CAIRO UNIVERSITY FACULTY OF ENGINEERING		ELECTRONICS AND COMMUNICATION DEPT. 2^{nd} Year
Parallel Resonance	*ELECTRIC CIRUITS*	*Sheet (3)*

[1]A parallel resonance circuit consists of 1 mH inductance having $Q = 30$ (at resonance) in parallel with a condenser of 1000 pF . Calculate the resonance frequency and plot the magnitude and phase of the normalized impedance of the circuit near resonance ($\delta = \pm 1\%$, $\pm 2\%$, … … … , $\pm 5\%$) .

[2]For the resonance circuit shown in Fig. 1 , find:

a)The value of X_C at resonance .

b) The total impedance at resonance .

c)The currents I_L and I_C at resonance and at a frequency 8% below resonance .

d)If the resonance frequency is 20 KHz . find the value of L and C .

e)The quality factor of the circuit Q_P and the bandwidth B.W.

[3]If it is required that the impedance Z_T of the circuit shown in Fig. 2 be a resistor of 50 KΩ at resonance :

a) Find the value of X_L and X_C .

b)Calculate the resonance frequency if L = 16 mH .

c)Find the value of C in μF .

Fig.1

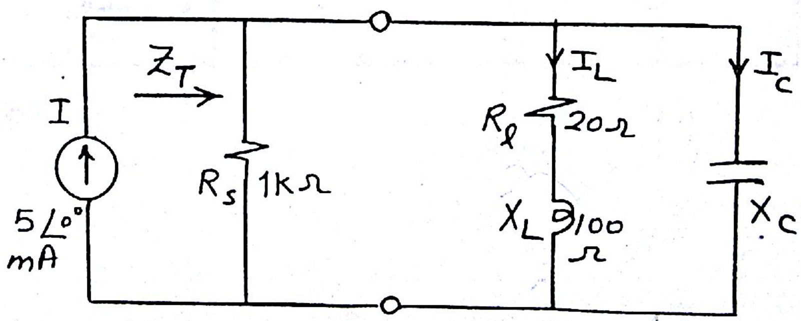
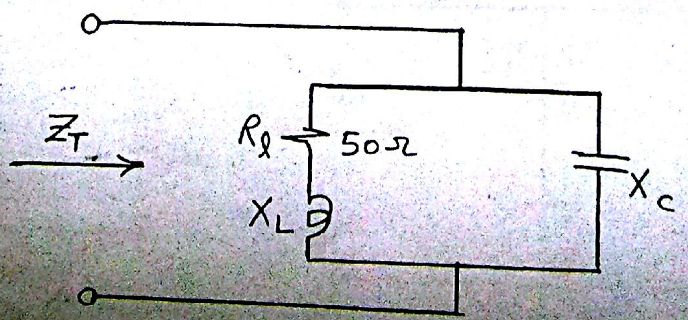


Fig.2



[4]For the circuit shown in Fig. 3 , find f_P and the voltage V_C at resonance and calculate the power absorbed from the source at resonance and the Bandwidth .

[5]For the circuit shown in Fig. 4 , the following specifications are given :
$f_P = 100$ KHz , B.W. =2500Hz , L =2 mH , Q = 80 . Find R_l ,R_S and C .

[6]For the circuit shown in Fig. 5 , find :

a) The value of X_L at resonance .

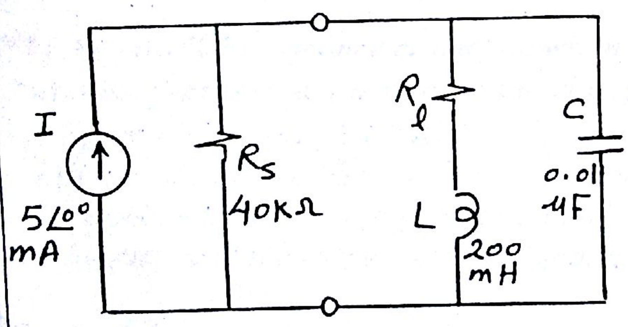
b) Q of the coil at resonance .

c) The resonance frequency if the B.W. is 1000 Hz .

d) The maximum value of the voltage V_C .

e) Sketch the curve of V_C versus frequency indicating the amplitudes at resonance and the cutoff frequencies .

[7]For the circuit shown in Fig. 6 , find the resonance frequency (for which Z_{in} is real).
What are the conditions on r_1 and r_2 to produce resonance ?



