Question 1

a) $\frac{V_{out}}{V_{in}} = \frac{1/sC}{1/sC + sL + R} = \frac{1}{1 + sCR + s^2LC}$

b) $\frac{1}{1+sCR+s^2LC} = \frac{1}{1+\frac{2\zeta s}{\omega_0}+\frac{s^2}{\omega_0^2}}$

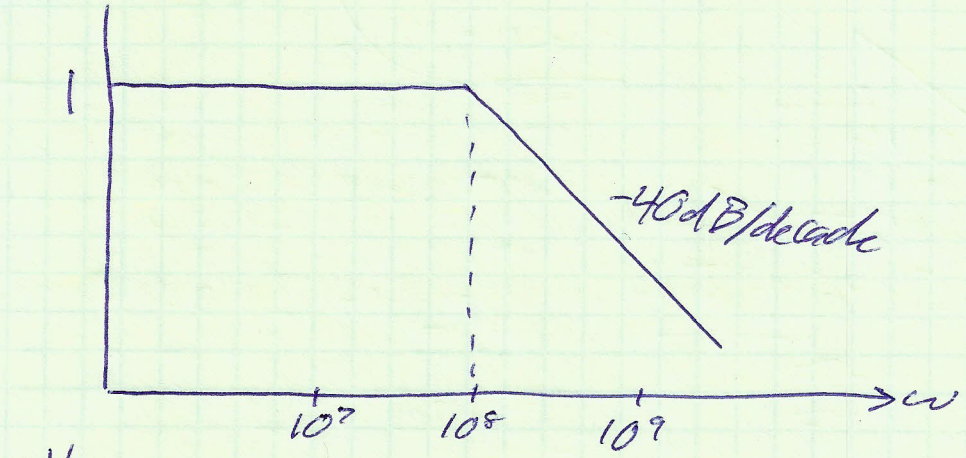
$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{10^{-7}\cdot 10^{-9}}} = \underline{10^8 \text{ rad/sec}}$

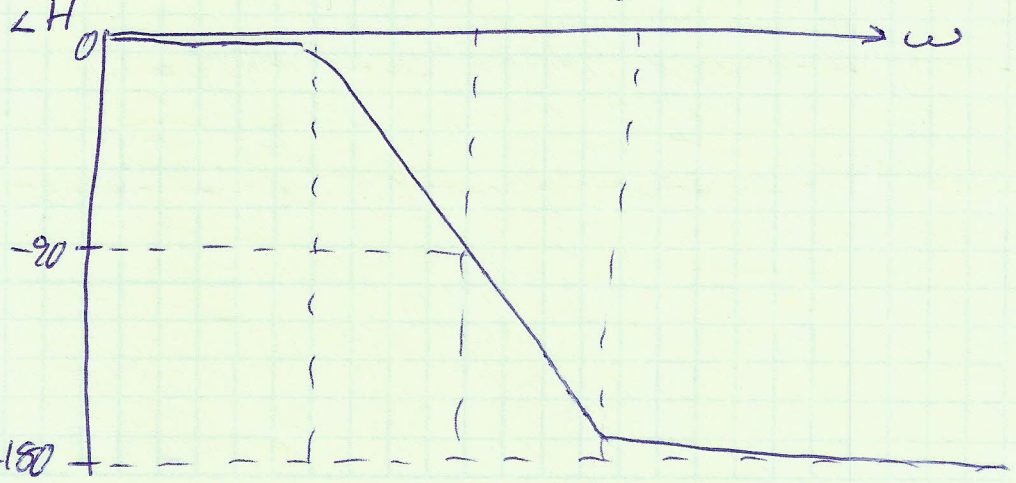
c) Butterworth: $\zeta = \frac{1}{\sqrt{2}}$

$\frac{2\zeta s}{\omega_0} = sCR \qquad \zeta = \frac{1}{2}CR\sqrt{\frac{L}{C}} = \frac{R}{2}\sqrt{\frac{C}{L}} \qquad R = 2\zeta\sqrt{\frac{L}{C}}$

