Chapter 21

1. a. $\omega_s = \dfrac{1}{\sqrt{LC}} = \dfrac{1}{\sqrt{(1\text{ H})(16\,\mu\text{F})}} = \mathbf{250\ rad/s}$

$f_s = \dfrac{\omega_s}{2\pi} = \dfrac{250\text{ rad/s}}{2\pi} = \mathbf{39.79\ Hz}$

b. $\omega_s = \dfrac{1}{\sqrt{(0.51\text{ H})(0.16\,\mu\text{F})}} = \mathbf{3496.50\ rad/s}$

$f_s = \dfrac{\omega_s}{2\pi} = \dfrac{3496.50\text{ rad/s}}{2\pi} = \mathbf{556.49\ Hz}$

c. $\omega_s = \dfrac{1}{\sqrt{(0.27\text{ mH})(7.5\,\mu\text{F})}} = \mathbf{22{,}173\ rad/s}$

$f_s = \dfrac{\omega_s}{2\pi} = \dfrac{22{,}173\text{ rad/s}}{2\pi} = \mathbf{3528.93\ Hz}$

2. a. $X_C = \mathbf{30\ \Omega}$ b. $Z_{T_s} = \mathbf{2\ \Omega}$ c. $I = \dfrac{E}{Z_{T_s}} = \dfrac{50\text{ mV}}{2\ \Omega} = \mathbf{25\ mA}$

d. $V_R = IR = (25\text{ mA})(10\ \Omega) = \mathbf{250\ mV} = E$
$V_L = IX_L = (25\text{ mA})(30\ \Omega) = \mathbf{750\ mV}$
$V_C = IX_C = (25\text{ mA})(30\ \Omega) = \mathbf{750\ mV}$
$V_L = V_C$

e. $Q_s = \dfrac{X_L}{R} = \dfrac{30\ \Omega}{2\ \Omega} = \mathbf{15}$ (medium Q) f. $P = I^2R = (25\text{ mA})^2\ 2\ \Omega = \mathbf{1.25\ mW}$

3. a. $X_L = \mathbf{2\ k\Omega}$

b. $I = \dfrac{E}{Z_{T_s}} = \dfrac{12\text{ V}}{100\ \Omega} = \mathbf{120\ mA}$

c. $V_R = IR = (120\text{ mA})(100\ \Omega) = \mathbf{12\ V} = E$
$V_L = IX_L = (120\text{ mA})(2\text{ k}\Omega) = \mathbf{240\ V}$
$V_C = IX_C = (120\text{ mA})(2\text{ k}\Omega) = \mathbf{240\ V}$
$V_L = V_C = 20\ V_R$

d. $Q_s = \dfrac{X_L}{R} = \dfrac{20000\ \Omega}{100\ \Omega} = \mathbf{20}$ (high Q)

e. $X_L = 2\pi fL,\ L = \dfrac{X_L}{2\pi f} = \dfrac{2\text{ k}\Omega}{2\pi(5\text{ kHz})} = \mathbf{63.7\ mH}$

$X_C = \dfrac{1}{2\pi f C},\ C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{2\pi(5\text{ kHz})(2\text{ k}\Omega)} = \mathbf{15{,}920\ pF}$

f. $BW = \frac{f_s}{Q_s} = \frac{5\text{ kHz}}{20} = \mathbf{250\text{ Hz}}$

g. $f_2 = f_s + \frac{BW}{2} = 5\text{ kHz} + \frac{0.25\text{ kHz}}{2} = \mathbf{5.13\text{ kHz}}$

$f_1 = f_s - \frac{BW}{2} = 5\text{ kHz} - \frac{0.25\text{ kHz}}{2} = \mathbf{4.88\text{ kHz}}$

4. a. $f_s = \frac{1}{2\pi\sqrt{LC}} \Rightarrow L = \frac{1}{(2\pi f_s)^2 C} = \frac{1}{(2\pi\ 1.8\text{ kHz})^2\, 2\,\mu\text{F}} = \mathbf{3.91\text{ mH}}$

b. $X_L = 2\pi fL = 2\pi(1.8\text{ kHz})(3.91\text{ mH}) = \mathbf{44.2\ \Omega}$

$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(1.8\text{ kHz})(2\,\mu\text{F})} = \mathbf{44.2\ \Omega}$

$X_L = X_C$

c. $E_{\text{rms}} = (0.707)(20\text{ mV}) = 14.14\text{ mV}$

$I_{\text{rms}} = \frac{E_{\text{rms}}}{R} = \frac{14.14\text{ mV}}{4.7\ \Omega} = \mathbf{3.01\text{ mA}}$

d. $P = I^2R = (3.01\text{ mA})^2\ 4.7\ \Omega = \mathbf{42.58\ \mu W}$

e. $S_T = P_T = \mathbf{42.58\ \mu VA}$

f. $F_p = \mathbf{1}$

g. $Q_s = \frac{X_L}{R} = \frac{44.2\ \Omega}{4.7\ \Omega} = \mathbf{9.4}$

$BW = \frac{f_s}{Q_s} = \frac{1.8\text{ kHz}}{9.4} = \mathbf{191.49\text{ Hz}}$

h. $$f_2 = \frac{1}{2\pi}\left[\frac{R}{2L} + \frac{1}{2}\sqrt{\left(\frac{R}{L}\right)^2 + \frac{4}{LC}}\right]$$

$$= \frac{1}{2\pi}\left[\frac{4.7\ \Omega}{2(3.91\text{ mH})} + \frac{1}{2}\sqrt{\left(\frac{4.7\ \Omega}{3.91\text{ mH}}\right)^2 + \frac{4}{(3.91\text{ mH})(2\ \mu\text{F})}}\right]$$

$$= \frac{1}{2\pi}\left[601.02 + 11.324\times10^3\right]$$

$= \mathbf{1897.93\text{ Hz}}$

$$f_1 = \frac{1}{2\pi}\left[-\frac{R}{2L} + \frac{1}{2}\sqrt{\left(\frac{R}{L}\right)^2 + \frac{4}{LC}}\right]$$

$$= \frac{1}{2\pi}\left[-601.02 + 11.324\times10^3\right]$$

$= \mathbf{1.71\text{ kHz}}$

$P_{\text{HPF}} = \frac{1}{2}P_{\max} = \frac{1}{2}(42.58\ \mu\text{W}) = \mathbf{21.29\ \mu W}$

