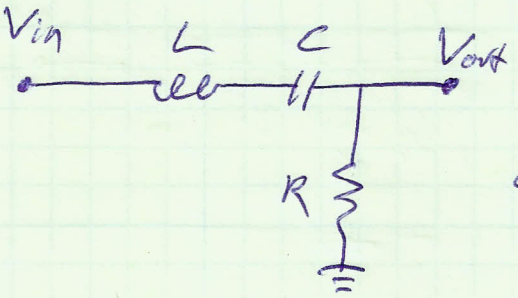
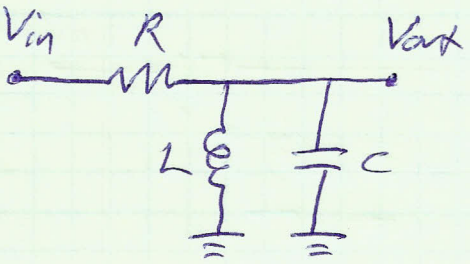
Question 1

a)



or



b)

$$H(s) = \frac{R}{R + sL + \frac{1}{sC}}$$

$$H(s) = \frac{sCR}{1 + sCR + s^2LC}$$

$$\boxed{\omega_0 = \frac{1}{\sqrt{LC}}}$$

$$\frac{2\zeta}{\omega_0} = CR \rightarrow \boxed{\zeta = \frac{R}{2}\sqrt{\frac{C}{L}}}$$

$$H(s) = \frac{\frac{1}{sC + \frac{1}{sL}}}{\frac{1}{sC + \frac{1}{sL}} + R}$$

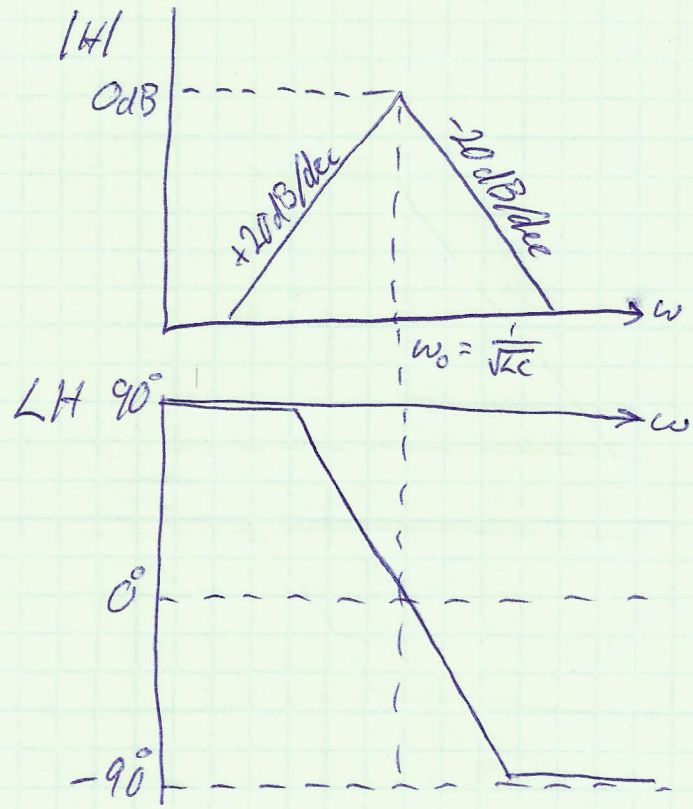
$$= \frac{1}{1 + sCR + \frac{R}{sL}}$$

$$H(s) = \frac{s\frac{L}{R}}{1 + s\frac{L}{R} + s^2LC}$$

$$\boxed{\omega_0 = \frac{1}{\sqrt{LC}}}$$

$$\frac{2\zeta}{\omega_0} = \frac{L}{R} \rightarrow \boxed{\zeta = \frac{1}{2R}\sqrt{\frac{L}{C}}}$$

c)



Question 2

a) $V_- = B V_{out}$, $B = \frac{R_1}{R_1 + R_2}$

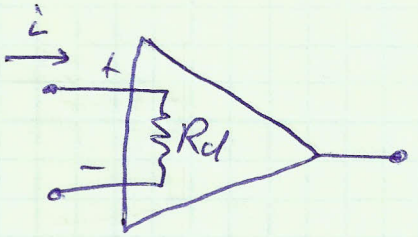
$V_{out} = A(V_+ - V_-) = A(V_{in} - B V_{out})$

