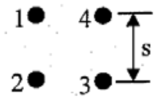
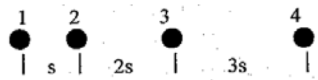
[Chapter1]

1.4 Using the equations leading to Eq. (1.8) we find



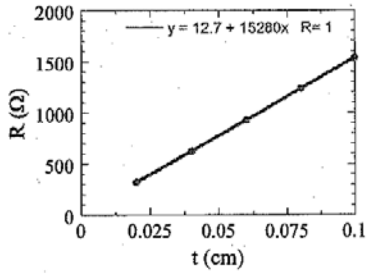
$$V=\frac{\rho I}{2\pi}\left(\frac{1}{s}-\frac{1}{\sqrt{2}s}-\frac{1}{\sqrt{2}s}+\frac{1}{s}\right)=\frac{\rho I}{2\pi}\frac{2-\sqrt{2}}{s}\Rightarrow\boxed{\rho=\frac{2\pi s}{2-\sqrt{2}}\frac{V}{I}}$$

1.5 Using the equations from the notes we find



$$V=\frac{\rho I}{2\pi}\left(\frac{1}{s}-\frac{1}{5s}-\frac{1}{3s}+\frac{1}{3s}\right)=\frac{\rho I}{2\pi}\frac{4}{5s}\Rightarrow\boxed{\rho=2.5s\frac{V}{I}}$$

1.7 The resistance is given by $R=\rho t/A + 2\rho_c/A$. Hence $\rho=(dR/dt)A$ and $2\rho_C=R_{intercept}A$. $A=7.85\text{x}10^{-5}$ cm^2. The resistance, plotted as a function of wafer thickness t, is:



From this plot we find

$$\boxed{\rho = 1.2\ \Omega\text{-cm},\ \rho_C = 5\text{x}10^{-4}\ \Omega\text{-cm}^2}$$

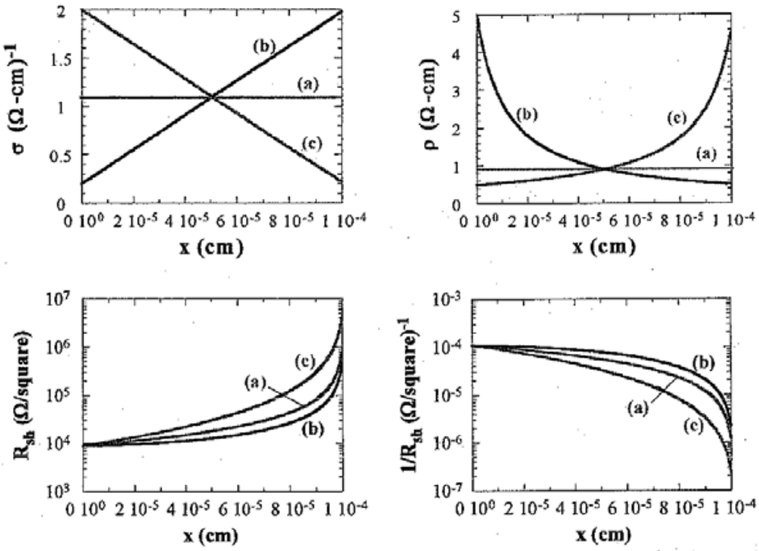
1.15 For an n-type layer on a p-type substrate: (i) $R_{sh}=\dfrac{1}{\int_0^t q n\mu_n dx}=\dfrac{5\times10^{15}}{\int_0^t n dx}=\dfrac{5\times10^{15}}{5.5\times10^{15}}$

$$\boxed{R_{sh}=9.1\times10^3\ \Omega/square}$$

(ii) calculate and plot: σ versus x (linear-linear plot), ρ versus x (linear-linear plot), R_{sh} versus x (log-linear plot) and $1/R_{sh}$ versus x (log-linear plot). Use

$$R_{sh}=\frac{1}{\int_x^t q\mu_n n dx}=\frac{1}{\int_x^t \sigma dx}$$

and let x vary from 0 to t.