5. a. $BW = f_s/Q_s = 6000\text{ Hz}/15 = \mathbf{400\ Hz}$

b. $f_2 = f_s + \dfrac{BW}{2} = 6000\text{ Hz} + 200\text{ Hz} = \mathbf{6200\ Hz}$

$f_1 = f_s - \dfrac{BW}{2} = 6000\text{ Hz} - 200\text{ Hz} = \mathbf{5800\ Hz}$

c. $Q_s = \dfrac{X_L}{R} \Rightarrow X_L = Q_sR = (15)(3\ \Omega) = \mathbf{45\ \Omega} = X_C$

d. $P_{\text{HPF}} = \dfrac{1}{2}P_{\max} = \dfrac{1}{2}(I^2R) = \dfrac{1}{2}(0.5\text{ A})^2\, 3\Omega = \mathbf{375\ mW}$

6. a. $L = \dfrac{X_L}{2\pi f} = \dfrac{200\ \Omega}{2\pi(10^4\text{ Hz})} = 3.185\text{ mH}$

$BW = \dfrac{R}{2\pi L} = \dfrac{5\ \Omega}{2\pi(3.185\text{ mH})} \cong \mathbf{250\ Hz}$

or $Q_s = \dfrac{X_L}{R} = \dfrac{X_C}{R} = \dfrac{200\ \Omega}{5\ \Omega} = 40,\ BW = \dfrac{f_s}{Q_s} = \dfrac{10{,}000\text{ Hz}}{40} = \mathbf{250\ Hz}$

b. $f_2 = f_s + BW/2 = 10{,}000\text{ Hz} + 250\text{ Hz}/2 = \mathbf{10{,}125\ Hz}$
$f_1 = f_s - BW/2 = 10{,}000\text{ Hz} - 125\text{ Hz} = \mathbf{9{,}875\ Hz}$

c. $Q_s = \dfrac{X_L}{R} = \dfrac{200\ \Omega}{5\ \Omega} = \mathbf{40}$

d. $\mathbf{I} = \dfrac{E\angle 0^\circ}{R\angle 0^\circ} = \dfrac{30\text{ V}\angle 0^\circ}{5\ \Omega\angle 0^\circ} = 6\text{ A}\angle 0^\circ,\ \mathbf{V}_L = (I\angle 0^\circ)(X_L\angle 90^\circ)$

$= (6\text{ A}\angle 0^\circ)(200\ \Omega\angle 90^\circ)$
$= \mathbf{1200\ V\angle 90^\circ}$

$\mathbf{V}_C = (I\angle 0^\circ)(X_C\angle -90^\circ) = \mathbf{1200\ V\angle -90^\circ}$

e. $P = I^2R = (6\text{ A})^2\, 5\ \Omega = \mathbf{180\ W}$

7. a. $BW = \dfrac{f_s}{Q_s} \Rightarrow Q_s = f_s/BW = 2000\text{ Hz}/200\text{ Hz} = \mathbf{10}$

b. $Q_s = \dfrac{X_L}{R} \Rightarrow X_L = Q_sR = (10)(2\ \Omega) = \mathbf{20\ \Omega}$

c. $L = \dfrac{X_L}{2\pi f} = \dfrac{20\ \Omega}{(6.28)(2\text{ kHz})} = \mathbf{1.59\ mH}$

$C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{(6.28)(2\text{ kHz})(20\ \Omega)} = \mathbf{3.98\ \mu F}$

d. $f_2 = f_s + BW/2 = 2000\text{ Hz} + 100\text{ Hz} = \mathbf{2100\text{ Hz}}$
$f_1 = f_s - BW/2 = 2000\text{ Hz} - 100\text{ Hz} = \mathbf{1900\text{ Hz}}$

8. a. $BW = 6000\text{ Hz} - 5400\text{ Hz} = \mathbf{600\text{ Hz}}$

b. $BW = f_s/Q_s \Rightarrow f_s = Q_s BW = (9.5)(600\text{ Hz}) = \mathbf{5700\text{ Hz}}$

c. $Q_s = \dfrac{X_L}{R} \Rightarrow X_L = X_C = Q_s R = (9.5)(2\ \Omega) = \mathbf{19\ \Omega}$

d. $L = \dfrac{X_L}{2\pi f} = \dfrac{19\ \Omega}{2\pi(5700\text{ Hz})} = \mathbf{0.53\text{ mH}}$

$C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{2\pi(5.7\text{ kHz})(19\ \Omega)} = \mathbf{1.47\ \mu F}$

9. $I_M = \dfrac{E}{R} \Rightarrow R = \dfrac{E}{I_M} = \dfrac{5\text{ V}}{500\text{ mA}} = \mathbf{10\ \Omega}$

$BW = f_s/Q_s \Rightarrow Q_s = f_s/BW = 8400\text{ Hz}/120\text{ Hz} = 70$

$Q_s = \dfrac{X_L}{R} \Rightarrow X_L = Q_s R = (70)(10\ \Omega) = \mathbf{700\ \Omega}$

