at maximum at resonance: $Vc(\omega_0) = -j\frac{0.4(4\times 10^3)}{\omega} \Rightarrow |Vc(\omega_0)| = 1.6\ kV$!!

This is a dangerous voltage!



19. $Zin = R + j(\omega L - \frac{1}{\omega C}),$

ω0=1.4e5; Q0=14.1

20. C = 2.85 μF

(a) When R1 = 0 then w0 = 3417 rad/s and |Z(w0)| = 150 Ω

(b) |Z(700)| = 21.7 Ω

(c) |Z(800)| = 25 Ω

21. (a) Xp=-3.3e3, Xs=-75.6,

So Q=0.15, Rs=488.9 Ω, Cs=69 μF

(b) Xp=40, Xs=39.74

So Q=12.5, Rs=3.2 Ω, Ls=200 mH

22. (a) Xs(40) = -0.25, Q(40) = 0.125, Xs(80) = -0.125, Q(80) = 0.0625

For ω= 40 rad/s, Xp(40) = -16.25, Rp = 2.03125 Ω, Cp = 1.54 mF

For ω= 80 rad/s, Xp(80) = -16.25, Rp = 2.0078 Ω, Cp = 389 μF

(b) Xs(40) =.12, Q(40) = 0.06, Xs(80) = .24, Q(80) = 0.12

For ω= 40 rad/s, Xp(40) = 33.45, Rp = 2.0072 Ω, Lp 0.836 H

For ω= 80 rad/s, Xp(80) = 16.91, Rp = 2.029 Ω, Lp = 0.211 H

23. . $Z = \frac{8(12\omega^4 - 13985\omega^3 i - 3999000\omega^2 + 890500000\omega i + 15000000000)}{3\omega^4 - 1150\omega^3 i - 394800\omega^2 + 33600000\omega i + 8000000000}$

ωhen im(Z)=0, ω=ω0

24. At ω0 set imaginary part of input impedance, Z(ω), to zero to obtain ω0 = 41 rad/s

Then, $Z(0.95\omega 0) = Z(39) = 1.845\angle{-2.2^o}\Omega$, $Is(39) = 0.542\angle 2.2^o A$ and

$Vx(39) = 0.98\angle 2.2^o V$

25. ω_0=1 rad/s

(a) kf=63700,

So R=1 Ω, C=47 μF, L=2.2 μH

(b) km=500000

So R=500 kΩ, C=2 μF, L=166.7 kH

(c) km=25, kf=238900

So R=25 Ω, L=34.9 H, C=50 μF

26. $\omega 0=1$ rad/s

(a) kf=2700,

So R=1 Ω, C=1.85 mF, L=74 μH

(b) km=100

So R=100 Ω, C=50 mF, L=20 H

(c) km=25, kf=4.71e6

So R=25 Ω, L=6.37 mH, C=708 pF

27. R'=1 Ωk, C'=3.5 μF, L'=285 mH

So $Iin = \frac{Vin}{1000} + \frac{Vin}{\frac{3.5}{s}+0.285s} + \frac{0.2Vin}{1000}$

Then $Zin = \frac{Vin}{Iin} = \frac{200s}{57s^2+700} + \frac{3}{25000}$

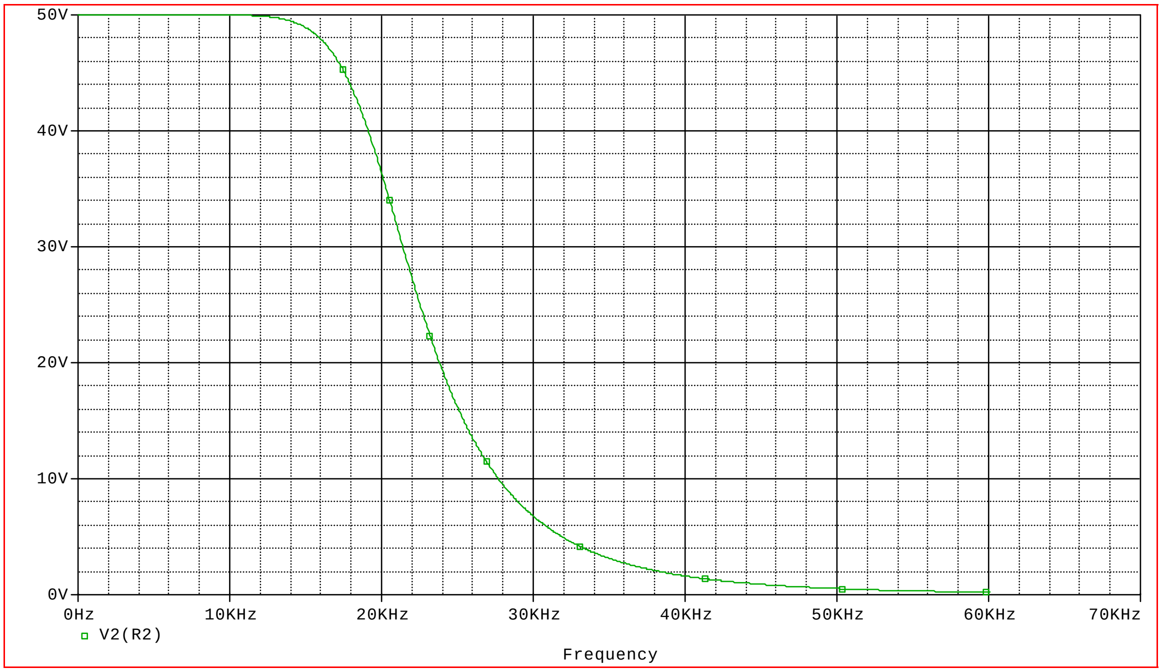
28. km = 0.5; kf = 20e-3

100 Ω → 50 Ω

9.82μH → 245.5 μH

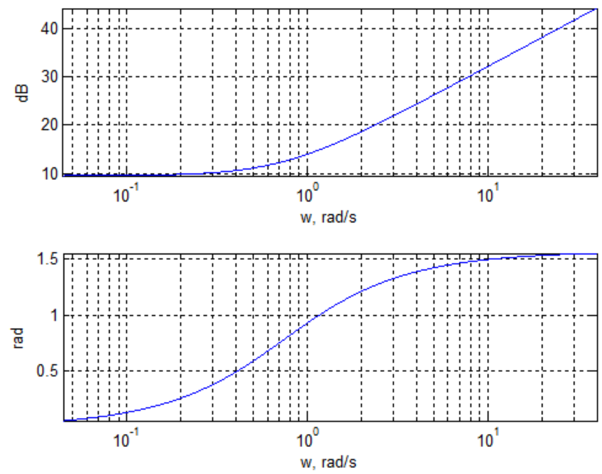
31.8 μH → 780 μH

2.57 nF → 257 nF

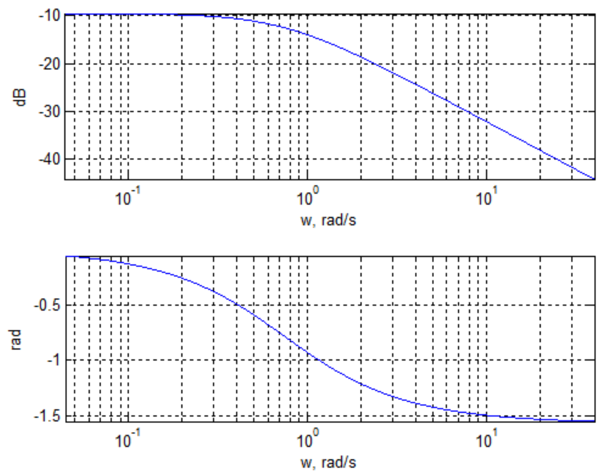


29. all elements are in parallel: C=-j1e6, R=1250, L=1.25j, source: 3.5j*Ix

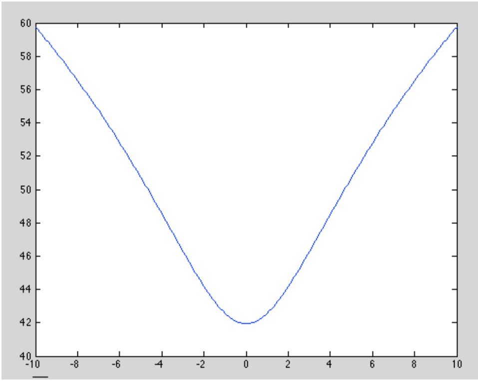
30. (a) $HdB = 20log\sqrt{9+16\omega^2}$; $angH(j\omega) = tan^{-1}\left(\frac{4}{3}\omega\right)\ rad$



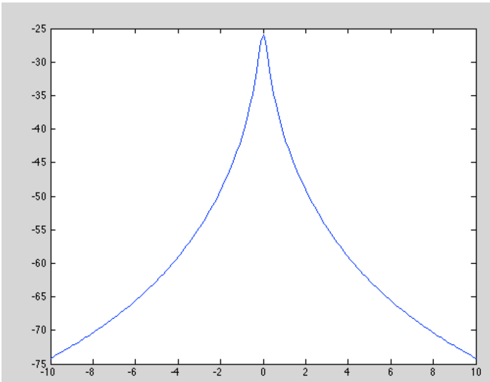
(b) $HdB = -20log\sqrt{9+16\omega^2}$; $angH(j\omega) = -tan^{-1}\left(\frac{4}{3}\omega\right)\ rad$



31. (a) $HdB = 20\log(\sqrt{9+16\omega^2})$

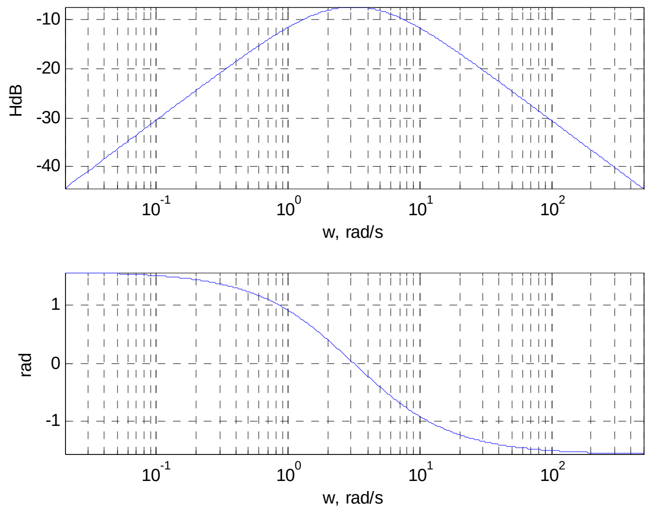


(b) $HdB = -20\log(\sqrt{9+16\omega^2})$



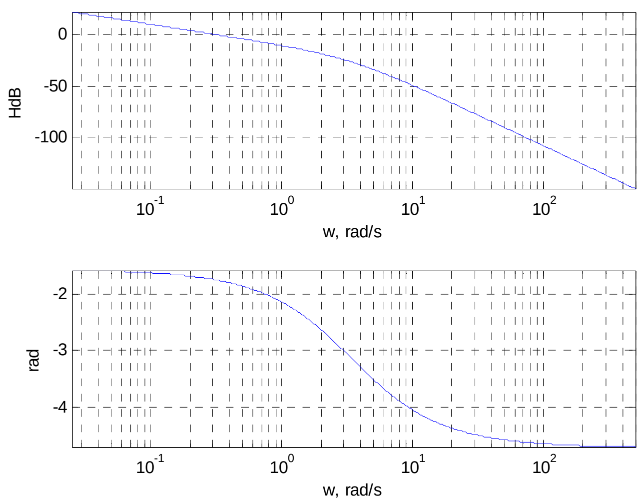
32. (a)

$$H(s) = \frac{0.3s}{(1+\frac{s}{2})(1+\frac{s}{5})}$$

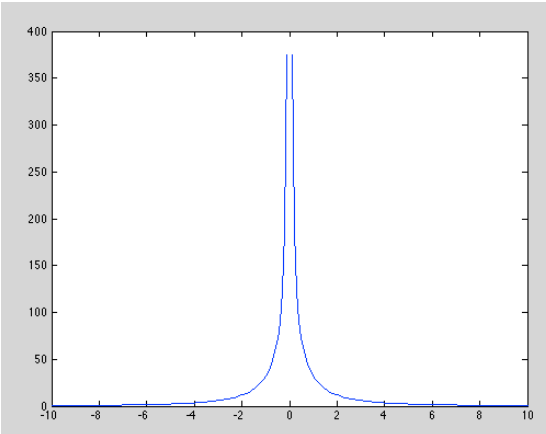


(b)

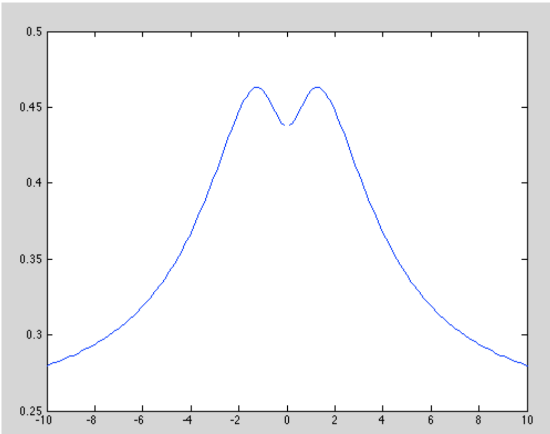
$$H(s) = \frac{1}{3s(1+\frac{s}{3})(1+\frac{s}{4})}$$