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

$$\boxed{\frac{V_{out}}{V_{in}} = \frac{A}{1 + AB}} \quad \text{or} \quad \frac{V_{out}}{V_{in}} = \frac{A}{1 + A\frac{R_1}{R_1 + R_2}}$$

b) $i = \frac{V_{in} - B V_{out}}{R_d}$

$$i = \frac{V_{in} - \frac{AB}{1+AB} V_{in}}{R_d}$$



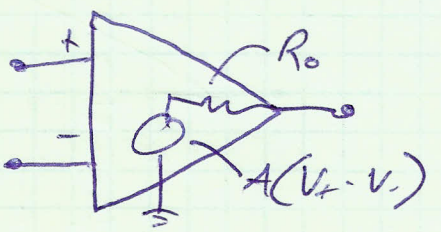
$$\frac{V_{in}}{i} = R_d \cdot \frac{1}{1 - \frac{AB}{1+AB}} = R_d \frac{1 + AB}{1 + AB - AB} = R_d(1 + AB)$$

$$Z_{in} = R_d\left(1 + \frac{GB}{s}\right) = R_d + \frac{1}{s C_{eff}}$$

$$\boxed{C_{eff} = \frac{1}{GBR_d}} \quad \text{or} \quad \frac{1}{GR_d} \cdot \frac{R_1 + R_2}{R_1}$$

c) $V_{oc} = V_{out} = \frac{A}{1 + AB} V_{in}$

$i_{sc} = A(V_+ - V_-)/R_o = A V_{in}/R_o$



$$Z_{out} = \frac{V_{oc}}{i_{sc}} = \frac{\frac{AV_{in}}{1+AB}}{AV_{in}/R_o} = \frac{R_o}{1 + AB} = \frac{1}{\frac{1}{R_o} + \frac{GB}{sR_o}} = \frac{1}{\frac{1}{R_o} + \frac{1}{sL_{eff}}}$$

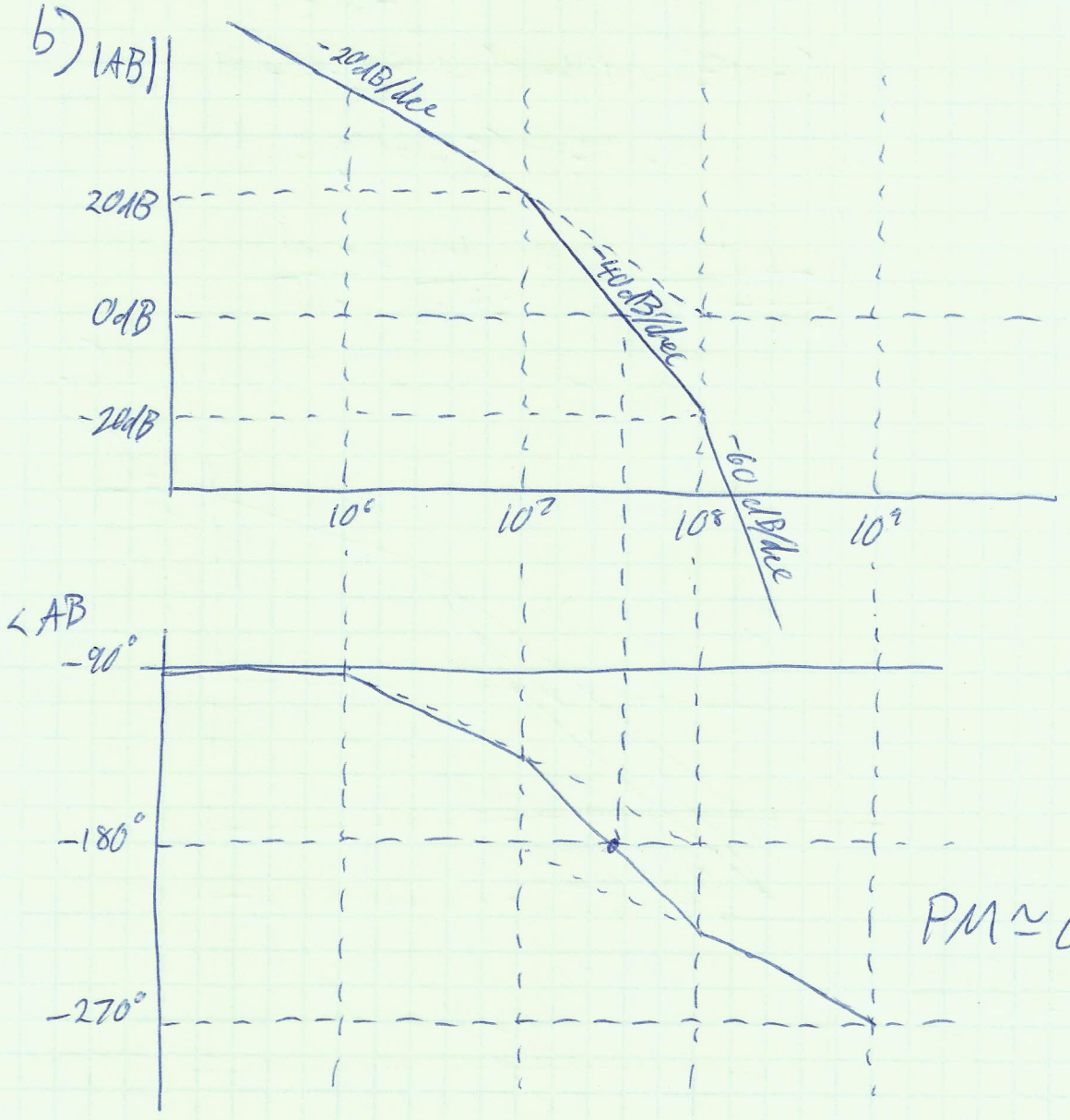
$$\boxed{L_{eff} = \frac{R_o}{GB}} \quad \text{or} \quad \frac{R_o}{G} \cdot \frac{R_1 + R_2}{R_1}$$