$X_C = X_L = \mathbf{700\ \Omega}$

$L = \dfrac{X_L}{2\pi f} = \dfrac{700\ \Omega}{(2\pi)(8.4\text{ kHz})} = \mathbf{13.26\text{ mH}}$

$C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{(2\pi)(8.4\text{ kHz})(0.7\text{ k}\Omega)} = \mathbf{27.07\text{ nF}}$

$f_2 = f_s + BW/2 = 8400\text{ Hz} + 120\text{ Hz}/2 = \mathbf{8.46\text{ kHz}}$
$f_1 = f_s - BW/2 = 8400\text{ Hz} - 60\text{ Hz} = \mathbf{8.34\text{ kHz}}$

10. $Q_s = \dfrac{X_L}{R} \Rightarrow X_L = Q_s R = 20(2\ \Omega) = \mathbf{40\ \Omega} = X_C$

$BW = \dfrac{f_s}{Q_s} \Rightarrow f_s = Q_s BW = (20)(400\text{ Hz}) = \mathbf{8\text{ kHz}}$

$L = \dfrac{X_L}{2\pi f} = \dfrac{40\ \Omega}{2\pi(8\text{ kHz})} = \mathbf{795.77\text{ mH}}$

$C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{2\pi(8\text{ kHz})(40\ \Omega)} = \mathbf{497.36\text{ nF}}$

$f_2 = f_s + BW/2 = 8000\text{ Hz} + 400\text{ Hz}/2 = \mathbf{8200\text{ Hz}}$
$f_1 = f_s - BW/2 = 8000\text{ Hz} - 200\text{ Hz} = \mathbf{7800\text{ Hz}}$

11. a. $f_s = \dfrac{\omega_s}{2\pi} = \dfrac{2\pi \times 10^6 \text{ rad/s}}{2\pi} = \mathbf{1\ MHz}$

b. $\dfrac{f_2 - f_1}{f_s} = 0.16 \Rightarrow BW = f_2 - f_1 = 0.16 f_s = 0.16(1 \text{ MHz}) = \mathbf{160\ kHz}$

c. $P = \dfrac{V_R^2}{R} \Rightarrow R = \dfrac{V_R^2}{P} = \dfrac{(120 \text{ V})^2}{20 \text{ W}} = \mathbf{720\ \Omega}$

$BW = \dfrac{R}{2\pi L} \Rightarrow L = \dfrac{R}{2\pi BW} = \dfrac{720\,\Omega}{(6.28)(160\text{ kHz})} = \mathbf{0.716\ mH}$

$f_s = \dfrac{1}{2\pi\sqrt{LC}} \Rightarrow C = \dfrac{1}{4\pi^2 f_s^2 L} = \dfrac{1}{4\pi^2(10^6\text{ Hz})^2(0.716\text{ mH})} = \mathbf{35.38\ pF}$

d. $Q_\ell = \dfrac{X_L}{R_\ell} = 80 \Rightarrow R_\ell = \dfrac{X_L}{80} = \dfrac{2\pi f_s L}{80} = \dfrac{2\pi(10^6\text{ Hz})(0.716\text{ mH})}{80} = \mathbf{56.23\ \Omega}$

12. a. $Q_\ell = \dfrac{X_L}{R_\ell}$

$R_\ell = \dfrac{X_L}{Q_\ell} = \dfrac{2\pi f L}{Q_\ell} = \dfrac{2\pi(1\text{MHz})(100\,\mu\text{H})}{12.5} = 50.27\ \Omega$

$\dfrac{f_2 - f_1}{f_s} = \dfrac{1}{Q_s} = 0.2$

$Q_s = \dfrac{1}{0.2} = 5 = \dfrac{X_L}{R} = \dfrac{2\pi f L}{R} = \dfrac{2\pi(1\text{ MHz})(100\,\mu\text{H})}{R} = \dfrac{628.32\,\Omega}{R}$

$R = \dfrac{628.32\,\Omega}{5} = 125.66\ \Omega$

$R = R_d + R_\ell$

$125.66\ \Omega = R_d + 50.27\ \Omega$

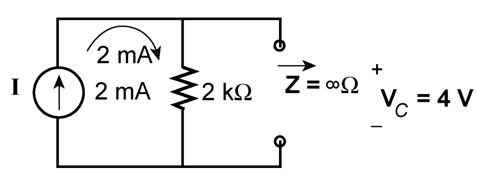
and $R_d = 125.66\ \Omega - 50.27\ \Omega = \mathbf{75.39\ \Omega}$

c. $X_C = \dfrac{1}{2\pi f C} = X_L$

$C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{2\pi(1\text{ MHz})(628.32\ \Omega)} = \mathbf{253.3\ pF}$

13. a. $f_p = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{2}{2\pi\sqrt{(0.1\text{ mH})(10\text{ nF})}} = \mathbf{159.16\ kHz}$

b.



c. $I_L = \dfrac{V_L}{X_L} = \dfrac{4\text{ V}}{2\pi f_p L} = \dfrac{4\text{ V}}{100\,\Omega} = \mathbf{40\ mA}$

$I_C = \dfrac{V_L}{X_C} = \dfrac{4\text{ V}}{1/2\pi f_p C} = \dfrac{4\text{ V}}{100\,\Omega} = \mathbf{40\ mA}$

d. $Q_p = \dfrac{R_s}{X_{L_p}} = \dfrac{2\text{ k}\Omega}{2\pi f_p L} = \dfrac{2\text{ k}\Omega}{100\,\Omega} = \mathbf{20}$

14. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(4.7\text{ mH})(30\text{ nF})}} = \mathbf{13.4\ kHz}$

b. $Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{2\pi f L}{R_\ell} = \dfrac{2\pi(13.4\text{ kHz})(4.7\text{ mH})}{8\,\Omega} = \mathbf{49.46} \geq 10$ (yes)

c. Since $Q_\ell \geq 10, f_p \cong f_s = \mathbf{13.4\ kHz}$

d. $X_L = 2\pi f_p L = 2\pi(13.4\text{ kHz})(4.7\text{ mH}) = \mathbf{395.72\ \Omega}$

$X_C = \dfrac{1}{2\pi f_p C} = \dfrac{1}{2\pi(13.4\text{ kHz})(30\text{ nF})} = \mathbf{395.91\ \Omega}$

$X_L = X_C$

e. $Z_{T_p} = Q_\ell^2 R_\ell = (49.46)^2\ 8\ \Omega = \mathbf{19.57\ k\Omega}$

f. $V_C = IZ_{T_p} = (10\text{ mA})(19.57\text{ k}\Omega) = \mathbf{195.7\ V}$

g. $Q_\ell \geq 10,\ Q_p = Q_\ell = \mathbf{49.46}$

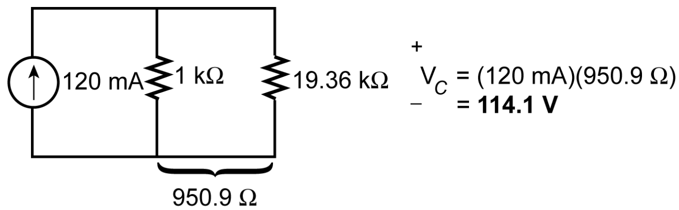
$BW = \dfrac{f_p}{Q_p} = \dfrac{13.4\text{ kHz}}{49.46} = \mathbf{270.9\ Hz}$

h. $I_L = I_C = Q_\ell I_T = (49.46)(10\text{ mA}) = \mathbf{494.6\ mA}$

15. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(200\,\mu\text{H})(120\,\mu\text{F})}}$ = **1.027 MHz**

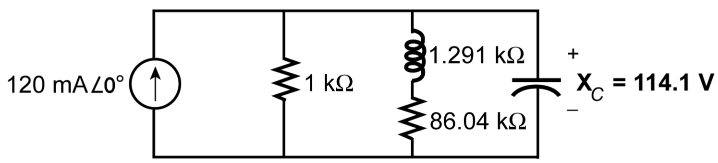
b. $Q_\ell = \dfrac{X_L}{R_\ell} \Rightarrow R_\ell = \dfrac{X_L}{Q_\ell} = \dfrac{2\pi(1.027\text{ MHz})(200\,\mu\text{H})}{15}$ = 86.04 Ω

$Z_p = Q_\ell^2 R_\ell = (15)^2 86.04\ \Omega$ = 19.36 kΩ



c. $P = I^2R = (120\text{ mA})^2(950.9\ \Omega)$ = **13.69 W**

d.



$X_L = 2\pi fL = 2\pi(1.027\text{ MHz})(200\,\mu\text{H}) = 1.291\text{ k}\Omega$

$\left|V_{R_\ell}\right| = \dfrac{(86.04\ \Omega\angle 0°)(114.1\text{ V})}{86.04\ \Omega + j1.291\text{ k}\Omega}$ = 7.587 V

$P = V_{R_\ell}^2 / R_\ell = (7.587\text{ V})^2 86.04\ \Omega$ = **669 mW**

13.69 W: 669 mW ≅ 20:1

16. a. $Q_\ell = \dfrac{X_L}{R_L} = \dfrac{100\ \Omega}{20\ \Omega} = 5 \leq 10$

$\therefore \dfrac{X_L}{R_\ell^2 + X_L^2} = \dfrac{1}{X_C} \Rightarrow X_C = \dfrac{R_\ell^2 + X_\ell^2}{X_L} = \dfrac{(20\ \Omega)^2 + (100\ \Omega)^2}{100\ \Omega}$ = **104 Ω**

b. $Z_T = R_s \parallel R_p = R_s \parallel \dfrac{R_\ell^2 + X_L^2}{R_\ell} = 1000\ \Omega \parallel \dfrac{10{,}400\ \Omega}{20}$ = **342.11 Ω**

c. $\mathbf{E} = \mathbf{IZ}_{T_p} = (5\text{ mA}\angle 0°)(342.11\ \Omega\angle 0°) = 1.711\text{ V}\angle 0°$

$\mathbf{I}_C = \dfrac{\mathbf{E}}{X_C\angle -90°} = \dfrac{1.711\text{ V}\angle 0°}{104\ \Omega\angle -90°}$ = **16.45 mA ∠90°**

$\mathbf{Z}_L = 20\ \Omega + j100\ \Omega = 101.98\ \Omega\angle 78.69°$

$\mathbf{I}_L = \dfrac{\mathbf{E}}{\mathbf{Z}_L} = \dfrac{1.711\text{ V}\angle 0°}{101.98\ \Omega\angle 78.69°}$ = **16.78 mA ∠−78.69°**

d. $L = \dfrac{X_L}{2\pi f} = \dfrac{100\,\Omega}{2\pi(20\text{ kHz})} = \mathbf{795.77\ mH}$

$C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{2\pi(20\text{ kHz})(104\,\Omega)} = \mathbf{76.52\ nF}$

e. $Q_p = \dfrac{R}{X_C} = \dfrac{342.11\,\Omega}{104\,\Omega} = \mathbf{3.29}$

$BW = f_p/Q_p = 20{,}000\text{ Hz}/3.29 = \mathbf{6079.03\ Hz}$

17. $Q_t = 35 = \dfrac{X_L}{R_\ell} \Rightarrow R_\ell = \dfrac{X_L}{35} = \dfrac{2\pi\left(\dfrac{2\times10^6}{2\pi}\text{ Hz}\right)(1\text{ mH})}{35} = \dfrac{2000\,\Omega}{35} = 57.14\,\Omega$

