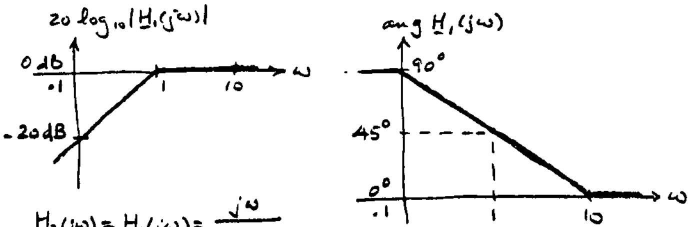
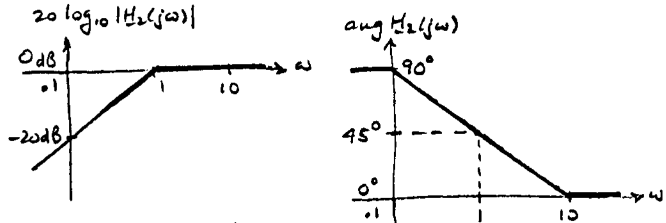
Physics 116A Fall 2006 Assignment 5 Solutions
from Instructor's Manual for Fundamentals of Elec. Engr. 2nd Ed. by Bobrow

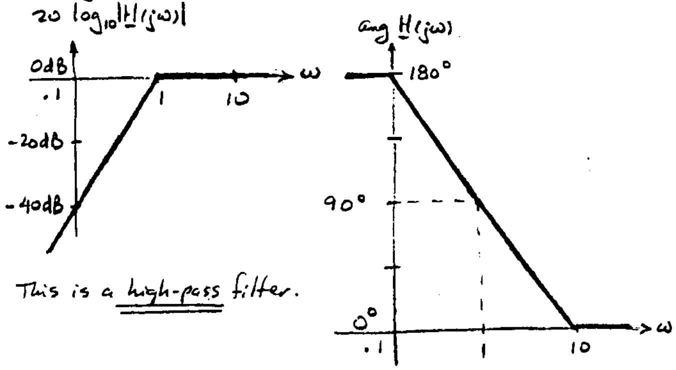
5.18 $\underline{H}_1(j\omega) = \frac{j\omega}{1+j\omega} \Rightarrow |\underline{H}_1(j\omega)| = \frac{\omega}{\sqrt{1+\omega^2}}$ $\quad \text{ang } \underline{H}_1(j\omega) = 90° - \tan^{-1}\omega$



$\underline{H}_2(j\omega) = \underline{H}_1(j\omega) = \frac{j\omega}{1+j\omega}$



Adding the plots yields



This is a <u>high-pass</u> filter.

6.17 Si has 5×10^{28} atoms/m^3, $n_i = 1.5\times10^{16}\,m^{-3}$, $T = 300\,K$, $V_0 = 0.7\,V$

<u>p side</u>

$N_A \approx 5\times10^{28}\left(\frac{1}{10^8}\right) = 5\times10^{20}\,m^{-3}$

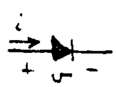
$V_0 = V_T \ln \frac{N_A N_D}{n_i^2} \Rightarrow \frac{V_0}{V_T} = \ln \frac{N_A N_D}{n_i^2} \Rightarrow e^{V_0/V_T} = \frac{N_A N_D}{n_i^2}$

$\therefore N_D = \frac{n_i^2}{N_A} e^{V_0/V_T} = \frac{(1.5\times10^{16})^2}{5\times10^{20}} e^{0.7/\frac{300}{11,586}} = 2.48\times10^{23}\,m^{-3}$

$N_D = 5\times10^{28}\left(\frac{x}{10^6}\right) = 2.48\times10^{23}\,m^{-3}$

$\therefore x = \frac{2.48\times10^{23}}{5\times10^{22}} = \underline{4.96 \text{ parts per } 10^6} \approx 5$ parts per million

6.22 Si diode



$I_s = 4\,nA$ @ 300 K
$\eta = 2 \quad i = 20\,mA$

$v = \eta V_T \ln\left(\frac{i}{I_s}+1\right) \qquad I_s(T_b) = 2^{(T_b - T_a)/10} I_s(T_a)$