33. (a) $H(j\omega) = \frac{j\omega+300}{j8\omega-5\omega^2}$

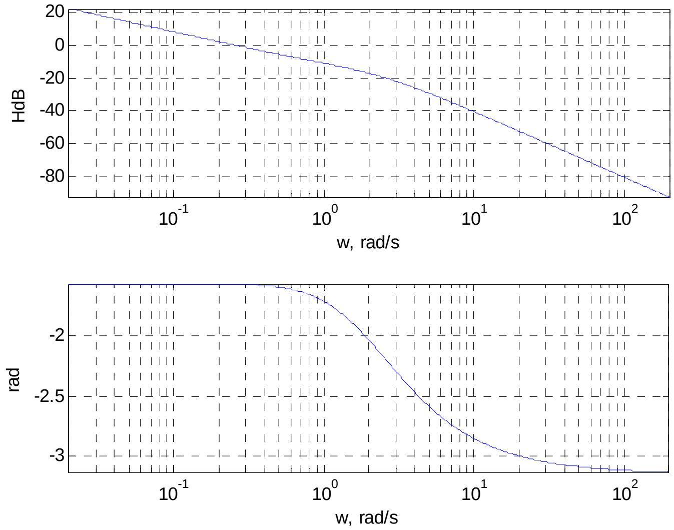


(b) $|H| = \frac{1}{-64\omega^2-25\omega^4}\sqrt{(1492\omega^2)^2 + (5\omega^2 + 2400\omega)^2}$



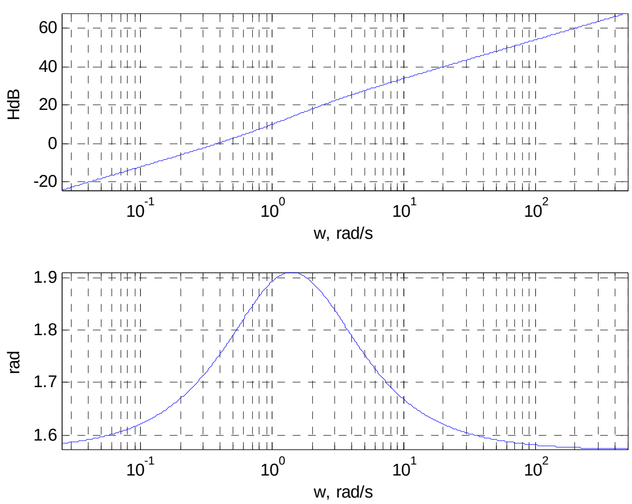
34. (a)

$$\mathrm{H(s)} = \frac{0.25(1+s)}{s\left(1+\frac{s}{2}\right)^2}$$



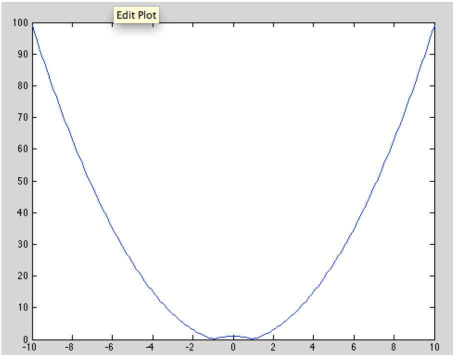
(b)

$$\mathrm{H(s)} = \frac{2.5s(1+s)}{\left(1+\frac{s}{2}\right)}$$

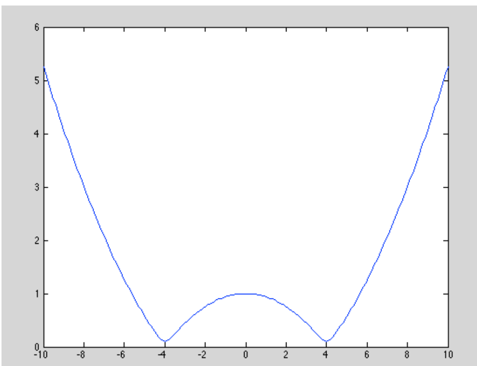


35.

(a)

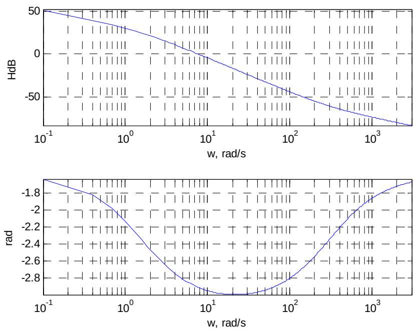

Edit Plot
100
90
80
70
60
50
40
30
20
10
0
-10
-8
-6
-4
-2
0
2
4
6
8
10

(b)

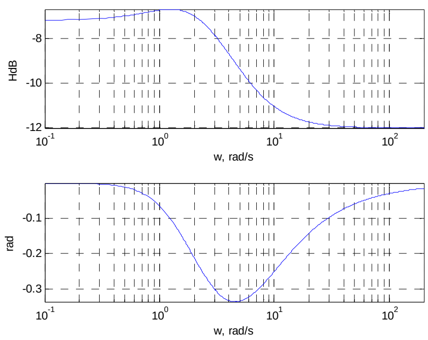

6
5
4
3
2
1
0
-10
-8
-6
-4
-2
0
2
4
6
8
10

36.

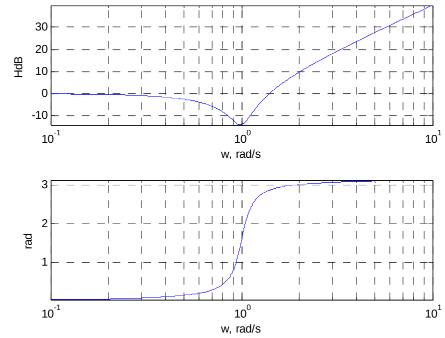
33 (a) $H(s) = \dfrac{300\left(1+\frac{s}{300}\right)}{8s\left(1+\frac{5s}{8}\right)}$



33(b) $H(s) = \dfrac{0.43\left(1+\frac{s}{1.2}\right)\left(1+\frac{s}{5.8}\right)}{\left(1+\frac{s}{2}\right)^2}$



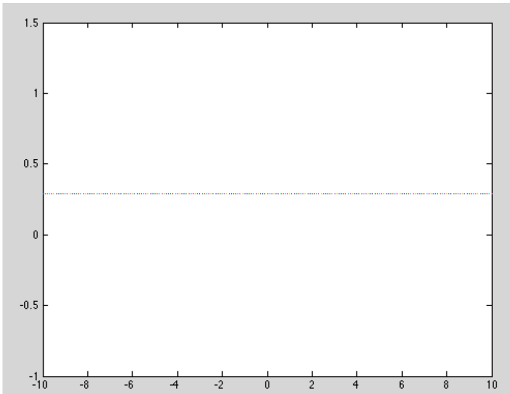
35(a) $H(s) = 1 + 0.2s + s^2$



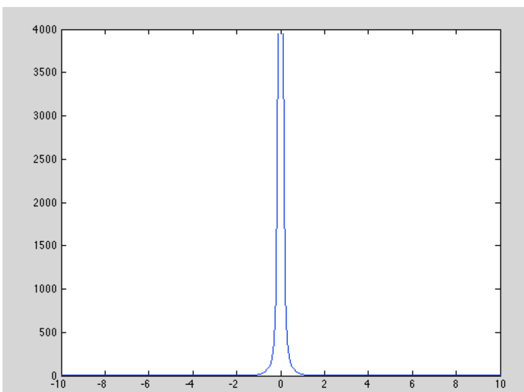
35(b) $H(s) = 1 + 0.1\left(\frac{s}{4}\right) + \left(\frac{s}{4}\right)^2$

37.

(a)

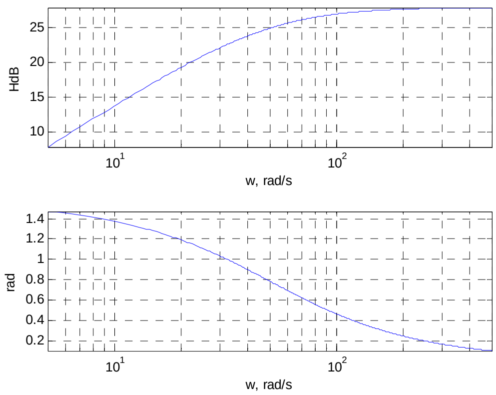

1.5
1
0.5
0
-0.5
-1
-10
-8
-6
-4
-2
0
2
4
6
8
10

(b)


4000
3500
3000
2500
2000
1500
1000
500
0
-10
-8
-6
-4
-2
0
2
4
6
8
10

38. (a) $\mathrm{H(s)} = \frac{0.5s}{1+\frac{s}{50}}$

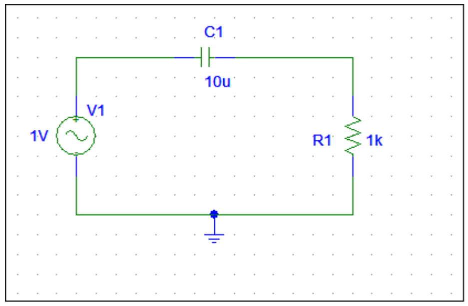
(b)

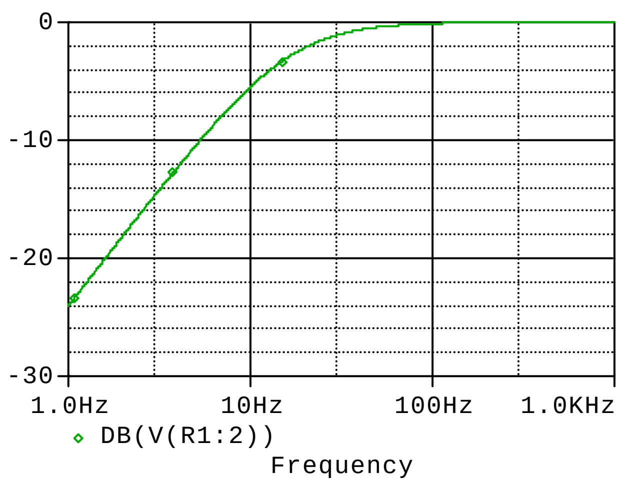


39. $\frac{V1}{50} = -Vin * 0.25s\ , \frac{Vi}{100} = -\frac{Vout}{200||\frac{1}{0.25s}}$

so, $H(s) = \frac{25s}{50s+1}$

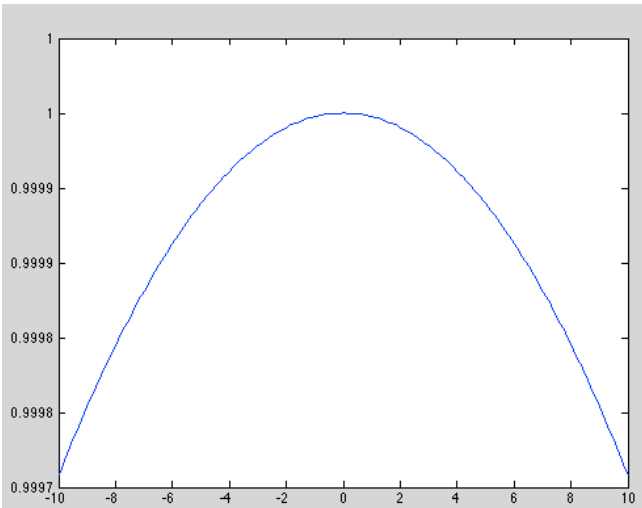
40. $H(s) = \frac{Vout}{Vin} = \frac{\frac{s}{100}}{1+\frac{s}{100}}$



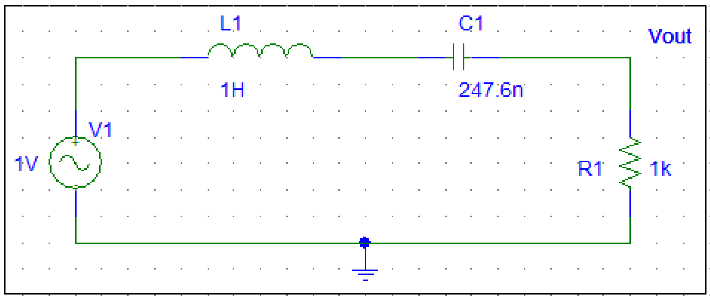


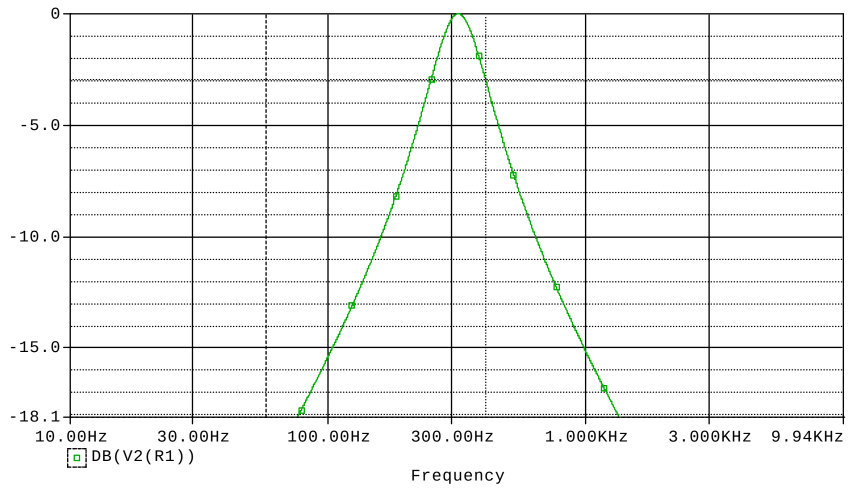
41. (a) $H(s) = \frac{1}{1+RCs}$, choose R=1 kΩ, C=2.2 μF,