Q = 20

Fig.3

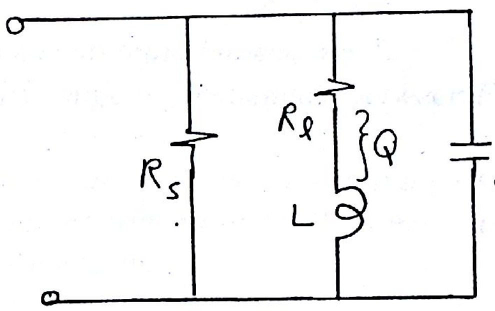


Fig.4

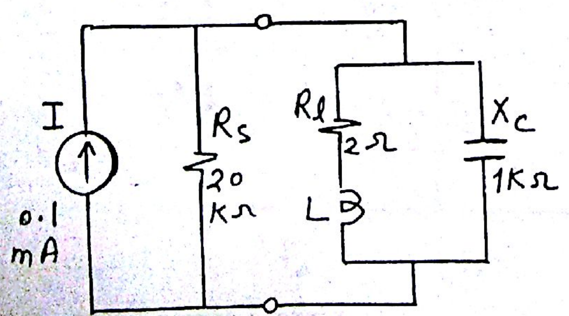


Fig.5

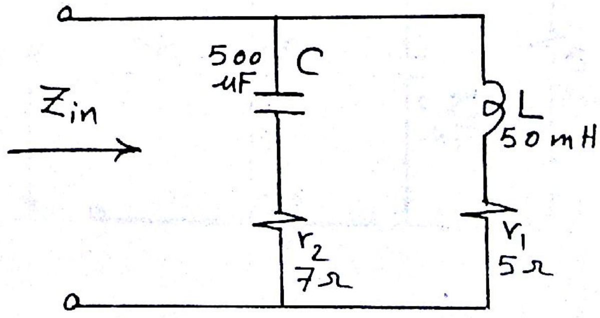


Fig.6

[8] A parallel resonance circuit has L= 159 μH and Q = 50 at resonance, and C =636 pF. Draw its all parallel circuit. If the circuit is operated from a current source having a resistance of 10 KΩ, calculate the quality factor of the circuit Q_P.

[9] a) Design the circuit elements of a parallel resonance circuit such that the input impedance to the circuit has a maximum value of 20 KΩ, its resonance frequency is 100 K rad./sec. and the quality factor of the coil at resonance is 20.

b) If a current source of 10 mA and internal resistance 20 KΩ is applied to the parallel resonance circuit designed in a), make the necessary derivations to sketch the magnitude of the voltage across the circuit in volts against frequency in Hz indicating the amplitudes at resonance and the cutoff frequencies.

c) Calculate the average power delivered to the circuit at a frequency 10 % below resonance.

Final 2010

[10] For the parallel resonance circuit shown in Fig.7, calculate:

a) The current in the capacitor C at a frequency 20 KHz.

b) The range of frequencies for which $|V_P| \leq 0.75\ V_{P\ maximum}$.

c) The additional parallel resistance required to change the Bandwidth of the output voltage signal to 6 KHz.

[11] The parallel resonance circuit shown in Fig.8 has an input impedance Z_{in}:

a) Make the necessary derivations to calculate the range of frequencies between F_a and F_b for which $|Z_{in}| \geq 1.5$ KΩ.

b) If the circuit is fed from a current source of 10 mA and an internal resistance 10 KΩ, calculate the circulating currents in the coil and the condenser at the upper cutoff frequency of the output voltage signal across the circuit.

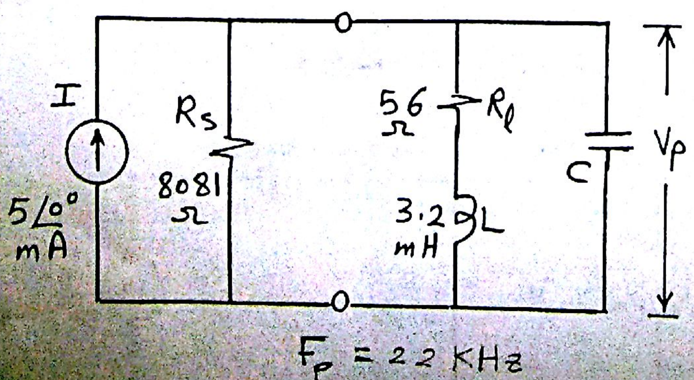


Fig.7

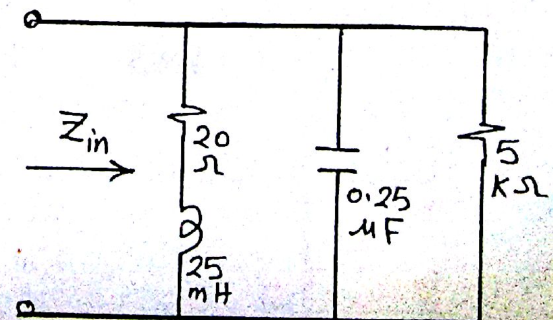
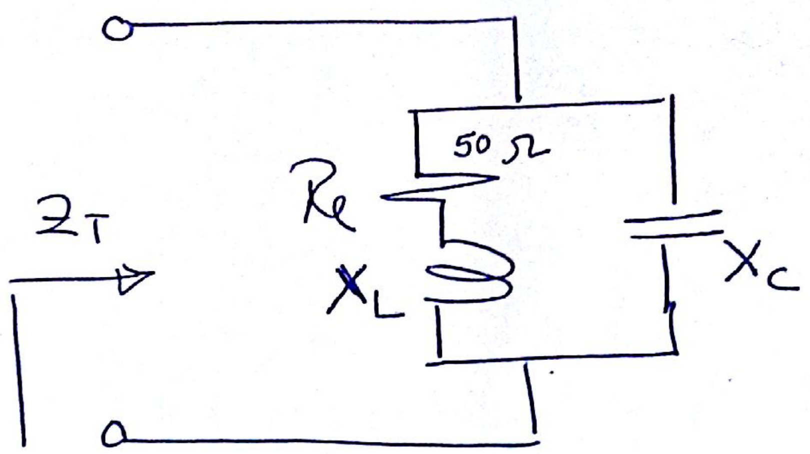