Question 3

a) $B = \frac{1/sC}{R + 1/sC} = \frac{1}{1+sCR}$

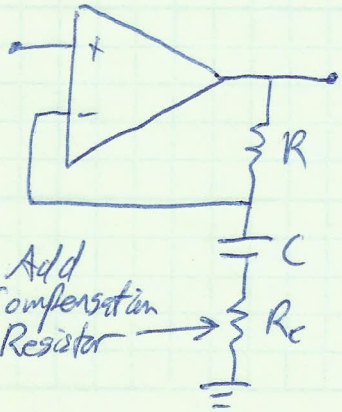
$$AB = \frac{G}{s} \cdot \frac{1}{1+s\tau} \cdot \frac{1}{1+sCR}$$

b)



PM ≃ 0

c)



$$B = \frac{1/sC + R_c}{1/sC + R_c + R} = \frac{1 + sCR_c}{1 + sC(R_c + R)}$$

this adds a zero to the transfer function at $\frac{1}{CR_c}$ → choose near unity gain frequency

$\frac{1}{CR_c} = 3\times10^7 \rightarrow R_c \simeq \frac{1}{3\times10^7 \times 10^{-10}}$

$$R_c \simeq 300\Omega$$

Question 4

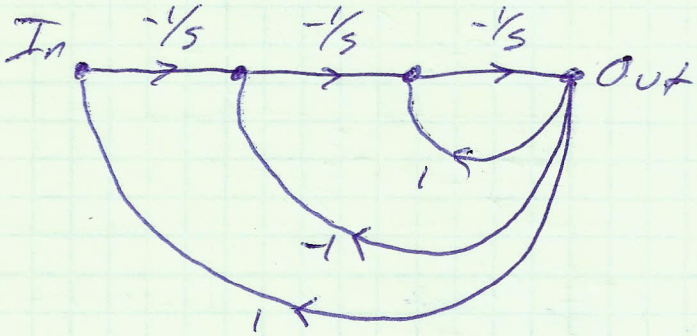
a) forward path = $-1/s^3$

$$\Delta = 1 + 1/s + 1/s^2 + 1/s^3$$

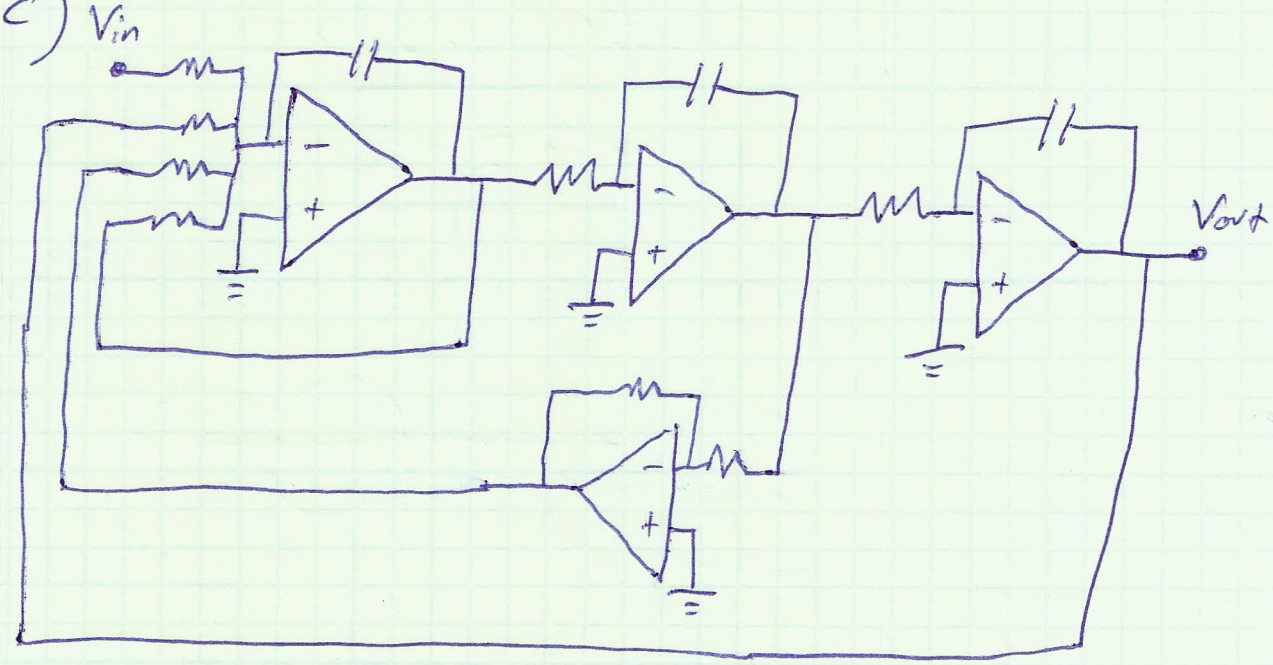
$$H(s) = \frac{-1/s^3}{1 + 1/s + 1/s^2 + 1/s^3}$$

$$\boxed{H(s) = \frac{-1}{1 + s + s^2 + s^3}}$$

b) Using flow reversal theorem:



c)



Question 5

a) gain $A = \frac{R_a + R_b}{R_a}$,

feedback term $B = \dfrac{-\dfrac{1}{\frac{1}{sL} + \frac{1}{R}}}{\dfrac{1}{\frac{1}{sL} + \frac{1}{R}} + sL + R}$