(b) $H(j\omega) = \frac{1}{1+2.2\times10^{-3}\,j\omega}$,



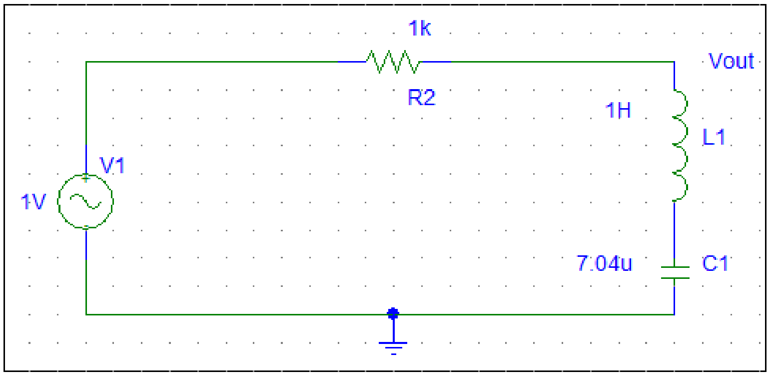
42. (a)

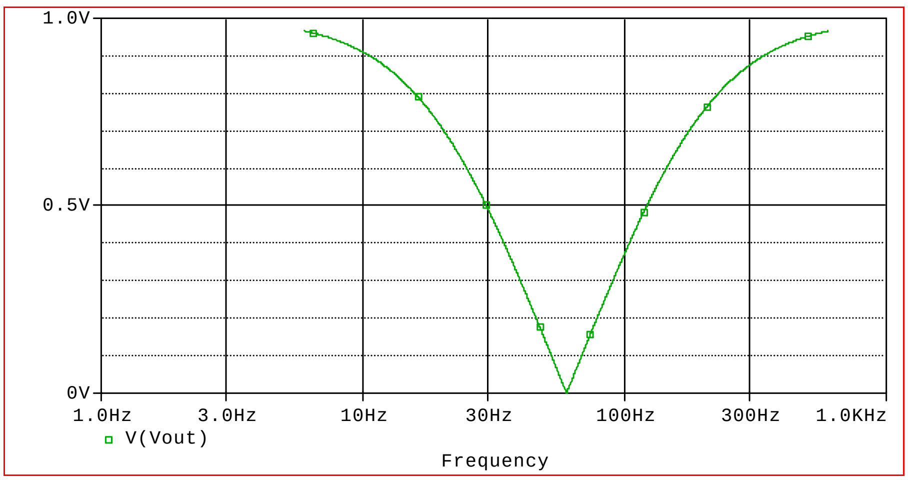

L1
C1
Vout
1H
247.6n
V1
1V
R1
1k


0
-5.0
-10.0
-15.0
-18.1
10.00Hz
30.00Hz
100.00Hz
300.00Hz
1.000KHz
3.000KHz
9.94KHz
DB(V2(R1))
Frequency

43. $\omega_L = \frac{\sqrt{(RC)^2+4LC}-RC}{2LC}$, $\omega_L = \frac{\sqrt{(RC)^2+4LC}+RC}{2LC}$

44.

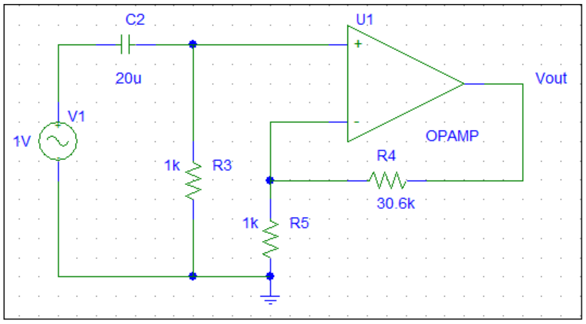

1k
R2
Vout
1H
L1
V1
1V
7.04u
C1

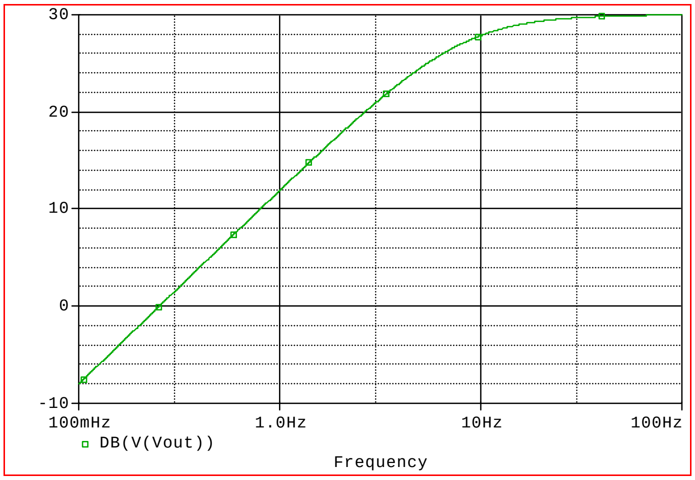

1.0V
0.5V
0V
1.0Hz
3.0Hz
10Hz
30Hz
100Hz
300Hz
1.0KHz
V(Vout)
Frequency

45. Fig. 16.41(b), $Vout = Vin\left(\frac{1}{1+sR2*C}\right)\left(1+\frac{Rf}{R1}\right)$

assume R1=100 Ω, C=1 μF, so Rf=1.7 kΩ, R2=1 kΩ

46.


C2
20u
U1
+
-
Vout
V1
1V
OPAMP
1k
R3
R4
30.6k
1k
R5


30
20
10
0
-10
100mHz
1.0Hz
10Hz
100Hz
DB(V(Vout))
Frequency

47. stage 1, LPF, $\omega H=1000$ rad/s, $Av=10$ dB

so, R1= 100Ω, Rf=216 Ω, C=1 μF, R2=909 Ω

stage 2: HPF, $\omega L=100$ rad/s, $Av=10$ dB

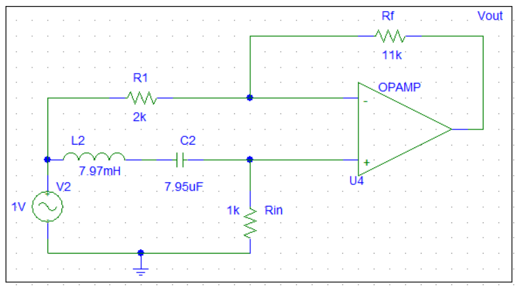
so, R1'=100 Ω, Rf'=216 Ω, C'=1 μF, R2'=10 kΩ

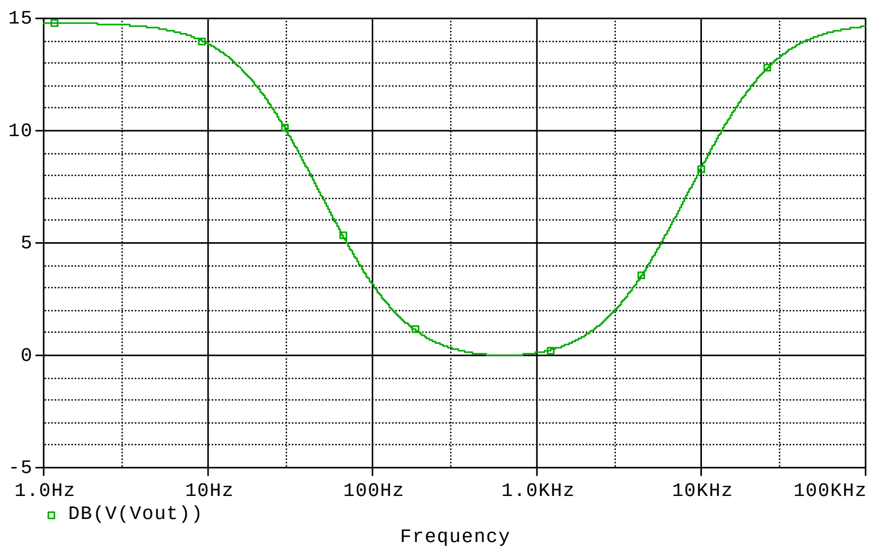
48. First design a RLC bandpass filter with the specified cutoff frequencies, taking the output across L and C, instead of instead R, to obtain the complementary bandstop response.

$$\frac{1}{LC} = \omega_H \omega_L = (2\pi 20000)(2\pi 20) = 15.79e6 \text{ and } B = \frac{R}{L}$$

Selecting R = 1 KΩ results in L = 7.97 mH and C = 7.95 µF

For the required gain of 15, may use a non-inverting opamp circuit. A PSpice simulation confirms the design.





.

49. LPF, f_L=500 Hz,

assume C=1 μF, so R_2=795 Ω, R_1=100 Ω, R_f adjustable to meet the requirement of A_v

50. The coefficients of the given transfer function are $a_0 = \left(\frac{1}{RC}\right)^2$ and $a_1 = \frac{2}{RC}$. For the LP Butterworth function these are 1 and 1.4142, respectively, and so it cannot be used to implement the given transfer function. For the LP Chebychev function these are 0.708 and 0.6449, respectively, and they do not relate as the coefficients in the given function.

51. (a) Fig. 16.48, assume Rq=R2=R, C1=C2=C;

$$H(s) = \frac{k}{s^2+1.4142s+1}, \frac{Vo}{Vi} = \frac{\frac{G}{R^2C^2}}{S^2+\left(\frac{2}{RC}+\frac{1-G}{RC}\right)s+\frac{1}{R^2C^2}},$$

so, RC=1, G=1.586,

set RB=1 kΩ, so RA= 586 Ω,

set C=1 nF, and Km=187, so R=187 Ω.

(b)$Av = \frac{1.00s4}{s^2+0.6449s+0.708}, RC = 1.189, G = 1.4158$

set RB=1 kΩ, so, RA=416 Ω,

and C=1 nF, Km=0.187, so R=222 Ω

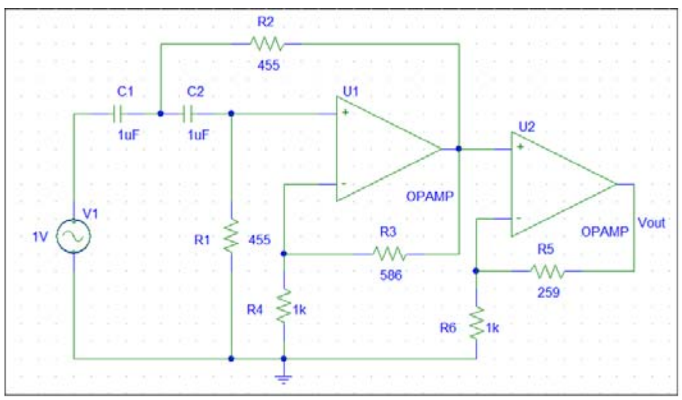
52. 2nd order HP filter implemented on the Sallen-Key amplifier with C1=C2=C and R1=R2=R. yields relationships: $a_0 = \frac{1}{R^2C^2} = 1;\ a_1 = \frac{3-G}{RC} = 1.4142; G = \frac{R_A+R_B}{R_B}$

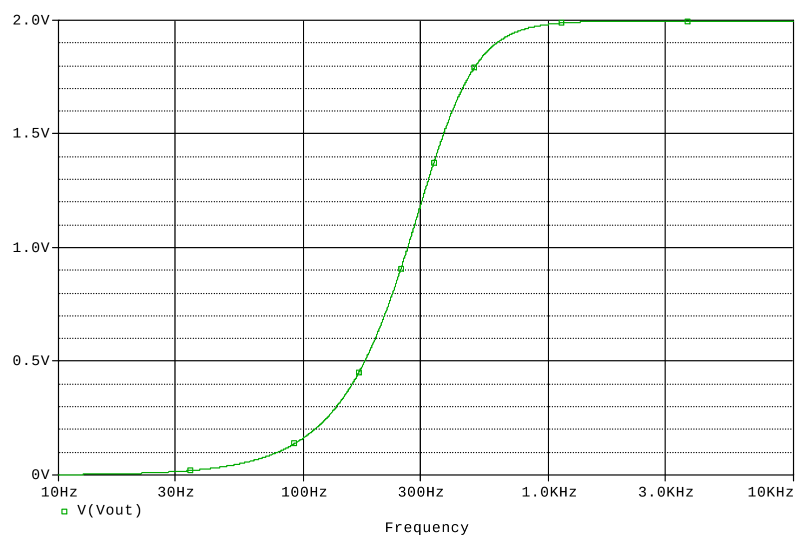
Letting RC = 1 we obtain G = 3-a_1 = 1.5858. Selecting R_B = 1 KΩ provides R_A = 586 Ω.

Setting R = 1 Ω and C = 1 μF and using k_f = 2π350/1 = 2199 we obtain

$$1\mu F = \frac{1F}{k_f k_m} = \frac{1F}{2199 k_m} \Rightarrow k_m = \frac{1}{2199e-6} = 455 \text{ so that } R' = k_m R = 455\ \Omega.$$

Provided gain is 20log(G) = 4 dB. The extra 2 dB, or gain of 1.259 can be provided with a non-inverting op amp circuit with R1=1 kΩ and Rf = 259 Ω.