Fig.8

$\boxed{3}$



Required Z_T to be resister → ∴ At Resonance

a) ∴ $Z_T = R_{tot} = R_p = \dfrac{Re^2 + x_L^2}{Re}$ → $\boxed{X_L = 1580.348\ \Omega}$

Z_T ↓ 50 kΩ

Re ↙ 50 Ω

& $X_C = X_{Lp} = \dfrac{Re^2 + X_L^2}{X_L} = 1581.93\ \Omega$

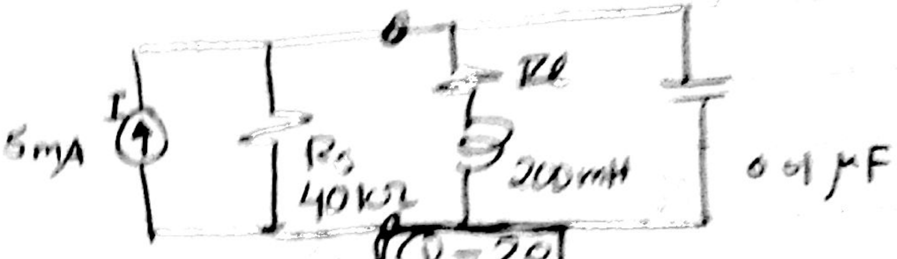
or $Q_{coil\ res.} = X_L / Re = 31.6 > 10 \rightarrow X_C = X_{Lp} \approx X_L = 1580.348\ \Omega$

b) $X_L = \omega_p L \Rightarrow \omega_p = \dfrac{X_L}{L} = \dfrac{1580.348}{16 * 10^{-3}} \approx 98771.75$ r/s

c) $\omega_p \approx \dfrac{1}{\sqrt{LC}} \rightarrow C = 6.4\ nF$

Due to high quality coil

(4)



$\boxed{Q=20}$

Required: f_p , $V_C|_{@\,Res.}$, $P_{Source\,@\,res}$, BW

Soln.

$Q = 20 > 10$ → Remember, if Q is given without any subscript, it is Q_{coil} @ Resonance.

$$f_p = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{200\times10^{-3}\times0.01\times10^{-6}}}$$

$$\approx 3.558 \text{ KHz}$$

$$V_C = V_{P_{res.}} = I\, Z_{Tp}$$

$$= I\,(R_s \parallel R_p)$$

$$= I\left(R_s \parallel \frac{R_l^2 + X_L^2}{R_l}\right)$$

$$Q = \frac{X_L}{R_l}$$

$$R_l = \frac{X_L}{Q} = \frac{2\pi f_p L}{Q} \cong 223.6\ \Omega$$

$$= (5\,mA)(40k\Omega \parallel 89.669\,k\Omega)$$

$$\approx \underline{\underline{138.3\ V}}$$

$$P_{Source} = P_{diss} = \frac{V_{P_{res}}^2}{R_{tot}} = \frac{(138.3)^2}{27660.9\ \Omega} \cong 0.691 \text{ Watts}$$

$$\cong P_{source} = |I|\,|V_p|\cos\theta = 5mA * 138.3^V * (\cos 0) = 0.69 \text{ Watts}$$

$BW = \omega_P / Q_P$

$2 = \omega_P C R$

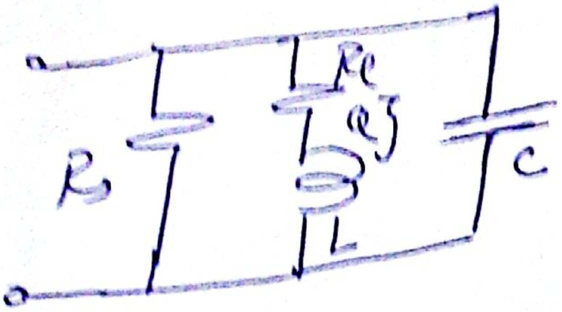
$= \omega_P / \omega_P C R = \frac{1}{CR}$

$= \frac{1}{0.01 \times 10^{-6} \times 27.66 \times 10^{3}}$

≈ 3615.32 r/s

≈ 575.39 Hz.