(b) $T = 316\,K \Rightarrow I_s(316) = 2^{(316-300)/10} I_s(300) = 2^{1.6}(4n) = 12.1\,nA$

$v = 2\,\frac{316}{11,586} \ln\left(\frac{20m}{12.1n}+1\right) = \underline{0.781\,V}$

6.2 $L = 1\,m \quad d = 10^{-3}\,m \Rightarrow r = 0.5\times10^{-3}\,m \quad R = 2.2\times10^{-2}\,\Omega \quad i = 2\,A$

(a) $J = \frac{i}{A} = \frac{i}{\pi r^2} = \frac{2}{\pi(0.5\times10^{-3})^2} = \underline{2.55\times10^6\,A/m^2}$

(b) $J = nqu \Rightarrow u = \frac{J}{nq}$

$u = \frac{2.55\times10^6}{(8.43\times10^{28})(1.6\times10^{-19})} = \underline{1.89\times10^{-4}\,m/s}$

(c) $v = Ri = (2.2\times10^{-2})(2) = 4.4\times10^{-2}\,V$

$\mathcal{E} = 4.4\times10^{-2}\,V/m$

$\mu = \frac{u}{\mathcal{E}} = \frac{1.89\times10^{-4}}{4.4\times10^{-2}} = \underline{4.3\times10^{-3}\,m^2/V\text{-}s}$

(d) $\sigma = nq\mu = (8.43\times10^{28})(1.6\times10^{-19})(4.3\times10^{-3}) = \underline{5.8\times10^7\,\mho/m}$

6.5 Si $\quad A = 1\,mm^2 = (10^{-3})^2 m^2 = 10^{-6}\,m^2 \quad T = 300\,K \quad R = 50\,k\Omega$
$n_i = 1.5\times10^{16}\,m^{-3} \quad \mu_n = 0.13\,m^2/V\text{-}s \quad \mu_p = 0.05\,m^2/V\text{-}s$

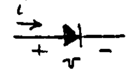
(a) $\sigma = (n\mu_n + p\mu_p)q = (n_i\mu_n + n_i\mu_p)q$

$\sigma = n_i(\mu_n + \mu_p)q$

$\sigma = (1.5\times10^{16})(0.13+0.05)(1.6\times10^{-19}) = \underline{4.32\times10^{-4}\,\mho/m}$

(b) $R = \frac{L}{\sigma A} \Rightarrow L = R\sigma A = 50k(4.32\times10^{-4})(10^{-6}) = 2.16\times10^{-5}\,m$
$= \underline{21.6\,\mu m}$

6.19 Si diode

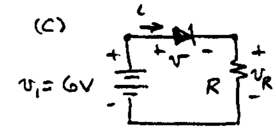


$I_s = 5\,nA \quad T = 300\,K$
$\eta = 2$

(a) $i = I_s\left(e^{v/\eta V_T} - 1\right) = 5n\left(e^{0.7/\frac{2(300)}{11,586}} - 1\right) = \underline{3.71\,mA}$

(b) $v = \eta V_T \ln\left(\frac{i}{I_s}+1\right) = 2\,\frac{300}{11,586} \ln\left(\frac{15m}{5n}+1\right) = \underline{0.772\,V}$

(c)



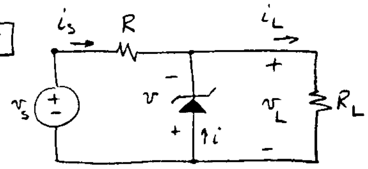
$v = \eta V_T \ln\left(\frac{i}{I_s}+1\right)$

$v = 2\,\frac{300}{11,586} \ln\left(\frac{15m}{5n}+1\right) = 0.772\,V$

$v_R = -v + v_1 = -0.772 + 6 = 5.23\,V$

$R = \frac{v_R}{i} = \frac{5.23}{15m} = \underline{349\,\Omega}$

6.65



$V_Z = 12\,V$
$i = -10\,mA$

(a) $v_s = 24\,V,\ R_L = 2\,k\Omega$. $\quad i_L = \frac{v_L}{R_L} = \frac{12}{2k} = 6\,mA$

$i_s = i_L - i = 6m + 10m = 16\,mA$

$R = \frac{v_s - v_L}{i_s} = \frac{24-12}{16m} = \underline{750\,\Omega}$