53. RC=1, G=1.586,

set RB=1 kΩ, so, RA=586 Ω,

Km=1120, so R=1.12 kΩ

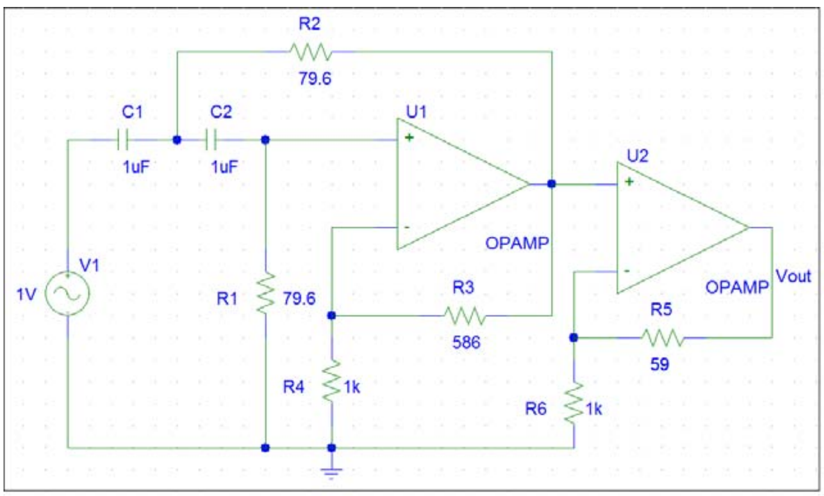
54. 2nd order HP filter implemented on the Sallen-Key amplifier with C1=C2=C and R1=R2=R. yields relationships: $a_0 = \frac{1}{R^2C^2} = 1;\ a_1 = \frac{3-G}{RC} = 1.4142; G = \frac{R_A+R_B}{R_B}$

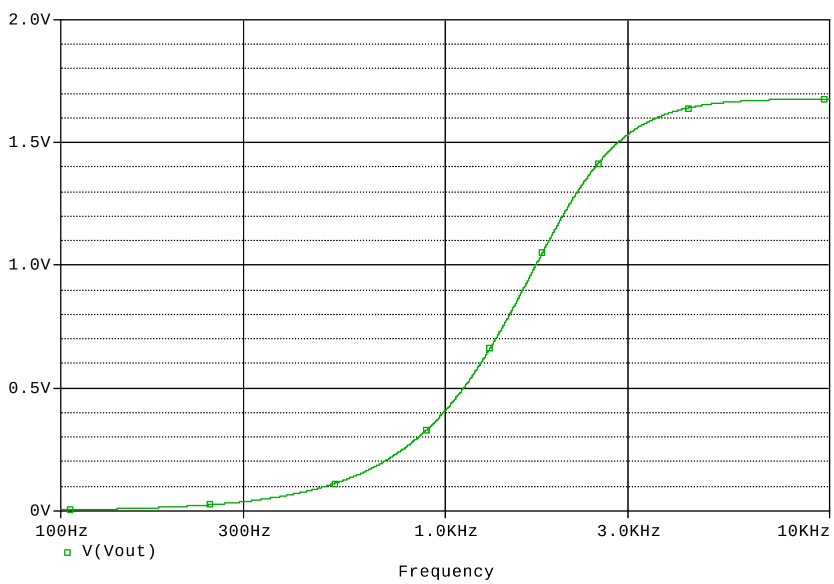
Letting RC = 1 we obtain G = 3-a_1 = 1.5858. Selecting R_B = 1 KΩ provides R_A = 586 Ω.

Setting R = 1 Ω and C = 1 μF and using k_f = 2π2000/1 = 12566 we obtain

$$1\mu F = \frac{1F}{k_f k_m} = \frac{1F}{12566 k_m} \Rightarrow k_m = \frac{1}{12566e-6} = 79.6 \text{ so that } R' = k_m R = 79.6\ \Omega.$$

Provided gain is 20log(G) = 4 dB. The extra 0.5 dB, or gain of 1.059 can be provided with a non-inverting op amp circuit with R1=1 kΩ and Rf = 59 Ω.





55. Fig.16.49, set R1=R2=R, C1=C2=C,

ωe get RC=1, G=4

set RA=3 kΩ, RB=1 kΩ

Kf=3768, Km=256

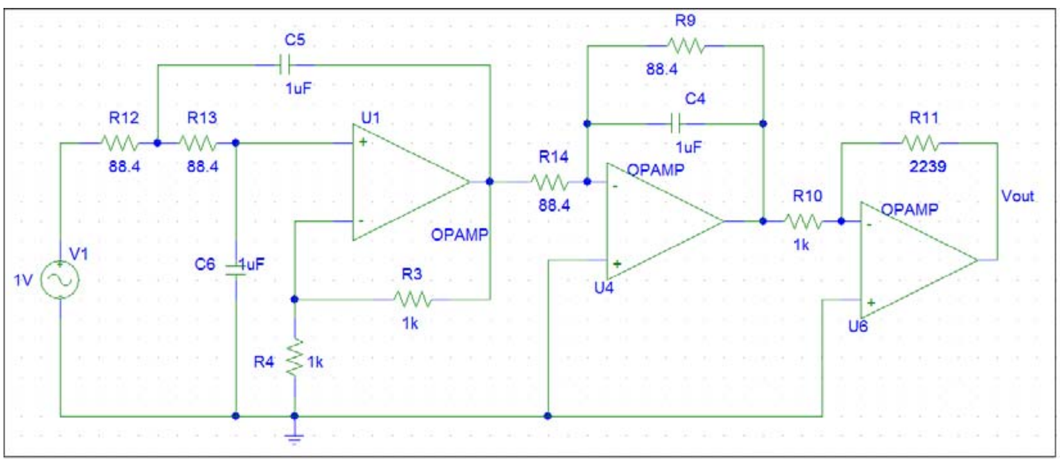
So R=256 Ω, C=1 μF

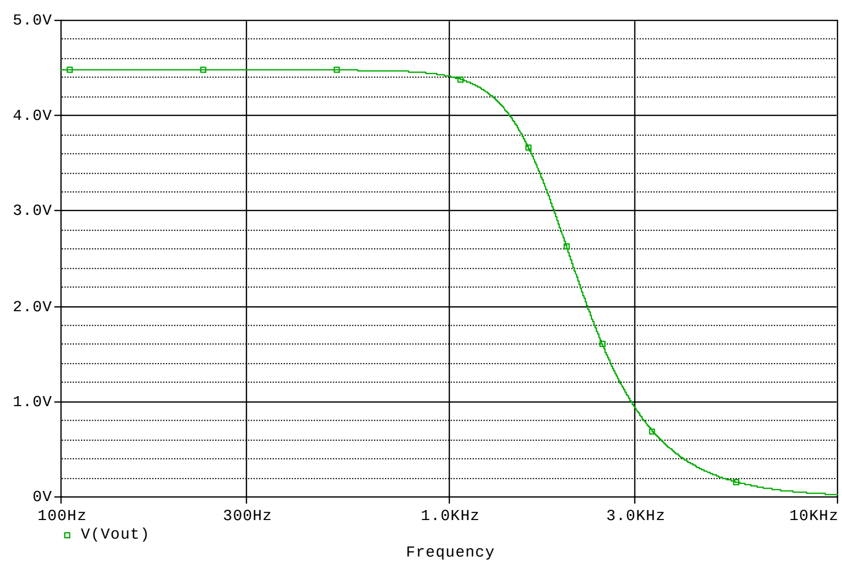
56.

(a) 3rd order Butterworth LPF has TF: $H(s) = \frac{Ka_0}{s^3+2s^2+2s+1} = Ka_0\left(\frac{1}{s^2+s+1}\right)\left(\frac{1}{s+1}\right) = H_1(s)H_2(s)$
$H_1(s)$ can be implemented by the Sallen-Key amplifier circuit. Setting RC = 1 yields G = 2, which is realized by selecting $R_A = R_B = 1$ kΩ. The gain of this stage is then 20log(G) = 6 dB. Setting R = 1 Ω and C = 1 μF and using $k_f = 2\pi 1800/1 = 11310$ we obtain

$$1\mu F = \frac{1F}{k_f k_m} = \frac{1F}{11310\ k_m} \Rightarrow k_m = \frac{1}{11310\ e{-6}} = 88.4 \text{ so that } R' = k_m R = 88.4\ \Omega.$$

$H_2(s)$ can be implemented by an op amp inverting circuit with resistor-coupled input and a parallel resistor-capacitor combination as feedback, which, setting capacitors as C and resistor as R yields TF: $H_2(s) = \frac{-1}{1+RCs}$. Setting RC = 1 results in $H_2(s) = \frac{-1}{1+s}$. With appropriate scaling, C = 1 μF and R = 88.4 Ω. To achieve the required 13 dB gain, we use an additional inverting op amp circuit to provide gain of 7 dB or 2.239, which is achieved with $R_1 = 1$ kΩ and $R_f = 2239$ Ω. (Phase inversion corrects for phase inversion of previous stage.)

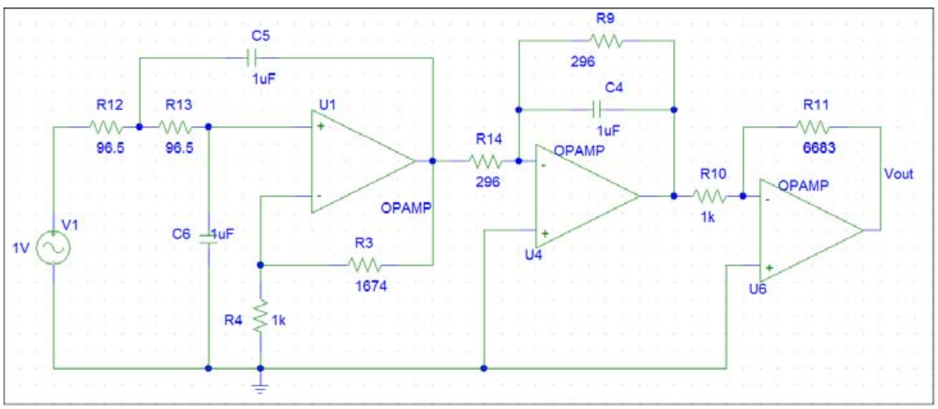


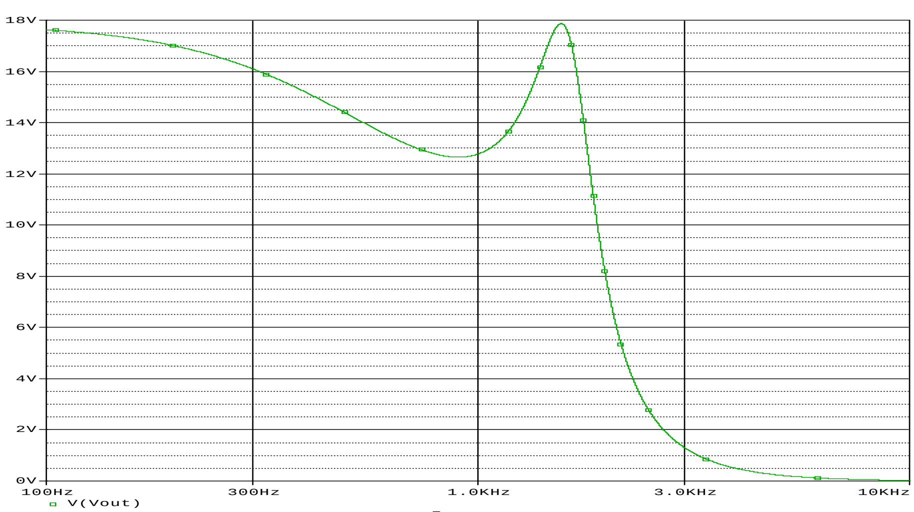


56. (b) 3rd order Chebychen LPF with TF $H(s) = \frac{Ka_0}{s^3+2s^2+2s+1}$ has a real root at s = -0.2986. Long division of the denominator polynomial with (s+0.2986) yields the factored form:

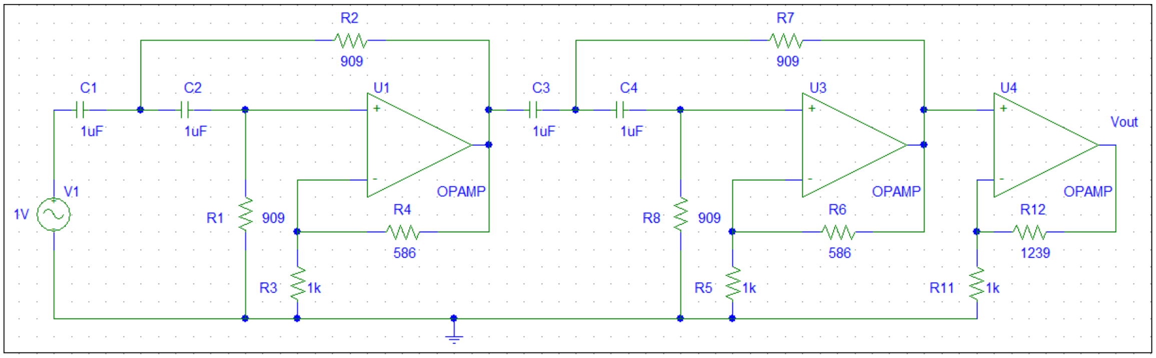
$H(s) = Ka_0\left(\frac{1}{s^2+0.2986s+0.8393}\right)\left(\frac{1}{s+0.2986}\right) = H_1(s)H_2(s)$ $H_1(s)$ can be implemented by the reference Sallen-Key amplifier circuit with RC = 1.0915 yielding G = 2.6741, which is realized by selecting R_B = 1 kΩ and R_A = 1674 Ω. The gain of this stage is then $20\log(G/(RC)^2)$ = 20log(2.2443) = 7 dB. Setting R = 1.0915 Ω and C = 1 μF and using $k_f = 2\pi1800/1 = 11310$ we obtain $1\mu F = \frac{1F}{k_f k_m} = \frac{1F}{11310\, k_m} \Rightarrow k_m = \frac{1}{11310\, e{-6}} = 88.42$ so that $R' = k_m R = 96.5\, \Omega$. $H_2(s)$ can be implemented by an op amp inverting circuit with resistor-coupled input and a parallel resistor-capacitor combination as feedback, which, setting capacitors as C and resistor as R yields TF:

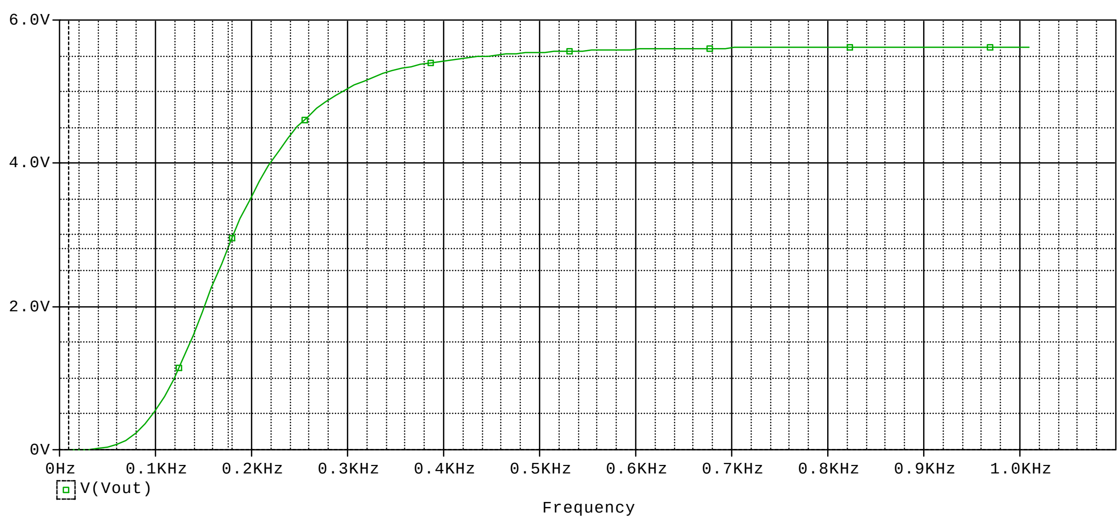
$H_2(s) = \frac{-1}{1+RCs} = \frac{-\frac{1}{RC}}{s+\frac{1}{RC}} = \frac{0.2986}{s+0.2986}$. Setting 1/RC = 0.2986 or RC = 3.349 with appropriate scaling, C = 1 μF and R = 296 Ω. This stage has gain 20log(0.2986) = -10.5. To achieve the required 13 dB gain, we use an additional inverting op amp circuit to provide gain of 13-7+10.5 = 16.5 dB or 6.683, which is achieved with R_1 = 1 kΩ and R_f = 6683 Ω. (Phase inversion corrects for phase inversion of previous stage.) The design meets the ripple and cutoff frequency specifications.