5



$f_p = 100\ KHz$

$B_w = 2500\ Hz$

$L = 2\ mH$

$Q = 80$

Required Rl, Ro and C

$\rightarrow Q = 80 > 10 \rightarrow L_p \approx L$

$Q_p = f_p / B_w = 10^5 / 2500 = 40 > 10$

$= R / X_L = \dfrac{R}{w_p L}$

$\therefore R = w_p L Q_p = 2\pi * 10^5 * 2 * 10^{-3} * 40 \simeq 50.265\ k\Omega$

also, $Q = \dfrac{w_p L}{R_l} = 80$

$R_l = \dfrac{w_p L}{Q} = \dfrac{2\pi * 10^5 * 2 * 10^{-3}}{80} \approx 15.7\ \Omega$

& $\underset{50.265\ k\Omega}{R} = \underset{100.48\ k\Omega}{R_p} \,//\, R_o$

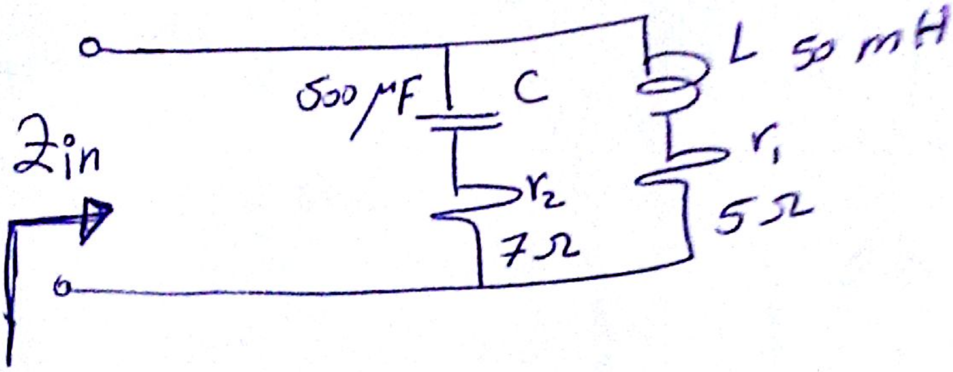
$\left\{ R_p = \dfrac{X_L^2 + R_l^2}{R_l} \approx Q^2 R_l \approx 100.48\ k\Omega \right.$

Get $R_o = 100.58\ k\Omega$

Also, $Q_p = R / X_c = \overset{2\pi * 10^5}{w_p} C \underset{50.265\ k\Omega}{R} = 40 \rightarrow$ Get $C = 1.2665\ nF$

or $f_p = \dfrac{1}{2\pi\sqrt{LC}} \rightarrow$ get C

7



$$Y_{in} = \frac{1}{jωL + r_1} + \frac{1}{\frac{1}{jωC} + r_2}$$

$$= \frac{1}{r_1 + jωL} + \frac{jωC}{1 + jωCr_2}$$

$$= \frac{r_1 - jωL}{r_1^2 + ω^2L^2} + \frac{jωC(1 - jr_2ωC)}{1 + ω^2C^2r_2^2}$$

@ Resonance $\quad Im(Y_{in}) = 0$

$$\therefore \quad \frac{-ω_pL}{r_1^2 + ω_p^2L^2} + \frac{ω_pC}{1 + ω_p^2C^2r_2^2} = 0$$

$$r_1^2C + ω_p^2L^2C = L + ω_p^2C^2r_2^2L$$

$$ω_p^2\left(LC(L - r_2^2C)\right) = L - r_1^2C$$

$$\boxed{ω_p = \sqrt{\frac{L - r_1^2C}{LC(L - r_2^2C)}}}$$

for $ω_p$ to be > 0

Denominator & Numerator must be +ve together or -ve together.

+ve

$L - r_1^2 C > 0$

$\frac{L}{C} > r_1^2$

$\boxed{r_1 < \sqrt{\frac{L}{C}}}$

& 4 and

$L - r_2^2 C > 0$

$\boxed{r_2 < \sqrt{\frac{L}{C}}}$

$r_1 \,\&\, r_2 < \sqrt{\frac{L}{C}}$

$\boxed{r_1 \,\&\, r_2 < 10\,\Omega}$

-ve

$L - r_1^2 C < 0$

$\boxed{r_1 > \sqrt{\frac{L}{C}}}$

& $L - r_2^2 C < 0$

$\boxed{r_2 > \sqrt{\frac{L}{C}}}$

$r_1 \,\&\, r_2 > \sqrt{L/C}$

$r_1 \,\&\, r_2 > 10\,\Omega$

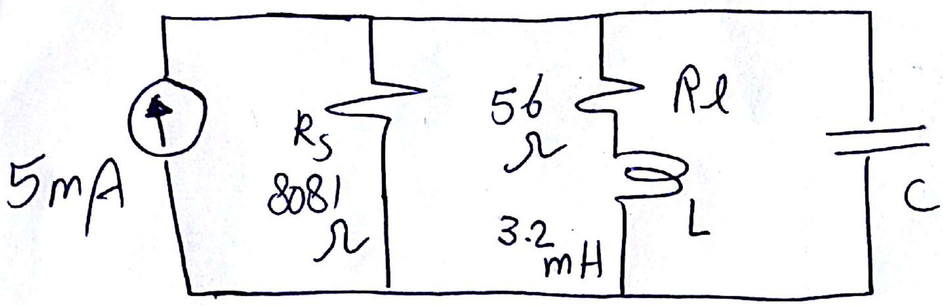
For the given values,

$$w_p = \sqrt{\frac{50\times10^{-3} - (25)(500\times10^{-6})}{50\times10^{-3}\times500\times10^{-6}\,(50\times10^{-3} - (49)(500\times10^{-6}))}}$$