$Q_\ell \geq 10 : Q_p = \dfrac{f_p}{BW} = \dfrac{2\times10^6/2\pi\text{ Hz}}{100{,}000\text{ Hz}} = 20$

$Q_p = 20 = \dfrac{R \,\|\, Q_\ell^2 R_\ell}{X_L} = \dfrac{R \,\|\, (35)^2 57.14\,\Omega}{2000}$

And $40{,}000 = R \,\|\, 70{,}000$

So $R = 93.33\text{ k}\Omega \Rightarrow$ use $R = \mathbf{91\ k\Omega}$ (standard value)

$Q_p \geq 10,\ X_C = X_L = 2000\,\Omega = \dfrac{1}{2\pi f C} = \dfrac{1}{2\pi\left(\dfrac{2\times10^6}{2\pi}\text{ Hz}\right)C}$

$C = 250\text{ pF} \Rightarrow$ use $C = \mathbf{240\ pF}$ (standard value)

18. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(80\,\mu\text{H})(0.03\,\mu\text{F})}} = \mathbf{102.73\ kHz}$

$f_p = f_s\sqrt{1 - \dfrac{R_\ell^2 C}{L}} = 102.73\text{ kHz}\sqrt{1 - \dfrac{(1.5\,\Omega)^2\ 0.03\,\mu\text{F}}{80\,\mu\text{H}}} = 102.73\text{ kHz}(.99958)$

$= \mathbf{102.69\ kHz}$

$f_m = f_s\sqrt{1 - \dfrac{1}{4}\left[\dfrac{R_\ell^2 C}{L}\right]} = 102.73\text{ kHz}(0.99989) = \mathbf{102.72\ kHz}$

Since $f_s \cong f_p \cong f_m \Longrightarrow$ high Q_p

b. $X_L = 2\pi f_p L = 2\pi(102.69\text{ kHz})(80\,\mu\text{H}) = \mathbf{51.62\ \Omega}$

$X_C = \dfrac{1}{2\pi f_p C} = \dfrac{1}{2\pi(102.69\text{ kHz})(0.03\,\mu\text{F})} = \mathbf{51.66\ \Omega}$

$X_L \cong X_C$

c. $Z_{T_p} = R_s \parallel Q_\ell^2 R_\ell$

$$Q_\ell = \frac{X_L}{R_\ell} = \frac{51.62\ \Omega}{1.5\ \Omega} = 34.41$$

$Z_{T_p} = 10\ \text{k}\Omega \parallel (34.41)^2 1.5\ \Omega = 10\ \text{k}\Omega \parallel 1.776\ \text{k}\Omega = \mathbf{1.51\ k\Omega}$

d. $Q_p = \dfrac{R_s \parallel Q_\ell^2 R_\ell}{X_L} = \dfrac{Z_{T_p}}{X_L} = \dfrac{1.51\ \text{k}\Omega}{51.62\ \Omega} = \mathbf{29.25}$

$BW = \dfrac{f_p}{Q_p} = \dfrac{102.69\ \text{kHz}}{29.25} = \mathbf{3.51\ kHz}$

e. Converting the voltage source to a current source:

$I_s = \dfrac{E}{R_s} = \dfrac{100\ \text{V}}{10\ \text{k}\Omega} = 10\ \text{mA}$

And $R_s = R_p = 10\ \text{k}\Omega$

Then $I_T = \dfrac{R_s I_s}{R_s + Q_\ell^2 R_\ell} = \dfrac{10\ \text{k}\Omega(10\ \text{mA})}{10\ \text{k}\Omega + 1.78\ \text{k}\Omega} = 8.49\ \text{mA}$

$I_C = I_L \cong Q_\ell I_T = (34.41)(8.49\ \text{mA}) = \mathbf{292.14\ mA}$

f. $V_C = IZ_{T_p} = (10\ \text{mA})(1.51\ \text{k}\Omega) = \mathbf{15.1\ V}$

19. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(0.5\ \text{mH})(1\ \mu\text{F})}} = \mathbf{7.12\ kHz}$

$f_p = f_s\sqrt{1 - \dfrac{R_\ell^2 C}{L}} = 7.12\ \text{kHz}\sqrt{1 - \dfrac{(8\ \Omega)^2(1\ \mu\text{F})}{0.5\ \text{mH}}} = 7.12\ \text{kHz}(0.9338) = \mathbf{6.65\ kHz}$

$f_m = f_s\sqrt{1 - \dfrac{1}{4}\left[\dfrac{R_\ell^2 C}{L}\right]} = 7.12\ \text{kHz}\sqrt{1 - \dfrac{1}{4}\left[\dfrac{(8\ \Omega)^2(1\ \mu\text{F})}{0.5\ \text{mH}}\right]} = 7.12\ \text{kHz}\ (0.9839)$

$= \mathbf{7.01\ kHz}$

Low Q_p

b. $X_L = 2\pi f_p L = 2\pi(6.647\ \text{kHz})(0.5\ \text{mH}) = 20.88\ \Omega$

$X_C = \dfrac{1}{2\pi f C} = \dfrac{1}{2\pi(6.647\ \text{kHz})(1\ \mu\text{F})} = 23.94\ \Omega$

$X_C > X_L$ (low Q)

c. $Z_{T_p} = R_s \parallel R_p = R_s \parallel \dfrac{R_\ell^2 + X_L^2}{R_\ell} = 500\ \Omega \parallel \dfrac{(8\ \Omega)^2 + (20.88\ \Omega)^2}{8\ \Omega} = 500\ \Omega \parallel 62.5\ \Omega$