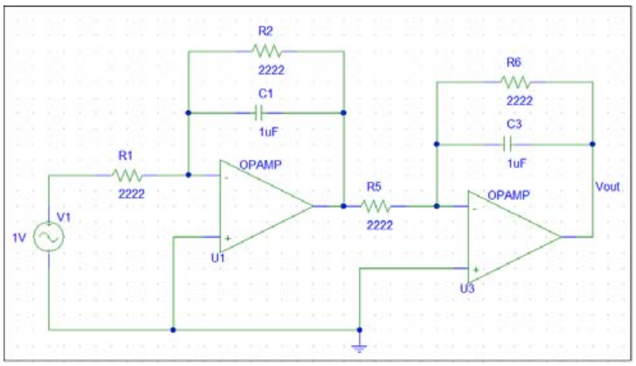


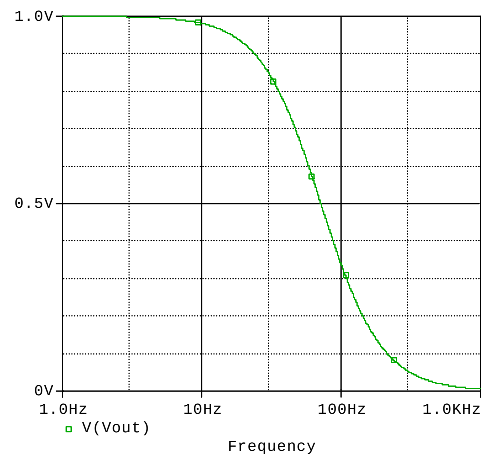
57. A 4^{th} order Butterworth HP filter can be implemented by cascading two identical Sallen-Key amplifier circuits, each realizing a 2^{nd} order HP TF. The achieved gain is G^2 = 2.5154 or 8 dB. The extra 7 dB gain, or 2.239, can be realized with a non-inverting op amp circuit with R_B = 1 KΩ and R_A = 1239 Ω. The specifications are realized, with pass band gain of 15 dB and cutoff frequency at 175 Hz = 1100 rad/s, but with 6 dB attenuation at ω_c due to the presence of the double poles for the cascaded identical stages.



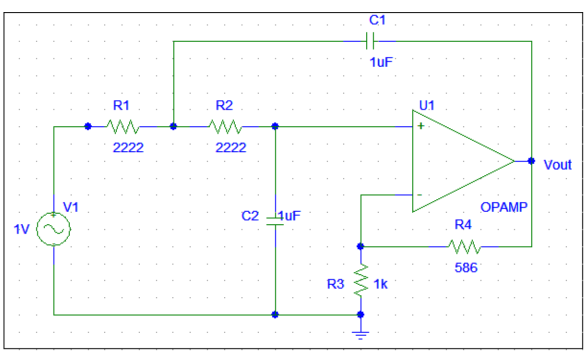


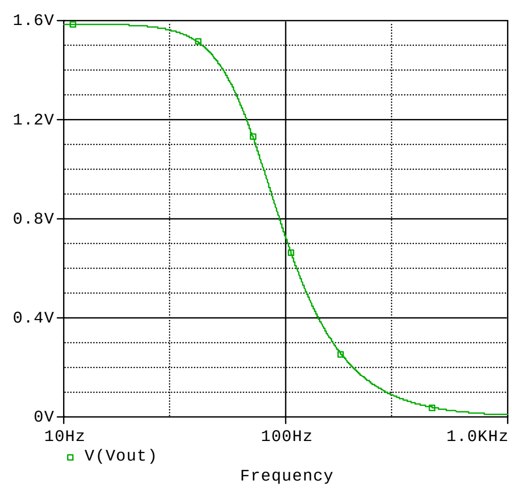
58. TF of equation [36] implemented by cascading two circuits of Figure 15.43(a) with $R_1 = R_f = R = 1\ \Omega$ and $C_f = C = 1\ \mu F$ has form $H(s) = \frac{1}{(s+1)^2}$. Setting C = 1 μF and using $k_f = 450$ we obtain $1\mu F = \frac{1F}{k_f k_m} = \frac{1F}{450\ k_m} \Rightarrow k_m = 2222$ so that $R' = k_m R = 2222\ \Omega$. Its simulation shows that at ωc = 450 rad/s the attenuation is at 6 dB due to the presence of the double pole there, while its 3-dB bandwidth is at 289 rad/s.





On the other hand, a 2nd order Butterworth LP has TF $H(s) = \frac{1}{s^2+1.4142s+1}$ may conveniently be implemented using the Sallen-Key amplifier, with G = 1.586 achieved with R_B = 1 KΩ and R_A = 586 Ω. Selecting C=1 μF scaling provides R = 2222 Ω. Its simulation shows a 4-dB gain, while its 3-dB bandwidth at 450 rad/s as required by the specifications.





59. $Q0=45$, $\omega 0=1.68e6$, sp $C=0.45$ nF, $L=0.27$ mH,

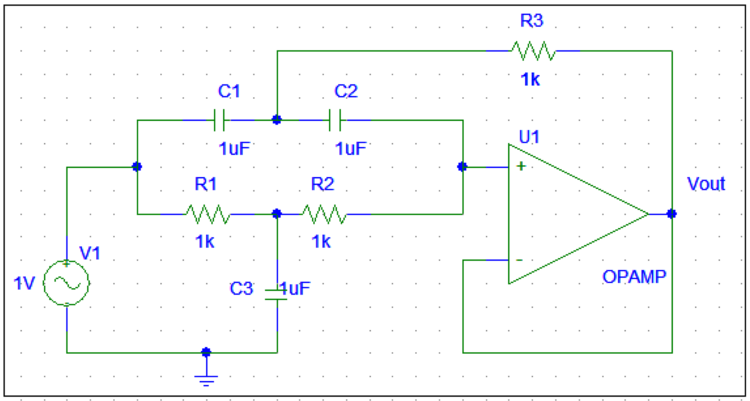
$Q0=45$, $\omega 0=5e6$, so, $C=0.45$ nF, $L=89$ µH.

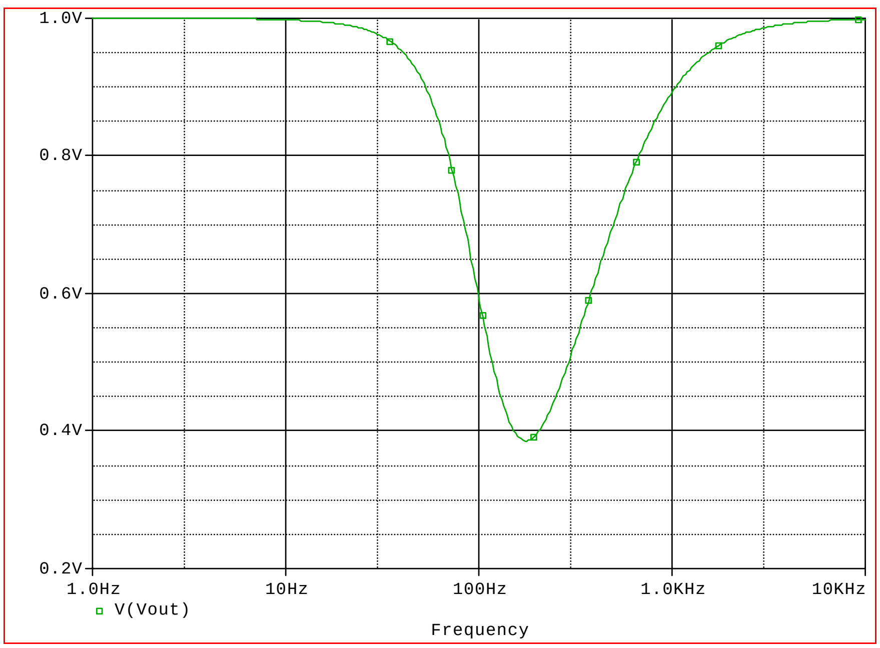
So, $C=0.45$ nF, $L_{max}=270$ µH, $L_{min}=89$ µH

60.

$$H(s) = \frac{sC_1R_1R_3\left(s^3C_1R_1R_2R_3C_2(C_1+C_2)+s^2\left(C_1R_1R_2C_3+C_1R_1R_3C_2+C_1^2R_1R_3+C_1R_1+C_2C_3R_2R_3+C_1C_3R_2R_3\right)+s(C_1R_1+C_3R_2+C_1R_3+R_3)+sC_1R_1R_3\right)}{s^3C_1C_2C_3R_1R_2R_3+s^2C_1R_1(3C_2R_3+C_3R_2)+s(C_1R_1+C_1R_3+R_2R_3)+1}$$

Which is a band stop filter. A simulation with cutoff at 1100 rad/s (175 Hz) is included:

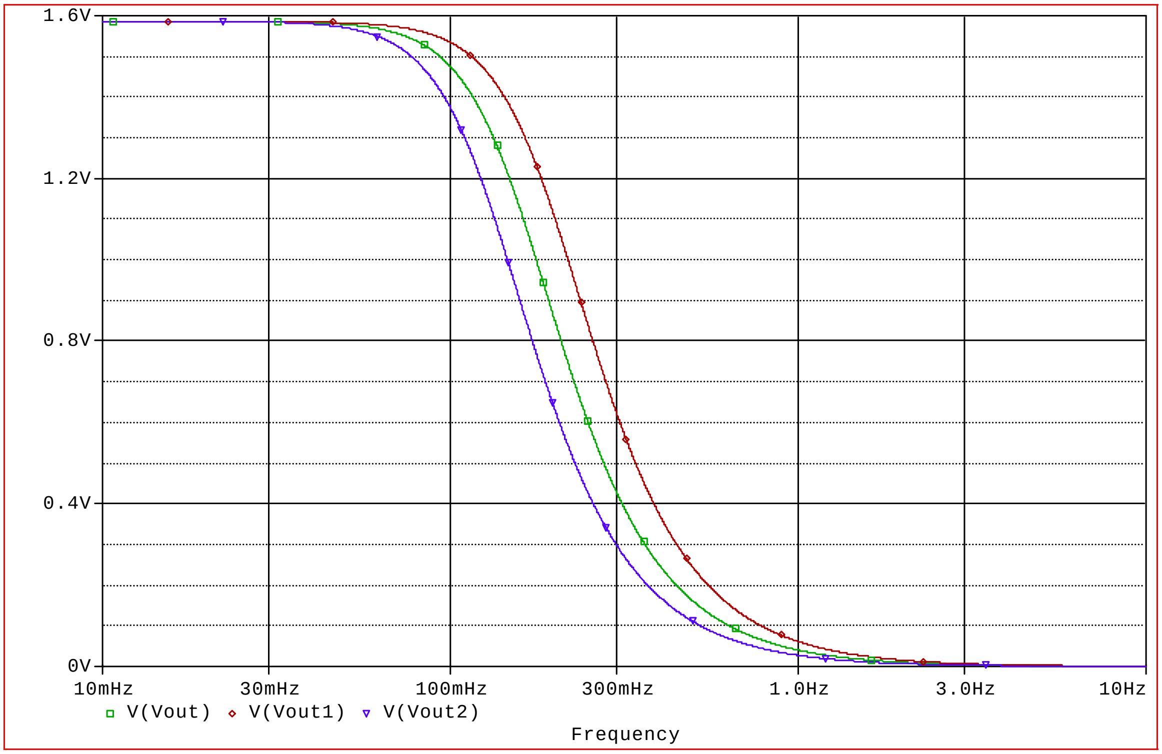




61. RC=8e-4, set C= 1 µF, so R=800 Ω,

and 1+Rf/R1=1.26, set R1= 1 1Ω, so Rf=260 Ω

62. Observing TF of circuit of Figure 16.48 in equation [40] the greatest deviation from the target design occurs when all components are simultaneously 10% above or 10% below their nominal values. PSpice simulation with component values altered accordingly can yield the extent of tolerance variations. Here nominal values are: R = 1 Ω, C = 1 μF, R_A = 586 Ω and R_B = 1 kΩ. The nominal cutoff frequency is 1 rad/s. For components 10% below their nominal values that frequency changes to 1.22 rad/s, or +22%. For components 10% above their nominal values that frequency changes to 0.82 rad/s or -18%.