$= \underline{242.535 \text{ rad/sec}}$

Good Luck

(10)



$F_p = 22\ \text{KHz}$

(a) to get I_c @ $f = 20\ \text{KHz}$ $\longrightarrow I_c = \dfrac{V_p}{-jX_c}$ $\rightarrow$ we need to get V_p & X_c

& $V_p = \dfrac{V_{pres}}{1+jQ_p\Omega}$ $\longrightarrow$ we need to get V_{pres}, Q_p & Ω

$$\Omega = f/f_p - f_p/f = \frac{20}{22} - \frac{22}{20} = \frac{-21}{110}$$

$$R_p = \frac{X_L^2 + R_\ell^2}{X_L} = 3549.94\ \Omega$$

$$Q_p = \frac{R_{tot}}{X_{Lp}} = \frac{\underbrace{(8081 // 3549.94)}_{\approx 2466.4\ \Omega}}{449.426} \approx 5.487$$

Then, $V_{p_{res}} = I\,Z_{T_p} = I\,R_{tot} = 5 * 10^{-3} * 2466.4$

$\approx \underline{12.332}$ volts

$X_L = W_pL$
$= 2\pi * 22000 * 3.2 * 10^{-3}$
$\approx 442.336\ \Omega$

$Q = \dfrac{W_pL}{R_\ell} = 7.89 < 10$

$X_{Lp} = X_c\big|_{res.} = \dfrac{R_\ell^2 + X_L^2}{X_L}$
$= 449.426\ \Omega$

Then, $V_p = \dfrac{V_{pres}}{1+jQ_p\Omega} = \dfrac{12.332}{1 - j\frac{21}{110}(5.487)} \approx 8.5153 \angle 46.329^\circ$ volts

$\therefore I_C = \dfrac{V_P}{-jX_C|_{f=20kHz}}$

$= \dfrac{8.5153 \angle 46.329}{-j * 494.36}$

$\approx 17.22 \angle 136.3^\circ$ mA

let $X_C|_{f=20kHz} = X_C'$

$X_C' = \dfrac{1}{\omega' C}$

$= \dfrac{\omega_P}{\omega' (\omega_P C)} X_C|_{res}$

$= \dfrac{2\pi * 22}{2\pi * 20} * 449.4$

$= 494.36 \ \Omega$

(or) You can get C

$X_C|_{res} = \dfrac{1}{\omega_P C}$

$C = 16.09 \text{ nF}$

$\therefore X_C' = \dfrac{1}{\omega' C}$

$\omega' = 2\pi * 20000$

$= 494.36 \ \Omega$

(b) $|V_P| \leq 0.75 \ V_{P maximum}$. Required range of frequencies ?!