$R = 2\cdot\frac{1}{\sqrt{2}}\cdot\sqrt{\frac{10^{-7}}{10^{-9}}} = \sqrt{2}\times 10 = \underline{14\,\Omega}$

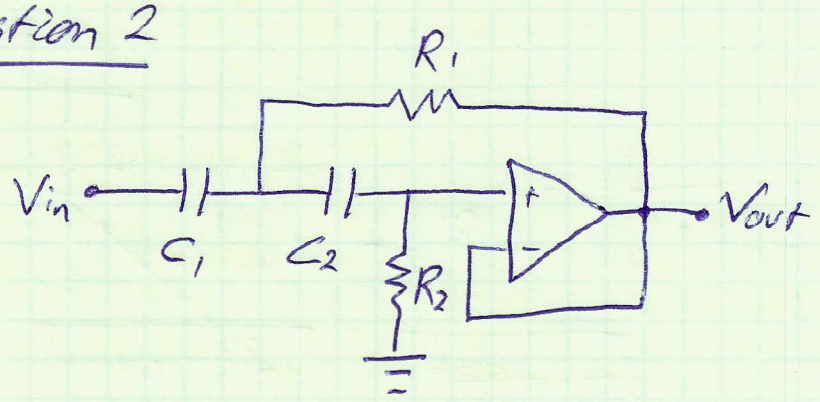
d) $|H|$





Question 2

a)



b) $$\frac{V_{out}}{V_{in}} = \frac{R_1 R_2}{\frac{1}{s^2 C_1 C_2} + R_1\left(\frac{1}{sC_1} + \frac{1}{sC_2}\right) + R_1 R_2}$$

$$= \frac{s^2 C_1 C_2 R_1 R_2}{1 + sR_1(C_1 + C_2) + s^2 C_1 C_2 R_1 R_2}$$

c) $C_1 = C_2 = C = 100\,pF$

$$sR_1 2C = \frac{2\zeta s}{\omega_0} \qquad \omega_0 = \frac{1}{C\sqrt{R_1 R_2}}$$

$$\zeta = R_1 C \omega_0 = \sqrt{\frac{R_1}{R_2}}$$

define $R_1 = Rx$ and $R_2 = R/x$

$$\omega_0 = \frac{1}{CR} \qquad \zeta = x = 0.5$$

$$R = \frac{1}{C\omega_0} = \frac{1}{10^{-10} \cdot 10^5} = 100k\Omega$$

$R_1 = 50k\Omega$ and $R_2 = 200k\Omega$

Question 3

a) $V_{out} = A(V_{in} - BV_{out})$ $\quad B = \frac{R_1}{R_1+R_2}$

$V_{out}(1+AB) = AV_{in}$

open circuit: $V_{oc} = \frac{A}{1+AB} V_{in}$

short circuit: $I_{sc} = A(V_{in} - 0)/R_o$

$$Z_{out} = \frac{V_{oc}}{I_{sc}} = \frac{\frac{A}{1+AB}V_{in}}{AV_{in}/R_o} = \frac{R_o}{1+AB}$$

$$Z_{out} = \frac{R_o}{1+GB/s}$$

b) $Z_{out} = \frac{R_o}{1+GB/s} = \frac{1}{1/R_o + GB/sR_o}$ resistor in parallel with inductor