63. only connected to "+" terminal: $Vo = \left(1 + \frac{RA}{RB}\right) V +$

only connected to "-" terminal: $V1 = Vi\left(\frac{1}{s*R1*C1}\right)$

so, $\frac{Vout}{Vin} = \frac{(RA+RB)(R3+2sC1+sC2)}{C1*C2*R1*RB*s^2+C2*RB*s+R3*Ra+R3*Rb}$

64.

65. 3rd order LPF, and 2nd order HPF

LPF (fig. 16.49) Ra=3 kΩ, Rb=1 kΩ, C=1 μF, R=159 Ω, Cf=1 μF, Rf=R1=159 Ω

HPF (fig. 16.48) RA=1 kΩ, RB=568 Ω, C=1 uF, R=1593 Ω

1. $\Delta Z = \begin{vmatrix} -2 & 4 & 0 \\ 5 & 1 & -9 \\ 2 & -5 & 4 \end{vmatrix}, \Delta 11 = \begin{vmatrix} 1 & -9 \\ -5 & 4 \end{vmatrix}, I1 = 1.757\ A$

2. (a) $\begin{bmatrix} 100 & -45 & 30 \\ 75 & 0 & 80 \\ 48 & 200 & 42 \end{bmatrix}\begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 0.2 \\ -0.1 \\ 0.5 \end{bmatrix}$

(b) $V_2 = \frac{\Delta_2}{\Delta_Y} = \frac{-3013}{-1181050} = 2.6\ mV$

3. (a) $\begin{cases} 470I1 - 470I2 = V \\ -470I1 + 12670I2 - 10000I3 - 2200I4 = 0 \\ -10000I2 + 13200I3 - 2200I4 = 0 \\ -2200I2 - 2200I3 + 9100I4 = 0 \end{cases}$

(b) $\Delta Z = \begin{vmatrix} 470 & -470 & 0 & 0 \\ -470 & 12670 & -10000 & -2200 \\ 0 & -10000 & 12300 & -2200 \\ 0 & -2200 & -2200 & 9100 \end{vmatrix} = 1.13e14, \Delta 11 = 2.9e11$

(c) $Zin = 389\ \Omega$

4.
$$\begin{cases} V_1 = 870I_1 - 870I_2 \\ 0 = -870I_1 + (870+870+1000)I_2 - 1000I_3 - 870I_4 \\ 0 = -1000I_2 + 1100I_3 - 100I_4 - 100I_5 \\ 0 = -870I_2 - 100I_3 + (870+220+100)I_4 \\ 0 = -100I_3 + 200I_5 \end{cases}$$

$$\Delta_Z = \begin{vmatrix} 870 & -870 & 0 & 0 & 0 \\ -870 & 2740 & -1000 & -870 & 0 \\ 0 & -1000 & 1100 & -100 & -100 \\ 0 & -870 & -100 & 1190 & 0 \\ 0 & 0 & -100 & 0 & 200 \end{vmatrix} = 2.7687e13\ \Omega^5$$

$$\Delta_{11} = \begin{vmatrix} 2740 & -1000 & -870 & 0 \\ -1000 & 1100 & -100 & -100 \\ -870 & -100 & 1190 & 0 \\ 0 & -100 & 0 & 200 \end{vmatrix} = 2.4750e11\ \Omega^4$$

$$Z_{in} = \frac{\Delta_Z}{\Delta_{11}} = 111.87\ \Omega$$

5. $\Delta Y = \begin{vmatrix} 3s & 0 & 0 \\ -3s & 33s & -10s \\ 0 & -10s & 17s \end{vmatrix} = 1383s^3, \Delta 11 = 461s^2, Yin = 3s$

6. (a) ω = 1 rad/s

$$\Delta Z = \begin{vmatrix} j0.05 & -j0.05 & 0 \\ -j0.05 & 6+j0.15 & -6 \\ 0 & -6 & 6-j50e6 \end{vmatrix} = 1.5002e7\angle 0.95^o\ \Omega^3$$

$$\Delta_{11} = \begin{vmatrix} 6+j0.15 & -6 \\ -6 & 6-j50e6 \end{vmatrix} = 3.0009e8\angle -88.6^o\ \Omega^2$$

$$Z_{in} = \frac{\Delta_Z}{\Delta_{11}} = 50\angle\ 89.5^o\ m\Omega$$

(b) ω = 1 rad/s

$$\Delta Z = \begin{vmatrix} j16 & -j16 & 0 \\ -j16 & 6+j48 & -6 \\ 0 & -6 & 6-j156e3 \end{vmatrix} = 8.1263e7\angle 79.4^o\ \Omega^3$$

$$\Delta_{11} = \begin{vmatrix} 6+j48 & -6 \\ -6 & 6-j156e3 \end{vmatrix} = 7.5462e6\angle -7^o\ \Omega^2$$

$$Z_{in} = \frac{\Delta_Z}{\Delta_{11}} = 10.8\angle\ 86.5^o\ \Omega$$

7. (a) $\begin{cases} -0.063j * V1 + (V1 - V2)(-0.032j) = 0 \\ (V2 - V1)(-0.032j) + V2 * 0.067 + (V2 - V3)(-0.032j) = 0 \\ (V3 - V2)(-0.032j) + V3 * j * 6.3 \times 10^{-6} = 0 \end{cases}$

So, $Yin = \frac{6(-6.5\omega^3 + 6.5j\omega^2 + 3.2\times10^{19}\omega - 1.2\times10^{21}j)}{\omega(-1.3j\omega^3 - 1600\omega^2 + j6.5\times10^{19}\omega + 3.9\times10^{21}j)}$

(b) $V = \frac{Iin}{Yin} = 0.0514\ V$

8. (a) $$\left.\begin{aligned} V_1 &= 10I_1 + 4(I_2 - I_3) \\ 0 &= -4I_1 + 19I_3 \\ 0 &= I_1 - I_2 + 2I_3 \end{aligned}\right\} \Rightarrow \Delta_Z = \begin{vmatrix} 10 & 4 & -4 \\ 0 & -4 & 19 \\ 1 & -1 & 2 \end{vmatrix} = 170\ \Omega^3$$

(b) $\Delta_{11} = \begin{vmatrix} -4 & 19 \\ -1 & 2 \end{vmatrix} = 11\ \Omega^2$. $\boxed{Z_{in} = \frac{\Delta_Z}{\Delta_{11}} = 15.45\ \Omega}$

9. (a) $\begin{cases} \frac{V1}{Rin} + \frac{V1-V2}{28} = 0 \\ \frac{V1-V2}{20} + \frac{V1}{Rx} = 0 \end{cases}$

(b) Rin=Rx

10. (a) Let input voltage be 1 V. For deal op ampType equation here. $V_i = 0$. Then, $V_{R4} = 1$ V.

$$I_4 = \frac{1}{R_4},\ \ V_4 = i_4\left(R_4 + \frac{1}{j\omega C}\right) = 1 + \frac{1}{j\omega C R_4},\ \ I_{R_3} = \frac{1 - V_4}{R_3} = \frac{1}{R_3}\left(1 - 1 - \frac{1}{j\omega C R_4}\right) = -\frac{1}{j\omega C R_3 R_4}$$

$$I_{R_2} = I_{R_3},\ \ V_{12} = R_2 I_{R_2} + 1 = 1 - \frac{R_2}{j\omega C R_3 R_4},\quad I_{R_1} = \frac{V_{R_1}}{R_1} = \frac{1 - V_{12}}{R_1} = \frac{R_2}{j\omega C R_1 R_3 R_4} = I_{in}$$

$$\therefore Z_{in} = \frac{1\ V}{I_{in}} = \frac{j\omega C R_1 R_3 R_4}{R_2}$$

(b) For $R_1 = 4$ kΩ, $R_2 = 10$ kΩ, $R_3 = 10$ kΩ, $R_4 = 1$ kΩ and C = 200 pF

$$Z_{in} = \frac{j\omega(200e - 12)(4e3)(10e3)(1e3)}{10e3} = j\omega 8 \times 10^4\ \Omega\ or\ equivalent\ to\ a\ 0.8\ mH\ inductor.$$

11. $\begin{cases} I1 = \frac{V1}{1000} + \frac{V1-V2}{10000} \\ I2 = \frac{V2}{8000} + \frac{v2-V1}{10000} \end{cases}$

So, $Y = \begin{bmatrix} 11 \times 10^{-4} & -10^{-3} \\ -10^{-4} & \frac{1}{8000} + \frac{1}{10000} \end{bmatrix}$

12. $\begin{cases} I1 = \frac{V1}{11} + \frac{V1-V2}{8} + \frac{V1-V2}{10} \\ I2 = \frac{V2}{20} + \frac{V2-V1}{8} + \frac{V2-V1}{1} \end{cases}$

So, $Y = \begin{bmatrix} 0.316 & -0.225 \\ -0.225 & 0.275 \end{bmatrix} S$

13.(a) $\begin{cases} I1 = 0.1s * V1 + 0.2s * (V1 - V2) \\ I2 = 0.25sV2 + 0.2s * (V2 - V1) \end{cases}$

(b) $Y = \begin{vmatrix} 0.3s & -0.2s \\ -0.2s & 0.15s \end{vmatrix}$

(c) $P = \frac{U^2}{R} = 10s$

14. $\begin{cases} I1 = \frac{V1-V2}{540} + \frac{V1-V3}{200} & (1) \\ I2 = \frac{V2-V1}{540} + \frac{V2-V3}{400} & (2) \end{cases}$ and $\frac{V3-V1}{200} + \frac{V3}{510} + \frac{V3-V2}{400} = 0 \quad (3)$

Substituting (3) into (1) and (2) we obtain: $\begin{bmatrix} I1 \\ I2 \end{bmatrix} = \begin{bmatrix} 4.21e-3 & -3.17e-3 \\ -3.2e-3 & 3.7e-3 \end{bmatrix} \begin{bmatrix} V1 \\ V2 \end{bmatrix}$

So $Y = \begin{bmatrix} 4.2 & -3.17 \\ -3.17 & 3.7 \end{bmatrix} mS$

15. (a) $Y = \begin{vmatrix} 11e-4 & -1e-3 \\ -1e-4 & 2.25e-4 \end{vmatrix}, \begin{cases} I1 = 11e-4 * V1 - 1e-3 * V2 \\ I2 = -1e-4 * V1 + 2.25e-4 * V2 \end{cases}$

(b) p=9e-6 W

16. (a) $\begin{cases} I1 = \frac{V1}{1k} + \frac{V1-V2}{10k} \\ I2 = \frac{V2}{8k} + \frac{V2-V1}{10k} \end{cases}$ ----(1) so, $Y = \begin{bmatrix} 11 & -1 \\ -1 & 2.25 \end{bmatrix} \times 10^{-4}\, S$

(b) For the one-port network:

$I1 = \frac{9-V1}{1k}$ and $I2 = -\frac{V2}{4k}$ substituting into (1) we obtain V1 = 4.329 V and V2 = 0.9114 V.

Then I1=4.67 mA, and Pin = 42 mW

17. $$\begin{cases} I1 = \frac{V1 - 1 * I1}{2} - 5I1 \\ I2 = -5I1 + \frac{V2}{5} + \frac{V2}{1} \end{cases}$$

So, $Y = \begin{vmatrix} 6.25 & 0 \\ -31.25 & 1.2 \end{vmatrix}$

18. $\begin{cases} I1 = 0.6V2 + \frac{V1}{5k} + \frac{V1-Va}{20k} & (1) \\ I2 = \frac{V2-Va}{10k} & (2) \\ \frac{Va-V1}{20k} + \frac{Va-V2}{10k} - 0.1I1 = 0 & (3) \end{cases}$ (3) can be written as: $Va = \frac{V1}{3} + \frac{V2}{1.5} + 667I1$ (4)

Substitute (4) into (1): $I1 = (241.4e-6)V1 + 0.6V2$ (5)

Substitute (4) and (5) into (2): $I2 = (-17.23e-6)V1 + (41.52e-3)V2$ (6)

$\therefore \mathbf{y} = \begin{bmatrix} 241.4e-6 & 0.6 \\ -17.23e-6 & 41.52e-3 \end{bmatrix} S$

(a) $I1 = y_{11}V_1 + y_{12}V_2 = (0.6)(1) = 0.6\ A$
$I2 = y_{21}V_1 + y_{22}V_2 = (41.52e-3)(1) = 41.52\ mA$

(b) $I1 = (241.4e-6)(-8) + (0.6)(3) = 1.8\ A$
$I2 = (-17.23e-6)(-8) + (41.52e-3)(3) = 125\ mA$

(c) $I1 = (241.4e-6)(5) + (0.6)(5) = 3\ A$
$I2 = (-17.23e-6)(5) + (41.52e-3)(5) = 207\ mA$

19. $$\begin{cases} I1 = \frac{V1-5I1}{1} + 0.3I1 \\ I2 = \frac{V2}{2} - 0.3I1 + \frac{V2}{5} \end{cases}$$

So, $Y = \begin{vmatrix} \frac{1}{5.7} & 0 \\ -\frac{1}{19} & 0.7 \end{vmatrix}$

20. (a) The input is applied at terminals G-S, while the output is taken from terminals D-S.