$\Rightarrow V_{P maximum} = V_{P resonance}$

$\Rightarrow \therefore \dfrac{|V_P|}{V_{P res}} \leq 0.75$

$\dfrac{1}{\sqrt{1+Q_P^2 \Omega^2}} \leq 0.75$

$\therefore \quad 1 + Q_p^2 \Omega^2 \geq \frac{16}{9}$

$$\Omega^2 \geq \frac{\frac{16}{9} - 1}{Q_p^2} = \frac{7/9}{Q_p^2}$$

$$Q_p^2 \rightarrow (5.487)^2$$

$$\Omega^2 \geq 0.025833$$

$$\Omega \geq \pm\ 0.1606991807$$

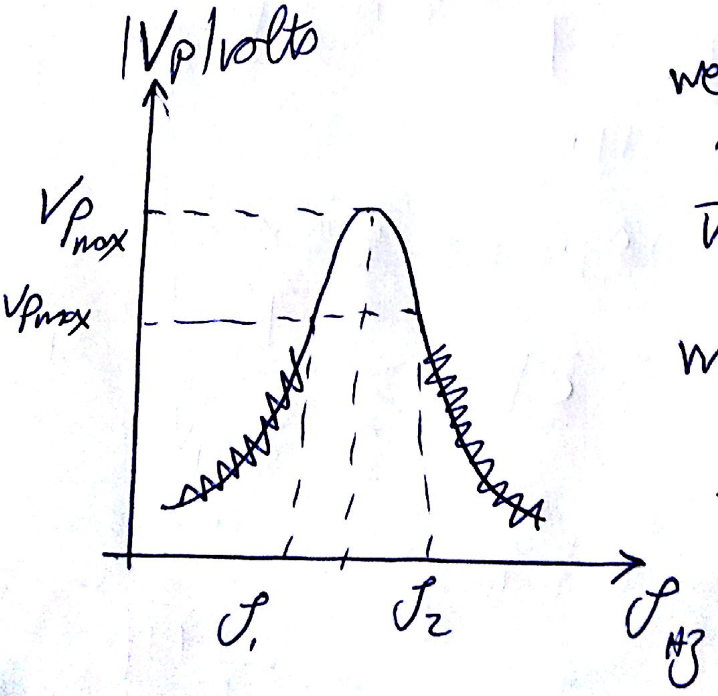
$$f/f_p - f_p/f \geq \pm\ 0.1606$$

$$f^2 \mp f(3535.38) - 484 \times 10^6 \geq 0$$

$$\rightarrow f^2 \mp f(3535.38) - 484 \times 10^6 = 0$$

$\rightarrow$ solve $f_1 = 20.3$ KHz

$f_2 = 23.83$ KHz



we need the range at which

$$\frac{V_p}{V_{P_{max}}} \leq (3/4)$$

which is the range below f_1 & above f_2

Range: $f < 20.3$ KHz

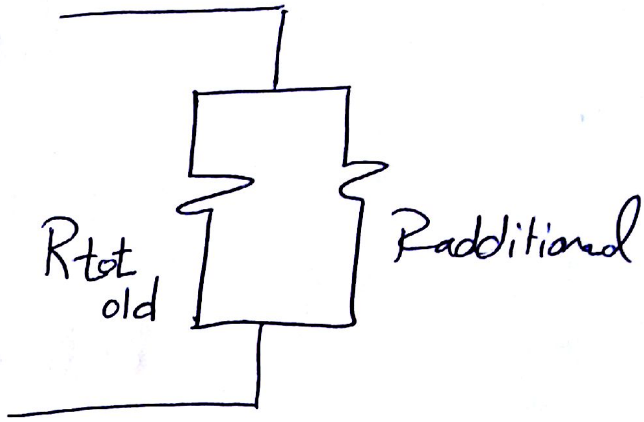
& $f > 23.83$ KHz

(c) Required $BW = 6\,KHz = 6000\ Hz$

$$BW = f_p / Q_p$$

$$6000 = \frac{22000}{Q_p'}$$

$$Q_p' = \frac{22}{6}$$



@ Resonance

$$Q_p' = \frac{R_{tot}'}{X_{Lp}}$$

$$\frac{22}{6} = \frac{R_{tot_{old}} \,//\, R_{add.}}{X_{Lp}}$$

$X_{Lp} \rightarrow 449.426\ \Omega$

$$R_{tot_{old}} // R_{add.} = 1647.89\ \Omega$$

$$\frac{1}{R_{tot_{old}}} + \frac{1}{R_{add.}} = \frac{1}{1647.89}$$

$R_{tot_{old}} \rightarrow 2466.4\ \Omega$

$$R_{add.} = 4.965\ k\Omega$$

(9) a) Design Parallel Resonance circuit such that

1] $Z_T|_{max} = 20\,k\Omega$

2] $\omega_p = 100\ Kr/s$

3] $Q = 20 > 10 \rightarrow X_{Lp} \approx X_L$ "$L_p \approx L$"

$$\Rightarrow \quad Z_T|_{max} = Z_{Tp} = R_{tot} = R_p \cong Q^2 R_e$$

$$R_e = \frac{20\,000}{(20)^2} = \underline{\underline{50\ \Omega}}$$

$$Q = \frac{X_L}{R_e} \longrightarrow X_L = Q R_e = (50)(20) = \underline{\underline{1000\ \Omega}}$$