$$L_{eff} = \frac{R_o}{GB}$$

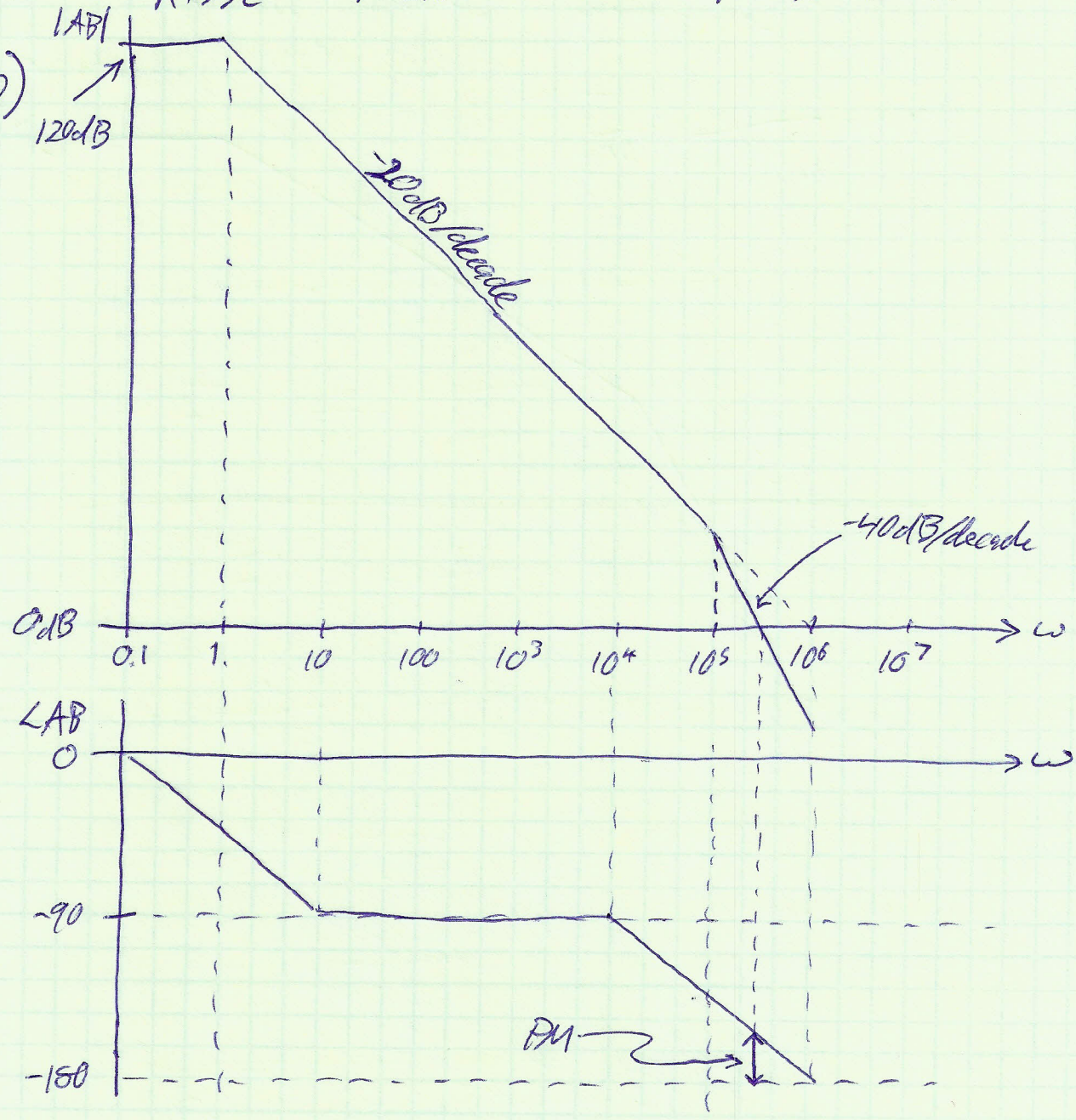
$$B = \frac{R_1}{R_1+R_2} = \frac{10k}{10k+90k} = 0.1$$

$$L_{eff} = \frac{50}{10^6 \cdot 0.1} = 5\times10^{-4} = \underline{500\mu H}$$

Question 4

a) $B = \frac{1/sC}{R + 1/sC} = \frac{1}{1+sRC}$ $\quad AB = \frac{A_0}{1+s\tau_A} \cdot \frac{1}{1+sRC}$

b)



c) unity gain frequency $\simeq 3 \times 10^5$ rad/sec

phase margin $\simeq$ 23° (about half of 45°)

d) circuit is stable because phase margin > 0