(b) $I_g = y_{is}V_{gs} + y_{rs}V_{ds}$
$I_d = y_{fs}V_{gs} + y_{os}V_{ds}$

$y_{is} = \left.\frac{I_g}{V_{gs}}\right|_{V_{ds}=0} = j\omega(C_{gs} + C_{gd})$ $\qquad$ $y_{rs} = \left.\frac{I_g}{V_{ds}}\right|_{V_{gs}=0} = -j\omega C_{gd}$

$y_{fs} = \left.\frac{I_d}{V_{gs}}\right|_{V_{ds}=0} = g_m - j\omega C_{gd})$ $\qquad$ $y_{os} = \left.\frac{I_d}{V_{ds}}\right|_{V_{gs}=0} = \frac{1}{r_d} + j\omega(C_{gs} + C_{gd})$

(c) $y_{is} = j\omega(3.4 + 1.4) \times 10^{-12} = j4.8\omega\ pS$

$y_{rs} = -j\omega 1.4 \times 10^{-12} = -j1.4\omega\ pS$

$y_{fs} = 4.7 \times 10^{-13} - j\omega 1.4 \times 10^{-12}\ S$

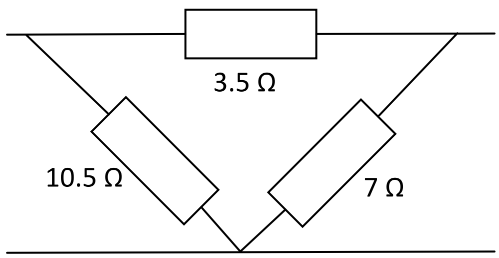
$y_{os} = 10^{-4} + j\omega(0.4 + 1.4) \times 10^{-12}\ S$

21. (a) simplify the circuit to a single resistor with value of 5.54 kΩ

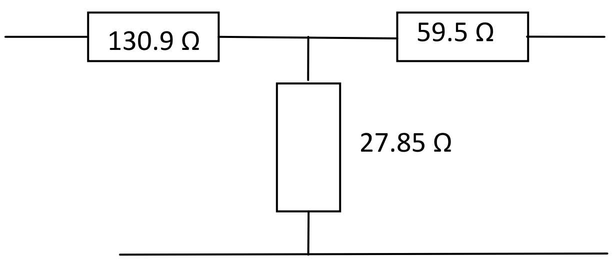
(b) $P = I^2R = 22.16\ W$

(c) $P = \frac{U^2}{R} = 14.62\ W$

22. (a)



(b)



23. (a) $\omega = 50, Zin = 69.9j$

(b) $\omega = 100, Zin = 141j$

24. (a) $\omega = 50, \quad Zin = 5.875\angle 7.6^o\ \Omega$

(b) $\omega = 100, \quad Zin = 6\ \Omega$

25. Zin=1.86 MΩ

26. Zin = 8.27 Ω

27.

(a) From solution of problem 14, $Y = \begin{bmatrix} 4.21 & -3.17 \\ -3.17 & 3.7 \end{bmatrix} mS$

So, $-y_{12} = 3.17\ mS$

$y_{11} + y_{12} = 1.04\ mS$

$y_{22} + y_{12} = 0.53\ mS$

And the dependent source is turned off.

(b) For circuit of Figure 17.43: $\begin{bmatrix} I1 \\ I2 \end{bmatrix} = \begin{bmatrix} 4.21e-3 & -3.17e-3 \\ -3.2e-3 & 3.7e-3 \end{bmatrix} \begin{bmatrix} V1 \\ V2 \end{bmatrix}$

Since I2 = -V2/2 we get $-0.5V2 = (-3.17e-3)V1 + (3.7e-3)V2 \Rightarrow V1 = 158.9V2$

And since I1 = 1 A we get $1 = (4.21e-3)V1 + (-3.17e-3)V2$

$V2 = 1.502\ volt.$

$Pout = \frac{V_2^2}{2} = 1.128\ W$

Same result for circuit of Figure 17.13(a)

28. (a) From solution of problem 14, $Y = \begin{bmatrix} 4.21 & -3.17 \\ -3.17 & 3.7 \end{bmatrix} mS$

So, $-y_{12} = 3.17\ mS$

$y_{11} + y_{12} = 1.04\ mS$

$y_{22} + y_{12} = 0.53\ mS$

And the dependent source is turned off.

(b) For circuit of Figure 17.43: $\begin{bmatrix} I1 \\ I2 \end{bmatrix} = \begin{bmatrix} 4.21e-3 & -3.17e-3 \\ -3.2e-3 & 3.7e-3 \end{bmatrix} \begin{bmatrix} V1 \\ V2 \end{bmatrix}$

Since I2 = -V2/1 we get $-V2 = (-3.17e-3)V1 + (3.7e-3)V2 \Rightarrow V1 = 313.66V2$

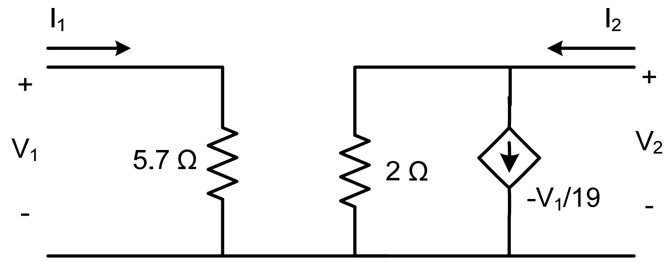
I_1 = 10mA, and $10e-3 = (4.21e-3)V1 + (-3.17e-3)V2$

$V2 = 7.6\ mV, \quad I2 = -7.6\ mA, \quad and\ \ V1 = 2.38\ V$

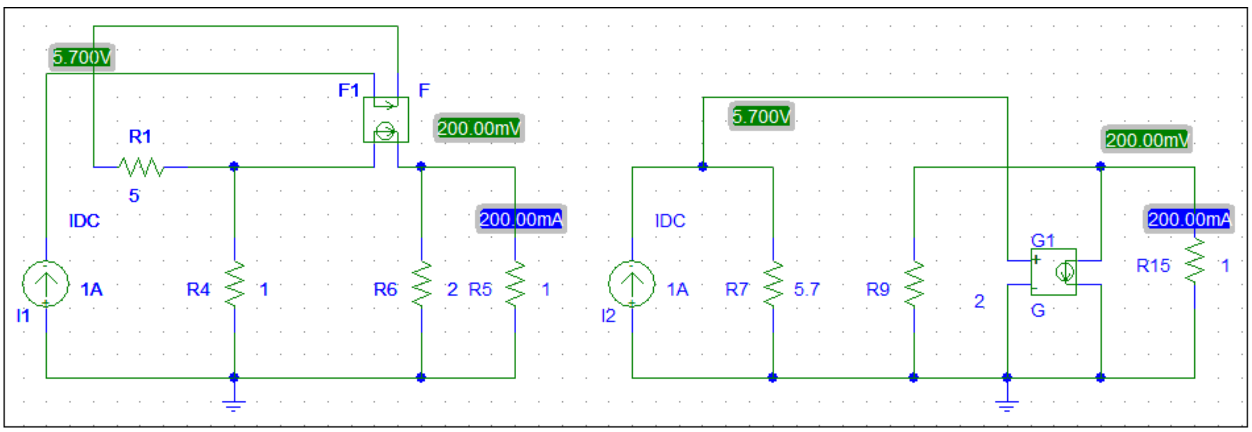
Same result for circuit of Figure 17.13(a)

29. $y_{11}=0.0041$, $y_{12}=-0.0031$, $y_{22}=0.0037$

30. (a) $Y = \begin{bmatrix} \frac{1}{5.7} & 0 \\ -\frac{1}{19} & 0.5 \end{bmatrix} S$



(b)



31. $\begin{cases} I1 = 0.1V1 - 0.05V2 \\ I2 = -0.5V1 + 0.2V2 \\ V1 = 1 - 10I1 \\ V2 = -5I2 \end{cases}, so \begin{cases} I1 = 0.027 \\ I2 = -0.182 \\ V1 = 0.727 \\ V2 = 0.901 \end{cases}$

(a) $Gv = \frac{V2}{V1} = 1.239$

(b) $Gi = \frac{I2}{I1} = -0.741$

(c) $Gp = -\frac{V2*I2}{V1*I1}$=8.35

(d) $Zin = \frac{V1}{I1} = 26.9\ \Omega$

(e) $Zout = \frac{V2}{I2} = -4.9\ \Omega$

32.

$$\mathbf{z} = \begin{bmatrix} 2 & 3 \\ 5 & 1 \end{bmatrix} \Omega \Rightarrow \mathbf{y} = \begin{bmatrix} -\frac{1}{13} & \frac{3}{13} \\ \frac{5}{13} & \frac{2}{13} \end{bmatrix} \ S$$

$$\mathbf{z} = \begin{bmatrix} 1000 & 470 \\ 2500 & 900 \end{bmatrix} \Omega \Rightarrow \mathbf{y} = \begin{bmatrix} -3.3 & 1.7 \\ 9.1 & -3.6 \end{bmatrix} \ mS$$

$$\mathbf{y} = \begin{bmatrix} 1 & 5 \\ 6 & 30 \end{bmatrix} mS \Rightarrow \mathbf{z} = \begin{bmatrix} -5.8 & 96 \\ 1.15 & -19 \end{bmatrix} \times 10^{17} \ \Omega$$

$$\mathbf{y} = \begin{bmatrix} 1 & 2 \\ -1 & 3 \end{bmatrix} S \Rightarrow \mathbf{z} = \begin{bmatrix} \frac{3}{5} & -\frac{2}{5} \\ -\frac{1}{5} & \frac{1}{5} \end{bmatrix} \ \Omega$$

33. $Z = \begin{bmatrix} 125 & 25 \\ 25 & 75 \end{bmatrix}$

34. $Z = \begin{bmatrix} 125 & 25 \\ 25 & 75 \end{bmatrix}$, $V_2 = -10I_2$, $V_1 = (6\angle 0^o mA - I_1)50$

So, $\begin{Bmatrix} 0.3 - 50I_2 = 125I_1 + 25I_2 \\ -10I_2 = 25I_1 + 75I_2 \end{Bmatrix} \Rightarrow \begin{Bmatrix} 0.3 = 175I_1 + 25I_2 \\ -10I_2 = 25I_1 + 85I_2 \end{Bmatrix} \Rightarrow \begin{Bmatrix} I_1 = 1.8\angle 0^o mA \\ I_2 = -0.5\angle 0^o mA \end{Bmatrix} \Rightarrow \begin{Bmatrix} V_1 = 0.21\angle 0^o V \\ V_2 = 5.3\angle 0^o mV \end{Bmatrix}$

$\therefore G_V = 0.025, \quad G_I = -0.294, \quad G_P = 7 \times 10^{-3}$

35. (a) $Z1 = \begin{vmatrix} 9 & 6 \\ 6 & 8 \end{vmatrix}, Z2 = \begin{vmatrix} 158.7 & 27.8 \\ 27.8 & 87.3 \end{vmatrix},$

so $Z = Z1 + Z2 = \begin{vmatrix} 167.7 & 33.8 \\ 33.8 & 95.3 \end{vmatrix}$

(b) $Y1 = \begin{vmatrix} \frac{8}{36} & -\frac{6}{36} \\ -\frac{6}{36} & \frac{9}{36} \end{vmatrix}, Y2 = \begin{vmatrix} \frac{87.3}{1300} & -\frac{27.8}{1300} \\ -\frac{27.8}{1300} & \frac{158.7}{1300} \end{vmatrix}$

So $Y = Y1 + Y2 = \begin{vmatrix} 0.289 & -0.188 \\ -0.188 & 0.372 \end{vmatrix}$

36. (a) $z = \begin{bmatrix} 16.54 & 15.66 \\ 15.8 & 17.55 \end{bmatrix} k\Omega$

(b) $G_I = -0.7, \quad G_V = 0.64, \quad G_P = 0.45$

37. $Z11 = \frac{V1}{I1} = \frac{5(I1-0.8V2)}{I1}$,

$$Z22 = \frac{V2}{I2} = \frac{0.1V1 + 2I2}{I2}$$

$$Z12 = \frac{V1}{I2} = 20\ \Omega$$

$$Z21 = \frac{V2}{I1} = \frac{V2}{0.8V2} = 1.25\ \Omega$$

38. $\mathbf{y} = \begin{bmatrix} 30 & 10 \\ 70 & 43.33 \end{bmatrix} \, mS, \quad \mathbf{z} = \begin{bmatrix} 72.3 & -16.7 \\ -116.9 & 50 \end{bmatrix} \, \Omega$

39. $V1 = Ia * 100000, V1 = Ib * (-2000j), V1 = 10000 * Ic + (Ic + 0.01V1)(-10000j)$

$Z11 = -0.0049 + 0.0055j$

$V2 = Zc * 10000, V1 = (i2 - iC - 0.04v1)(385 - 1.9 \times 10^3 J)$

So, $z22 = 4.94 \times 10^3 + 2.88 \times 10^3 j, Z12 = 48.5 - 30.9j$

$V1 = Ic * Z11, Ic = (-0.0047 + 0.0053j)I1$

So, $Z21 = -470 + 530j$

40. $\boldsymbol{h} = \begin{bmatrix} 166.7\ \Omega & 1/3 \\ -1/3 & \frac{1}{75} S \end{bmatrix}$

41. $h1 = \begin{vmatrix} 50\ \Omega & 1 \\ -1 & 40\ ms \end{vmatrix}, h2 = \begin{vmatrix} 1.67\ \Omega & 0.67 \\ -0.67 & 13.3\ ms \end{vmatrix}$

42. (a) $\boldsymbol{z} = \begin{bmatrix} 3500 & -300 \\ -5 & 100 \end{bmatrix} \Omega$