$$= X_C$$

$$\Downarrow$$

$$\omega_p L = 1000 \rightarrow L = 10\ mH$$

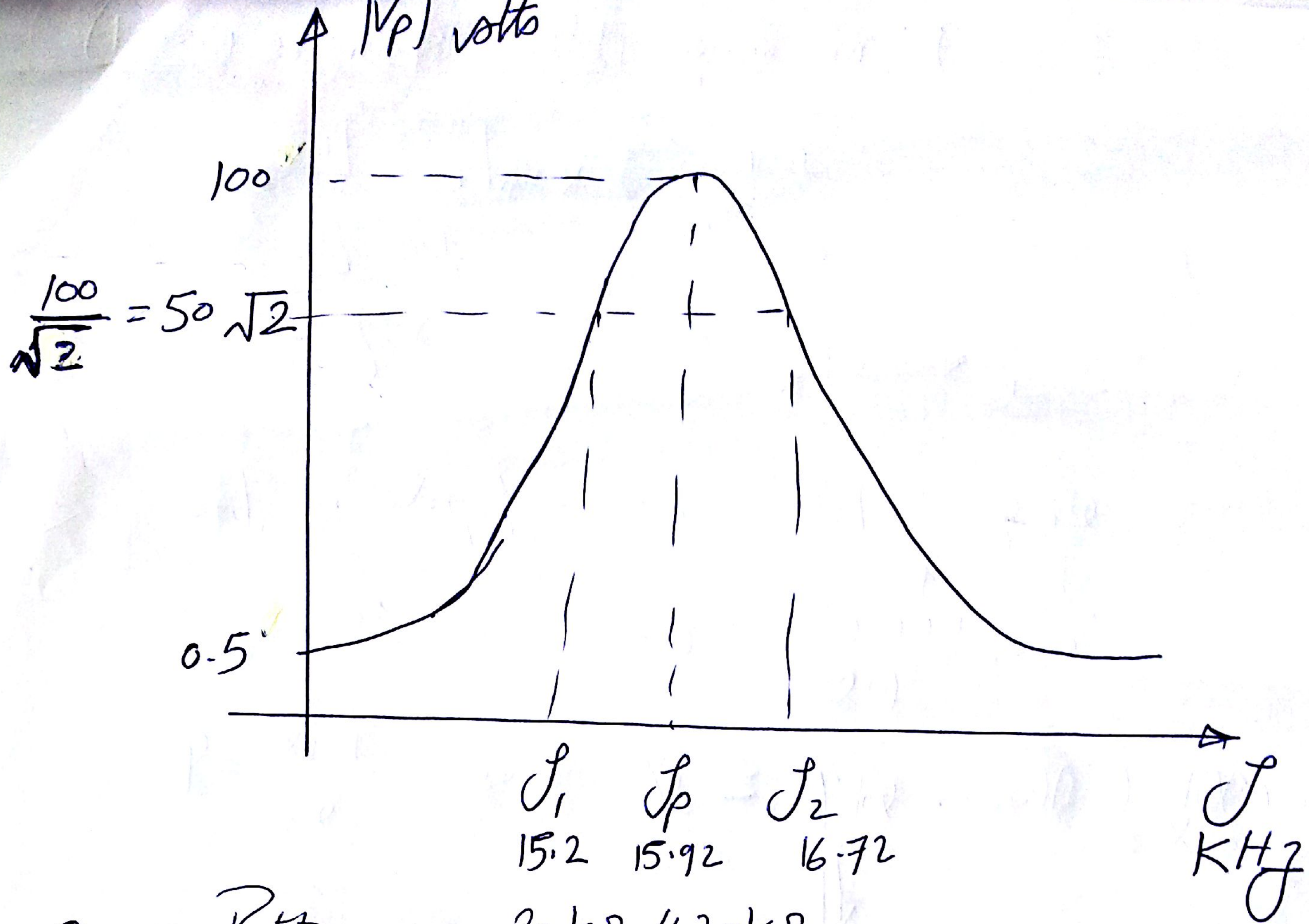
$$\frac{1}{\omega_p C} = 1000 \rightarrow C = 10\ nF$$

(b) $I_s = 10\,mA$, $R_s = 20\,k\Omega$

{make Derivations as in lecture} to get $\left(V_p = \frac{V_{p\,res}}{1 + jQ_p\Omega}\right)$

$$V_{p\,res} = V_{p\,max} = I_s Z_{T_p} = 10\,mA * (20\,k\Omega // 20\,k\Omega) = 100^V$$

$$V_p\Big|_{f=0} = IR' = I(R_s // \underset{\substack{\downarrow \\ R_p = R_e}}{R_e}) \cong 0.5^V$$



$$Q_p = \frac{R_{tt}}{X_{Lp} \approx X_L} = \frac{20k\Omega // 20k\Omega}{1000} = 10$$

$$BW = f_p / Q_p = \frac{(100 * 10^3)/2\pi}{10} = 1591.55\ Hz$$

$$f_{1,2} = f_p \mp \frac{BW}{2} = 15.2\ kHz,\ 16.72\ kHz$$

$$\rightarrow f_p = \omega_p / 2\pi = 15.92\ kHz$$

(c)

$$P_{delivered} = \frac{|V_p|^2}{R_{tot.}}$$

$$V_p\Big|_{\substack{10\% \\ below\ res.}} = \frac{V_p|_{res.}}{1+jQ_p\Omega}$$

$$= \frac{I R_{tot.}}{1+jQ_p\Omega}$$

$$\Omega = 0.9 - \frac{1}{0.9} = -0.21$$

$$= 42.8\angle 64.65^\circ \ V$$

$$Q_p = 10$$

$$P_{tot} = \frac{42.8^2}{(20k\Omega // 20k\Omega)} = \boxed{0.18326 \text{ Watts}}$$

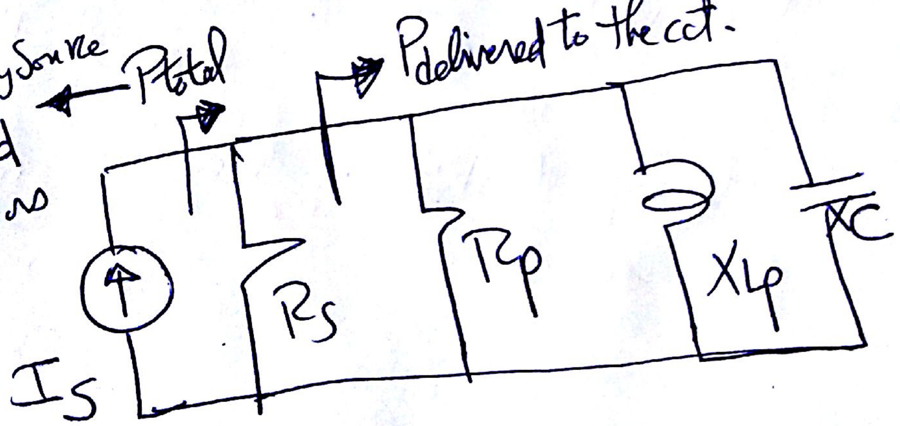
But, $P_{\substack{delivered \\ to\ the\ cct.}} = P_{R_p} = \frac{|V_p|^2}{R_p}$

