# Problem 3 solutions

**(a)** From the transfer function, we can know this is a bandpass filter. so we have:

center frequency: $\omega_0 = \sqrt{1/R_1R_2C_1C_2} = 2 \times 10^6 rad/s \ldots (1)$
bandwidth: $\beta = 1/R_1C_1 = 10^5 rad/s \ldots (2)$

rewrite the transfer function:

$$H(s) = \frac{-\frac{1}{R_2C_1}s}{s^2 + \beta s + w_0^2}$$

at corner frequency,

$$H(s = jw_0) = \frac{-1/R_2C_1}{\beta} = \frac{-1/R_2C_1}{1/R_1C_1} = R_1/R_2 \ldots (3)$$

The gain at corner frequency is 52 dB. Thus

$$|H(s = jw_0)| = 10^{52/20} = 398 \ldots (4)$$

Combining equation(3)(4), we know $R_1/R_2 = 398 \ldots (5)$
From equation(1),(2)and(5), we can find there are four unknown parameters in 3 equations,so we need to set $C_1$ to be 50pF. As a result, we will have $R_1 = 200K\Omega$ from(2), $R_2 = 502\Omega$ from(5), $C_2 = 50pF$ from(1). Finally, we get

$$R_1 = 200K\Omega,\ R_2 = 502\Omega,\ C_1 = 50pF,\ C_2 = 50pF$$

Note: if you set $C_2 = 50pF$ you will get almost the same result.

**(b)** The lower cutoff frequency is $w_{c1}$, upper cutoff frequency is $w_{c2}$.we have

$$\beta = w_{c2} - w_{c1}$$
$$w_{c2}w_{c1} = w_0^2 = 4 \times 10^{12}$$

Solving above two equations we can get

$$w_{c1} = 1.95 \times 10^6 rad/s,\ w_{c2} = 2.05 \times 10^6 rad/s$$

Finally, the two cutoff frequencies are

$$f_{c1} = w_{c1}/2\pi = 310\text{KHz}$$

$$f_{c2} = w_{c2}/2\pi = 326\text{KHz}$$