$= \mathbf{55.56\ \Omega}$

d. $Q_p = \dfrac{Z_{T_p}}{X_{L_p}} = \dfrac{55.56\ \Omega}{23.94\ \Omega} = \mathbf{2.32}$

$$BW = \frac{f_p}{Q_p} = \frac{6.647 \text{ kHz}}{2.32} = \mathbf{2.87 \text{ kHz}}$$

e. One method: $V_C = IZ_{T_p} = (40 \text{ mA})(55.56\ \Omega) = 2.22 \text{ V}$

$$I_C = \frac{V_C}{X_C} = \frac{2.22 \text{ V}}{23.94\ \Omega} = \mathbf{92.73 \text{ mA}}$$

$$I_L = \frac{|V_C|}{|R_\ell + jX_L|} = \frac{2.22 \text{ V}}{|8 + j20.88|} = \frac{2.22 \text{ V}}{22.36\ \Omega} = \mathbf{99.28 \text{ mA}}$$

f. $V_C = \mathbf{2.22 \text{ V}}$

20. a. $Z_{T_p} = \dfrac{R_\ell^2 + X_L^2}{R_\ell} = 50 \text{ k}\Omega$

$$(50\ \Omega)^2 + X_L^2 = (50 \text{ k}\Omega)(50\ \Omega)$$

$$X_L = \sqrt{250 \times 10^4 - 2.5 \times 10^3} = \mathbf{1580.3\ \Omega}$$

b. $Q = \dfrac{X_L}{R_\ell} = \dfrac{1580.3}{50} = 31.61 \geq 10$

$\therefore X_C = X_L = \mathbf{1580.3\ \Omega}$

c. $X_L = 2\pi f_p L \Rightarrow f_p = \dfrac{X_L}{2\pi L} = \dfrac{1580.3\ \Omega}{2\pi(16 \text{ mH})} = \mathbf{15.72 \text{ kHz}}$

d. $X_C = \dfrac{1}{2\pi f_p C} \Rightarrow C = \dfrac{1}{2\pi f_s X_C} = \dfrac{1}{2\pi(15.72 \text{ kHz})(1580.3\ \Omega)} = \mathbf{6.4 \text{ nF}}$

21. a. $Q_\ell = 20 > 10 \therefore f_p = f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(200 \text{ mH})(10 \text{ nF})}} = \mathbf{3558.81 \text{ Hz}}$

b. $Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{2\pi f L}{R_\ell} \Rightarrow R_\ell = \dfrac{2\pi f L}{Q_\ell} = \dfrac{2\pi(3558.81 \text{ Hz})(0.2 \text{ H})}{20} = 223.61\ \Omega$

$Z_{T_p} = R_s \parallel R_p = R_s \parallel Q_\ell^2 R_\ell = 40 \text{ k}\Omega \parallel (20)^2\, 223.61\ \Omega$

$Z_{T_p} = 27.64 \text{ k}\Omega$

Converting the voltage source to a current source:

$I_s = \dfrac{E}{R_s} = \dfrac{200 \text{ V}}{40 \text{ k}\Omega} = 5 \text{ mA}$

$R_p = R_s = 40 \text{ k}\Omega$

$V_C = IZ_{T_p} = (5 \text{ mA})(27.64 \text{ k}\Omega) = \mathbf{138.2 \text{ V}}$

c. $P = I^2R = (5\text{ mA})^2 27.64\text{ k}\Omega = \mathbf{691\ mW}$

d. $Q_p = \dfrac{R}{X_L} = \dfrac{R_s \parallel R_p}{X_L} = \dfrac{27.64\text{ k}\Omega}{2\pi(3558.81\text{ Hz})(0.2\text{ H})} = \mathbf{6.18}$

$BW = \dfrac{f_p}{Q_p} = \dfrac{3558.81\text{ Hz}}{6.18} = \mathbf{575.86\ Hz}$

22. a. Ratio of X_C to R_ℓ suggests high Q system.
$\therefore X_L = \mathbf{400\ \Omega} = X_C$

b. $Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{400\,\Omega}{8\,\Omega} = \mathbf{50}$

c. $Q_p = \dfrac{R}{X_L} = \dfrac{R_s \parallel R_p}{X_L} = \dfrac{R_s \parallel Q_\ell^2 R_\ell}{X_L} = \dfrac{20\text{ k}\Omega \parallel (50)^2\, 8\,\Omega}{400\,\Omega} = \dfrac{10\text{ k}\Omega}{400\,\Omega} = \mathbf{25}$

$BW = \dfrac{f_p}{Q_p} \Rightarrow f_p = Q_p BW = (25)(1000\text{ Hz}) = \mathbf{25\ kHz}$

d. $V_{C_{\max}} = IZ_{T_p} = (0.1\text{ mA})(10\text{ k}\Omega) = \mathbf{1\ V}$

e. $f_2 = f_p + BW/2 = 25\text{ kHz} + \dfrac{1\text{ kHz}}{2} = \mathbf{25.5\ kHz}$

$f_1 = f_p - BW/2 = 25\text{ kHz} - \dfrac{1\text{ kHz}}{2} = \mathbf{24.5\ kHz}$

23. a. $X_C = \dfrac{R_\ell^2 + X_L^2}{X_L} \Rightarrow X_L^2 - X_L X_C + R_\ell^2 = 0$

$$X_L^2 - 100\, X_L + 144 = 0$$

$$X_L = \frac{-(-100) \pm \sqrt{(100)^2 - 4(1)(144)}}{2}$$

$$= 50\,\Omega \pm \frac{\sqrt{10^4 - 576}}{2} = 50\,\Omega \pm 48.54\,\Omega$$

$X_L = \mathbf{98.54\ \Omega}$ or ~~1.46 Ω~~

b. $Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{98.54\,\Omega}{12\,\Omega} = \mathbf{8.21}$

c. $Q_p = \dfrac{R_s \parallel R_p}{X_{L_p}} = \dfrac{40\text{ k}\Omega \parallel \dfrac{R_\ell^2 + X_L^2}{R_\ell}}{X_C} = \dfrac{40\text{ k}\Omega \parallel \dfrac{(12\,\Omega)^2 + (98.54\,\Omega)^2}{12\,\Omega}}{100\,\Omega}$