$$= \frac{42.8^2}{20k\Omega} = 0.091592 \ W$$

$$= 91.592 \ mW$$

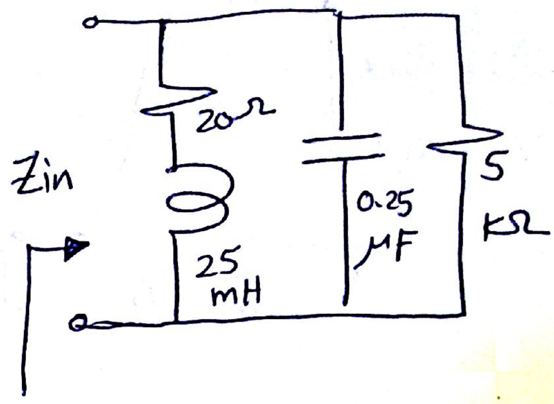
$|V|\cos\theta$

$P_{supplied\ by\ Source} = P_{dissipated\ by\ resistors}$



(11) (a) $Z_{in} = \dfrac{Z_{Tp}}{1+jQ_p\Omega}$

$|Z_{in}| = \dfrac{|Z_{Tp}|}{\sqrt{1+Q_p^2\Omega^2}}$ → R_{tot}



$W_p = \dfrac{1}{\sqrt{LC}}\sqrt{1-R_e^2\dfrac{C}{L}} = 12623.787$ r/s

$Q = \dfrac{X_L}{R_e} = \dfrac{W_pL}{R_e} = 15.78 > 10$

$R_p \approx Q^2 R_e = 4980.168\ \Omega$

$\therefore R_{tot} = R_p // R_L = (4980.168 // 5000) \approx 2495\ \Omega$

$\therefore \sqrt{1+Q_p^2\Omega^2} = \dfrac{R_{tot}}{|Z_{in}|} = \dfrac{2495}{1500}$

$Q_p = W_pCR$
$= 12623.787 * 0.25*10^{-6} * 2495$
≈ 7.87

$\sqrt{1+Q_p^2\Omega^2} = 1.66$

$Q_p^2\Omega^2 = 1.7556$

You may proceed as problem (10)

put $Q_p = 7.87$

$\Omega = f/f_p - f_p/f$

Solve to get f_1 & f_2.

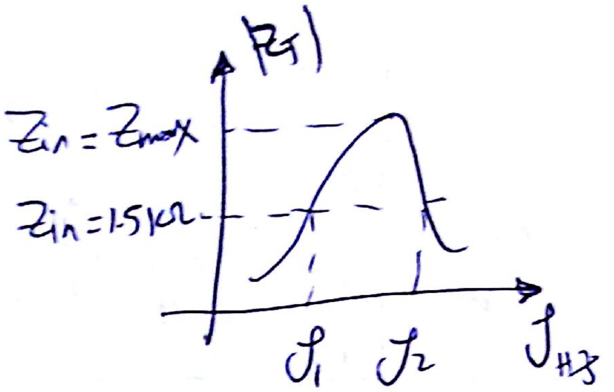
$\Omega = \pm 1.3249 \dfrac{1}{Q_p}$ $\dfrac{1}{Q_p}$

$\therefore f_{1,2} = f_p\left(\sqrt{1+\dfrac{1}{4Q_p}} \mp \dfrac{1}{2Q_p}\right)$

2009.1 Hz

$\dfrac{Q_p}{1.3249} = 5.94$

Get $f_1 = 1847$ Hz, $f_2 = 2185.3$ Hz



we need the range @ which $Z_{in} > 1.5\,k\Omega$, that is the range between f_1 & f_2

$|Z_{in}| \geq 1.5k\Omega$ if $1846\,Hz \leq f \leq 2185\,Hz$

(b) $I_s = 10\,mA$, $R_s = 10k\Omega$

$R_{tot} = R_s // R_p // R_L = 2495 // 10000 \cong 1996.8\,\Omega$

$f_2 \big|_{\text{upper cut off}} = f_p \left(\sqrt{1 + \frac{1}{4 Q_p^2}} + \frac{1}{2Q_p} \right) = 2140.77\,Hz$

$\Omega = f/f_p - f_p/f = 0.127$

$V_p = \frac{V_{p\,res}}{1 + jQ_p\Omega} = \frac{I\,R_{tot}}{1 + jQ_p\Omega} = 14.12 \angle -45^\circ$ Volts

$I_L = \frac{V_p}{R_e + jX_{L_2}} = \frac{14.12 \angle -45^\circ}{20 + j\,336.271} \approx 0.04196 \angle -131.596^\circ\,A$

$I_c = \frac{V_p}{-jX_{c_2}} = \frac{14.12 \angle -45^\circ}{-j\,297.486} \approx 0.04174 \angle 45^\circ\,A$