(b) $\boldsymbol{y} = \begin{bmatrix} 0.5 & 1.5 \\ 2.5 & 17.5 \end{bmatrix} mS$

43. (a) $h = \begin{vmatrix} 20\ \Omega & -2 \\ 5 & 0.1\ s \end{vmatrix}$

(b) $h = \begin{vmatrix} 100\ \Omega & -2 \\ 5 & 0.14\ s \end{vmatrix}$

44. (a) $\boldsymbol{h} = \begin{bmatrix} 5\ k\Omega & 0.55 \times 10^{-4} \\ 300 & 39\ \mu S \end{bmatrix}$

(b) $G_I = \frac{I_2}{I_1} = h_{21} = 300$

(c) $Z_{out} = \frac{1}{h_{22}} = 25.64\ k\Omega$

(d) KVL at input loop: $(100 + h_{11})|I_1| = 5\ mV \Rightarrow |I_1| = \frac{5\ mV}{100+h_{11}}$

$$|V_1| = h_{11}|I_1| = h_{11}\frac{5\ mV}{100 + h_{11}}$$

$$|V_2| = \frac{|V_1|}{h_{12}} = \frac{h_{11}\frac{5\ mV}{100 + h_{11}}}{h_{12}} \Rightarrow |V_2| = 89.13\ Volt$$

45. $\begin{cases} V1 = 1 - 5I1 \\ V2 = 2 * I2 \end{cases}$

so $\boxed{\begin{cases} V1 = \frac{1}{6}V \\ V2 = \frac{2}{3}\ V \\ I1 = \frac{1}{6}\ A \\ I2 = \frac{1}{3}\ A \end{cases}}$

46. Convert to t-parameters using Table 17.1, multiply resulting matrices and convert back to h.

$$\boldsymbol{h_A} = \begin{bmatrix} 50\ \Omega & 1 \\ -1 & 40\ \mu S \end{bmatrix} \ \ and \ \ \boldsymbol{h_B} = \begin{bmatrix} 16.67\ \Omega & 0.33 \\ -0.33 & 13.35\ \mu S \end{bmatrix}$$

$$\boldsymbol{t_A} = \begin{bmatrix} 0.3 & 50\ \Omega \\ 40\ mS & 1 \end{bmatrix} \ \ and \ \ \boldsymbol{t_B} = \begin{bmatrix} 1.0009 & 50.0051\ \Omega \\ 40.1\ mS & 3.0003 \end{bmatrix}$$

$\boldsymbol{t} = \boldsymbol{t_A}\boldsymbol{t_B} = \begin{bmatrix} 5.0053 & 300.03\ \Omega \\ 80.1\ mS & 5.0005 \end{bmatrix}$, and

$$\boldsymbol{h} = \begin{bmatrix} 60\ \Omega & 0.2 \\ -0.2 & 16\ \mu S \end{bmatrix}$$

May confirm by combining two original networks and apply basic circuit laws.

47. Convert to y-parameters using Table 17.1, add resulting matrices and convert back to h.

$$\boldsymbol{h_A} = \begin{bmatrix} 50\ \Omega & 1 \\ -1 & 40\ \mu S \end{bmatrix} \quad and \quad \boldsymbol{h_B} = \begin{bmatrix} 16.67\ \Omega & 0.33 \\ -0.33 & 13.35\ \mu S \end{bmatrix}$$

$$\boldsymbol{y_A} = \begin{bmatrix} 20 & -20 \\ -20 & 60 \end{bmatrix} mS \quad and \quad \boldsymbol{y_B} = \begin{bmatrix} 60 & -20 \\ -20 & 20 \end{bmatrix} mS$$

$\boldsymbol{y} = \boldsymbol{y_A} + \boldsymbol{y_B} = \begin{bmatrix} 80 & -40 \\ -40 & 80 \end{bmatrix} mS$, and

$$\boldsymbol{h} = \begin{bmatrix} 12.5\ \Omega & 0.5 \\ -0.5 & 60\ \mu S \end{bmatrix}$$

May confirm by combining two original networks and apply basic circuit laws.

48. (a) $\mathbf{y} = \begin{bmatrix} \frac{1}{R} & -\frac{1}{R} \\ -\frac{1}{R} & \frac{1}{R} \end{bmatrix}, \quad \mathbf{h} = \begin{bmatrix} R & 1 \\ -1 & 0 \end{bmatrix}$

(b) $\mathbf{z} = \begin{bmatrix} R & R \\ R & R \end{bmatrix}, \quad \mathbf{h} = \begin{bmatrix} 0 & 1 \\ -1 & \frac{1}{R} \end{bmatrix}$

49. $I1 = \frac{V1}{1000} - 10^{-5}V2, V2 = I2 * 10000 - 100V1$

So $h = \begin{vmatrix} 1000\ \Omega & 0.01 \\ 10 & 5\ ks \end{vmatrix}$

50. (a) $\begin{cases} I_1 = \frac{V_1}{5} + \frac{V_1 - V_2}{10} \\ I_2 = \frac{V_2}{20} + \frac{V_2 - V_1}{10} \end{cases} \Rightarrow \boldsymbol{t} = \begin{bmatrix} 1.5 & 10\ \Omega \\ 350\ mS & 3 \end{bmatrix}$

(b) $\boldsymbol{h} = \begin{bmatrix} \frac{10}{3}\ \Omega & \frac{1}{3} \\ -\frac{1}{3} & 0.1167\ S \end{bmatrix}$

51. $\begin{cases} V1 = (631.6 + 12530)I1 + 0.2V2 \\ V2 = 12530I1 + 0.2V2 \end{cases}$, so $t11 = 1.04$

and $\begin{cases} -I2 = \frac{V1}{631.6+(1890||112530)} * \frac{12530}{12530+1890} \\ \end{cases}, so\ t12 = 0.803\ \Omega$

and $\begin{cases} I1 = \frac{V1-0.2V2}{12530+631.6} \\ V2 = I1 * 12530 + 0.2V2 \end{cases}, so\ t21 = 6.35 \times 10^{-5} s$

and $V2 = I1(1890 + 12530) + I1 * 12530, so t22 = 1.15$

then, $t = \begin{vmatrix} 1.04 & 0.803\ \Omega \\ 6.35 \times 10^{-5} s & 1.15 \end{vmatrix}$

52. (a) $\boldsymbol{ab} = \begin{bmatrix} 9.5 & 6 \\ 5.5 & 3 \end{bmatrix}$, (b) $\boldsymbol{ba} = \begin{bmatrix} 8.5 & 7 \\ 5.5 & 4 \end{bmatrix}$, (c) $\boldsymbol{ac} = \begin{bmatrix} -18 \\ 0 \end{bmatrix}$

(d) $\boldsymbol{bc} = \begin{bmatrix} -5 \\ -3.5 \end{bmatrix}$, (e) $\boldsymbol{bac} = \begin{bmatrix} -27 \\ -18 \end{bmatrix}$, (f) $\boldsymbol{aa} = \begin{bmatrix} 27 & 18 \\ 9 & 18 \end{bmatrix}$

53 (a) $t = t1 * t2 = \begin{vmatrix} 16.8 & 1.87 \times 10^4 \\ 0.004 & 4.2 \end{vmatrix}$

(b) $t = t2 * t1 = \begin{vmatrix} 6.67 & 1.14 \times 10^4 \\ 8.26 \times 10^{-3} & 1.43 \end{vmatrix}$

54. (a) $\boldsymbol{t_A} = \begin{bmatrix} \frac{3}{2} & 1\ \Omega \\ \frac{1}{2}S & 1 \end{bmatrix}$, $\boldsymbol{t_B} = \begin{bmatrix} \frac{7}{4} & 3\ \Omega \\ \frac{1}{4}S & 1 \end{bmatrix}$, $\boldsymbol{t_B} = \begin{bmatrix} \frac{11}{6} & 5\ \Omega \\ \frac{1}{6}S & 1 \end{bmatrix}$

(b) $\boldsymbol{t} = \boldsymbol{t_A t_B t_C} = \begin{bmatrix} 6.19 & 19.88\ \Omega \\ 2.48\ S & 8.12 \end{bmatrix}$

(c) $\left\{ \begin{matrix} \frac{V_x - V_1}{1} + \frac{V_x}{2} + \frac{V_x - V_y}{3} = 0 \\ I_1 = \frac{V_1 - V_x}{1} \\ \frac{V_y - V_x}{3} + \frac{V_y}{4} + \frac{V_y - V_2}{5} = 0 \\ I_2 = \frac{V_2 - V_y}{5} + \frac{V_2}{6} \end{matrix} \right\} \Rightarrow \boldsymbol{y} = \begin{bmatrix} 408.4 & -50.3 \\ -50.3 & 311.3 \end{bmatrix} mS$

Converting these y-parameters into t-parameters confirms (b).

55. (a) $t = t_{right} * t_{left} = \begin{vmatrix} 2.12 & 36.15 \\ 0.12 & 2.49 \end{vmatrix}$

(b) $t = t_{left} * t_{right} = \begin{vmatrix} 3.01 & 82.1 \\ 0.047 & 1.59 \end{vmatrix}$

56. (a)Using the t-parameter definitions we can get: $\boldsymbol{t} = \begin{bmatrix} 0.1 & 20\ \Omega \\ 2.8\ S & 4 \end{bmatrix}$

(b) t-parameter relationship equations: $\begin{matrix} V_1 = t_{11}V_2 - t_{12}I_2 \\ I_1 = t_{21}V_2 - t_{22}I_2 \end{matrix}$

KVL at input loop: $V_1 = V_s - 100I_1 = V_s - 100(t_{21}V_2 - t_{22}I_2) = V_s - 100t_{21}V_2 + 100t_{22}I_2$

But $V_1 = t_{11}V_2 - t_{12}I_2 = V_s - 100t_{21}V_2 + 100t_{22}I_2$

Turning Vs source off: $Z_{out} = \frac{V_2}{I_2} = \frac{t_{12}+100t_{22}}{t_{11}+100t_{21}} \Rightarrow Z_{out} = 1.5\ \Omega$

57. $t = t * t * t = \begin{vmatrix} 307 & 2.2 \times 10^4 \\ 0.252 & 181 \end{vmatrix}$

58. (a) $\boldsymbol{t_a} = \begin{bmatrix} 1 & 0 \\ \frac{1}{R} & 1 \end{bmatrix}, \quad \boldsymbol{t_b} = \begin{bmatrix} 1 & R \\ 0 & 1 \end{bmatrix}, \quad \boldsymbol{t_c} = \begin{bmatrix} \frac{1}{a} & 0 \\ 0 & a \end{bmatrix}$

(b) $\boldsymbol{t} = \begin{bmatrix} 1 & 2 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \frac{1}{10} & 1 \end{bmatrix} \begin{bmatrix} \frac{1}{4} & 0 \\ 0 & 4 \end{bmatrix} \begin{bmatrix} 1 & 20 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \frac{1}{50} & 1 \end{bmatrix} = \begin{bmatrix} 0.58 & 14\ \Omega \\ 0115\ S & 4.5 \end{bmatrix}$

59. $Z = \begin{vmatrix} 15 & 5 \\ 5 & 15 \end{vmatrix}, h = \begin{vmatrix} 13.3 & 0.33 \\ -0.33 & 0.667 \end{vmatrix}, Y = \begin{vmatrix} 0.075 & -0.025 \\ -0.025 & 0.075 \end{vmatrix}, t = \begin{vmatrix} 3 & 40 \\ 0.5 & 3 \end{vmatrix}$

60. $y = \begin{bmatrix} 0.075 & -0.025 \\ -0.025 & 0.075 \end{bmatrix}^4 = \begin{bmatrix} 53.13 & -46.88 \\ -46.88 & 53.13 \end{bmatrix} \mu S$

Use Table 17.1 to convert to the following:

$z = \begin{bmatrix} 15 & 5 \\ 5 & 15 \end{bmatrix} \Omega$

$h = \begin{bmatrix} \frac{1000}{75} \Omega & 1/3 \\ -1/3 & \frac{1}{15} S \end{bmatrix}$

$t = \begin{bmatrix} 3 & 40\ \Omega \\ 0.2\ S & 3 \end{bmatrix}$

61. $t = t * t * t * t = \begin{vmatrix} 1561 & 13920 \\ 174 & 1561 \end{vmatrix}$,

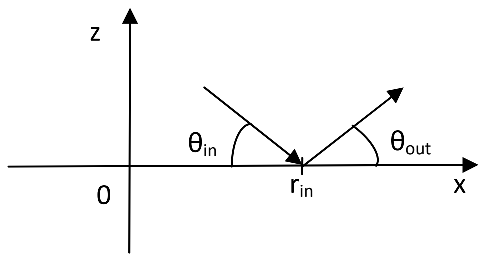
$Y = \begin{vmatrix} 0.112 & -1.05 \\ -7.2 \times 10^{-5} & 0.112 \end{vmatrix}$,

$Z = \begin{vmatrix} 8.97 & 84.1 \\ 0.0057 & 8.97 \end{vmatrix}$,

$h = \begin{vmatrix} 0.892 & 9.38 \\ -6.4 & 0.11 \end{vmatrix}$

62. (a) $A = \left.\frac{r_{out}}{r_{in}}\right|_{\theta_{in}=0}$, $B = \left.\frac{r_{out}}{\theta_{in}}\right|_{r_{in}=0}$, $C = \left.\frac{\theta_{out}}{r_{in}}\right|_{\theta_{in}=0}$, $D = \left.\frac{\theta_{out}}{\theta_{in}}\right|_{r_{in}=0}$

(b) A perfectly reflecting flat mirror:



63. (a) $t1 = \begin{vmatrix} 1 & 0.5d \\ 0 & 1 \end{vmatrix}, t = t1 * t1 = \begin{vmatrix} 1 & d \\ 0 & 1 \end{vmatrix}$

(b) $r_{out} = A * r_{in} + B * \theta_{in}, \theta_{out} = C * r_{in} + D * \theta_{in}$

Unit: A: 1; B: m/rad; C: rad/m; D: 1