$= \dfrac{40\text{ k}\Omega \parallel 821.18\,\Omega}{100\,\Omega} = \dfrac{804.66\,\Omega}{100\,\Omega} = \mathbf{8.05}$

$BW = f_p/Q_p \Rightarrow f_p = Q_p BW = (8.05)(1\text{ kHz}) = \mathbf{8.05\ kHz}$

d. $V_{C_{max}} = IZ_{T_p} = (6\text{ mA})(804.66\ \Omega) = \mathbf{4.83\ V}$

e. $f_2 = f_p + BW/2 = 8.05\text{ kHz} + \dfrac{1\text{ kHz}}{2} = \mathbf{8.55\ kHz}$

$f_1 = f_p - BW/2 = 8.05\text{ kHz} - \dfrac{1\text{ kHz}}{2} = \mathbf{7.55\ kHz}$

24. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(0.5\text{ mH})(30\text{ nF})}} = \mathbf{41.09\ kHz}$

$f_p = f_s\sqrt{1-\dfrac{R_\ell^2 C}{L}} = 41.09\text{ kHz}\sqrt{1-\dfrac{(6\ \Omega)^2\ 30\text{ nF}}{0.5\text{ mH}}} = 41.09\text{ kHz}(0.9978) = \mathbf{41\ kHz}$

$f_m = f_s\sqrt{1-\dfrac{1}{4}\left[\dfrac{R_\ell^2 C}{L}\right]} = 41.09\text{ kHz}\sqrt{1-\dfrac{1}{4}\left[\dfrac{(6\ \Omega)^2(30\text{ nF})}{0.5\text{ mH}}\right]} = 41.09\text{ kHz}(0.0995)$

$= \mathbf{41.07\ kHz}$

High Q_p

b. $\mathbf{I} = \dfrac{80\text{ V}\angle 0°}{20\text{ k}\Omega\angle 0°} = 4\text{ mA}\angle 0°,\ R_s = 20\text{ k}\Omega$

$Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{2\pi fL}{R_\ell} = \dfrac{2\pi(41\text{ kHz})(0.5\text{ mH})}{6\ \Omega} = \mathbf{21.47}$ (high Q coil)

$$Q_p = \frac{R_s \parallel R_p}{X_{L_p}} = \frac{R_s \parallel \dfrac{R_\ell^2 + X_L^2}{R_\ell}}{\dfrac{R_\ell^2 + X_L^2}{X_L}} = \frac{20\text{ k}\Omega \parallel \dfrac{(6\ \Omega)^2 + (128.81\ \Omega)^2}{6\ \Omega}}{\dfrac{(6\ \Omega)^2 + (128.81\ \Omega)^2}{128.81\ \Omega}}$$

$= \dfrac{20\text{ k}\Omega \parallel 2.771\text{ k}\Omega}{129.09\ \Omega} = \dfrac{2.434\text{ k}\Omega}{129.09\ \Omega} = \mathbf{18.86}$ **(high** $\boldsymbol{Q_p}$**)**

c. $Z_{T_p} = R_s \parallel R_p = 20\text{ k}\Omega \parallel 2.771\text{ k}\Omega = \mathbf{2.43\ k\Omega}$

d. $V_C = IZ_{T_p} = (4\text{ mA})(2.43\text{ k}\Omega) = \mathbf{9.74\ V}$

e. $BW = \dfrac{f_p}{Q_p} = \dfrac{41\text{ kHz}}{18.86} = \mathbf{2.17\ kHz}$

f. $X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(41\text{ kHz})(30\text{ nF})} = \mathbf{129.39\ \Omega}$

$I_C = \dfrac{V_C}{X_C} = \dfrac{9.736\text{ V}}{129.39\ \Omega} = \mathbf{75.25\ mA}$

$I_L = \dfrac{V_C}{|R + jX_L|} = \dfrac{9.736\text{ V}}{6\ \Omega + j128.81\ \Omega} = \dfrac{9.736\text{ V}}{128.95\ \Omega} = \mathbf{75.50\ mA}$

25. $Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{2\pi f_p L}{R_\ell} \Rightarrow R_\ell = \dfrac{2\pi f_p L}{Q_\ell} = \dfrac{2\pi(20\text{ kHz})(2\text{ mH})}{80} = \mathbf{3.14\ \Omega}$

$BW = f_p/Q_p \Rightarrow Q_p = f_p/BW = 20\text{ kHz}/1.8\text{ kHz} = \mathbf{11.11}$

High $Q \therefore$ $f_p \cong f_s = \dfrac{1}{2\pi\sqrt{LC}} \Rightarrow C = \dfrac{1}{4\pi^2 f_p^2 L} = \dfrac{1}{4\pi^2(20\text{ kHz})^2\ 2\text{ mH}} = \mathbf{31.66\ nF}$

$Q_p = \dfrac{R}{X_C} \Rightarrow R = Q_p X_C = \dfrac{Q_p}{2\pi f_p C} = \dfrac{11.11}{2\pi(20\text{ kHz})(31.66\text{ nF})} = \mathbf{2.79\ k\Omega}$