$$B = \frac{-1}{1 + \left(\frac{1}{sL} + \frac{1}{R}\right)(sL + R)} = \frac{-1}{1 + \frac{1}{2} + \frac{sL}{R} + \frac{R}{sL} + 1}$$

$$B = \frac{-\frac{sL}{R}}{1 + \frac{s}{2}\cdot\frac{sL}{R} + \frac{s^2L^2}{R^2}}$$

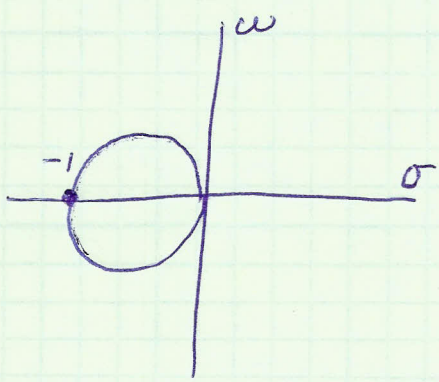
$$\boxed{AB = \frac{-\left(\frac{R_a + R_b}{R_a}\right)\frac{sL}{R}}{1 + \frac{sL}{R} + \frac{s^2L^2}{R^2}}}$$

b) at resonance, $-\left(\frac{R_a + R_b}{R_a}\right)\frac{L}{R} = -\frac{sL}{R}$

$$2R_a + 2R_b = 5R_a$$

$$\boxed{R_b = \frac{3}{2}R_a}$$

c)



Question 6

a) Schmitt trigger switches when $V_+ = 0$

$$\frac{V_+ - V_A}{R_1} + \frac{V_+ - V_B}{R_2} = 0 \qquad \frac{-V_A}{R_1} = \frac{V_B}{R_2}$$

$V_A = -5v \qquad V_B = 10v$

$$\boxed{R_2 = 2R_1}$$

b) Integrator: $\frac{V_- - V_A}{1/sC} + \frac{V_- - V_B}{R_3} = 0 \qquad V_- = 0$

$$\frac{V_A}{1/sC} = \frac{-V_B}{R_3} \qquad \frac{V_A}{V_B} = \frac{-1}{sCR_3}$$

$$V_A(t) = \frac{-1}{R_3C}\int_0^t V_B(\tau)\,d\tau + V_A(0)$$

$$\frac{1}{R_3C} \times 10v \times 0.5 \times 10^{-6}s = 10v$$

$$\boxed{R_3C = 0.5 \times 10^{-6}\,sec}$$

c)