$R_p = Q_\ell^2 R_\ell = (80)^2\ 3.14\ \Omega = 20.1\text{ k}\Omega$

$R = R_s \parallel R_p = \dfrac{R_s R_p}{R_s + R_p} \Rightarrow R_s = \dfrac{R_p R}{R_p - R} = \dfrac{(20.1\text{ k}\Omega)(2.793\text{ k}\Omega)}{20.1\text{ k}\Omega - 2.793\text{ k}} = \mathbf{3.24\ k\Omega}$

26. $V_{C_{\max}} = IZ_{T_p} \Rightarrow Z_{T_p} = \dfrac{V_{C_{\max}}}{I} = \dfrac{1.8\text{ V}}{0.2\text{ mA}} = 9\text{ k}\Omega$

$Q_p = \dfrac{R}{X_L} = \dfrac{R_s \parallel R_p}{X_L} = \dfrac{R_p}{X_L} \Rightarrow X_L = \dfrac{R_p}{Q_p} = \dfrac{9\text{ k}\Omega}{30} = \mathbf{300\ \Omega} = X_C$

$BW = \dfrac{f_p}{Q_p} \Rightarrow f_p = Q_p BW = (30)(500\text{ Hz}) = \mathbf{15\ kHz}$

$L = \dfrac{X_L}{2\pi f} = \dfrac{300\ \Omega}{2\pi(15\text{ kHz})} = \mathbf{3.18\ mH}$

$C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{2\pi(15\text{ kHz})(300\ \Omega)} = \mathbf{35.37\ nF}$

$Q_p = Q_\ell\ (R_s = \infty\ \Omega) = \dfrac{X_L}{R_\ell} \Rightarrow R_\ell = \dfrac{X_L}{Q_p} = \dfrac{300\ \Omega}{30} = \mathbf{10\ \Omega}$

27. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(200\ \mu\text{H})(2\text{ nF})}} = 251.65\text{ kHz}$

$Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{2\pi(251.65\text{ kHz})(200\ \mu\text{H})}{20\ \Omega} = 15.81 \geq 10$

$\therefore f_p = f_s = \mathbf{251.65\ kHz}$

b. $Z_{T_p} = R_s \parallel Q_\ell^2 R_\ell = 40\text{ k}\Omega \parallel (15.81)^2\ 20\ \Omega = \mathbf{4.44\ k\Omega}$

c. $Q_p = \dfrac{R_s \parallel Q_\ell^2 R_\ell}{X_L} = \dfrac{4.444\text{ k}\Omega}{316.23\ \Omega} = \mathbf{14.05}$

d. $BW = \dfrac{f_p}{Q_p} = \dfrac{251.65\text{ kHz}}{14.05} = \mathbf{17.91\ kHz}$

e. **20 μH, 20 nF**

f_s the same since product LC the same

f_s = 251.65 kHz

$$Q_\ell = \frac{X_L}{R_\ell} = \frac{2\pi(251.65\text{ kHz})(20\,\mu\text{H})}{20\,\Omega} = 1.581$$

Low Q_ℓ:

$$f_p = f_s\sqrt{1-\frac{R_\ell^2 C}{L}} = (251.65\text{ kHz})\sqrt{1-\frac{(20\,\Omega)^2(20\text{ nF})}{20\,\mu\text{H}}}$$

$= (251.65\text{ kHz})(0.775) =$ **194.93 kHz**

$X_L = 2\pi f_p L = 2\pi(194.93\text{ kHz})(20\,\mu\text{H}) = 24.496\,\Omega$

$$R_p = \frac{R_\ell^2 + X_L^2}{R_\ell} = \frac{(20\,\Omega)^2 + (24.496\,\Omega)^2}{20\,\Omega} = 50\,\Omega$$

$Z_{T_p} = R_s \parallel R_p = 40\text{ k}\Omega \parallel 50\,\Omega = \mathbf{49.94\,\Omega}$

$$Q_p = \frac{R}{X_L} = \frac{49.94\,\Omega}{24.496\,\Omega} = \mathbf{2.04}$$

$$BW = \frac{f_p}{Q_p} = \frac{194.93\text{ kHz}}{2.04} = \mathbf{95.55\text{ kHz}}$$

f. **0.4 mH, 1 nF**

f_s = 251.65 kHz since LC product the same

$$Q_\ell = \frac{X_L}{R_\ell} = \frac{2\pi(251.65\text{ kHz})(0.4\text{ mH})}{20\,\Omega} = 31.62 \geq 10$$

$\therefore f_p = f_s =$ **251.65 kHz**

$Z_{T_p} = R_s \parallel Q_\ell^2 R_\ell = 40\text{ k}\Omega \parallel (31.62)^2\, 20\,\Omega = 40\text{ k}\Omega \parallel (\cong 20\text{ k}\Omega) \cong \mathbf{13.33\text{ k}\Omega}$

$$Q_p = \frac{R_s \parallel Q_\ell^2 R_\ell}{X_L} = \frac{13.33\text{ k}\Omega}{632.47\,\Omega} = \mathbf{21.08}$$

$$BW = \frac{f_p}{Q_p} = \frac{251.65\text{ kHz}}{21.08} = \mathbf{11.94\text{ kHz}}$$

g. Network $\dfrac{L}{C} = \dfrac{200\,\mu\text{H}}{2\text{ nF}} = \mathbf{100 \times 10^3}$

part (e) $\dfrac{L}{C} = \dfrac{20\,\mu\text{H}}{20\text{ nF}} = \mathbf{1 \times 10^3}$

part (f) $\dfrac{L}{C} = \dfrac{0.4\text{ mH}}{1\text{ nF}} = \mathbf{400 \times 10^3}$

h. Yes, as $\dfrac{L}{C}$ ratio increased BW decreased.

Also, $V_p = IZ_{T_p}$ and for a fixed I, Z_{T_p} and therefore V_p will increase with increase in the L/C ratio.