1.16

$$\rho = \frac{4.532tF(R_{12,34} + R_{23,41})}{2}$$

where F is obtained from the relationship $\frac{R_r - 1}{R_r + 1} = \frac{F}{\ln(2)} ar\cosh\left(\frac{\exp[\ln(2)/F]}{2}\right)$

where $R_r = R_{12,34}/R_{23,41}$. For this problem, $R_r = 74/6 = 12.33$ leading to F=0.664 and

$$\boxed{\rho = 6\ \Omega\text{·cm},\ R_{sh} = \rho/t = 120\ \Omega/\text{square}}$$

1.24

$$R_{sh} = \frac{1}{q\mu_p \int_0^{10^{-4}} 10^{19} e^{-kx} dx} = \frac{6.25\times 10^{-3}\times 10^5}{1-e^{-10}} = 625$$

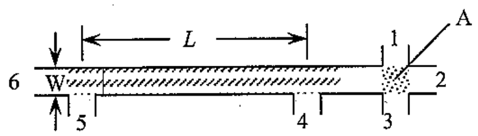
$$V_{34} = \frac{R_{sh} I_{12}}{4.532} = \frac{625\times 10^{-3}}{4.532} = 0.18;\ V_{45} = \frac{R_{sh} L I_{16}}{W} = \frac{625\times 5\times 10^{-2}\times 10^{-3}}{10^{-3}} = 31.3$$

$$\boxed{R_{sh} = 625\ \Omega/\text{square},\ V_{34} = 0.18\ \text{V},\ V_{45} = 31.3\ \text{V}}$$

1.25 .(a)

$$R_{sh} = \frac{4.532 V_{34}}{I_{12}} = \frac{4.532x11}{0.5} = 100$$

$$t = \frac{\rho}{R_{sh}} = \frac{5x10^{-3}}{100} = 5x10^{-5}$$



$$R_{line} = \frac{V_{45}}{I_{26}} = 5x10^4 \Rightarrow W = \frac{R_{sh} L}{R_{line}} = \frac{100x10^{-2}}{5x10^4} = 2x10^{-5}$$

$$\boxed{R_{sh} = 100\ \Omega\ /\text{square},\ t = 0.5\ \mu\text{m},\ W = 0.2\ \mu\text{m}}$$

(b) Now we have $\rho(x) = 0.5x+0.005$ ohm-cm, with x in cm.

$$R_{ine} = \frac{1}{Wt}\int_0^L (0.5x + 0.005)dx = 7.5x10^4;\ W_{eff} = \frac{R_{sh} L}{R_{line}} = \frac{100x10^{-2}}{7.5x10^4} = 1.33x10^{-5}$$

$$\boxed{W_{eff} = 0.133\ \mu\text{m}}$$

[Chapter2]

2.3

$$\frac{C_{inv}}{C_{ox}} = \frac{1}{1+\dfrac{2K_{ox}}{K_s t_{ox}}\sqrt{\dfrac{K_s \varepsilon_o kT \ln(N_A/n_i)}{qN_A}}}$$

(a) In this problem, C_{ox}=C_{ins}. With R=0.32, K_{ox}=K_{ins}=8 and t_{ox}=t_{ins}=30 nm, solving the "N_A" equation gives:

$$\boxed{N_A = 1.26\text{x}10^{17}\ \text{cm}^{-3}}$$

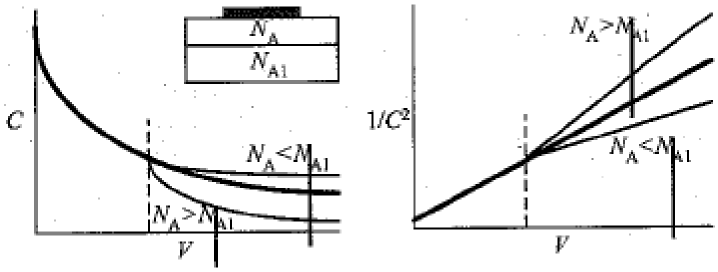
(b) for N_A=10^{16} cm^{-3}:

$$\boxed{C_{inv}/C_{ins} = 0.126}$$

(c) Using Eq. (2.19):

$$\boxed{N_A = 1.41\text{x}10^{17}\ \text{cm}^{-3}}$$

2.4



2.16 $$C_p = \frac{C}{(1+r_sG)^2+(2\pi f r_s C)^2};\ G_p = \frac{G(1+r_sG)+r_s(2\pi f C)^2}{(1+r_sG)^2+(2\pi f r_s C)^2}$$

At high frequencies: $C_p \approx \dfrac{C}{(2\pi f r_s C)^2}$; $G_p \approx \dfrac{1}{r_s} \Rightarrow r_s = 400\ \Omega$

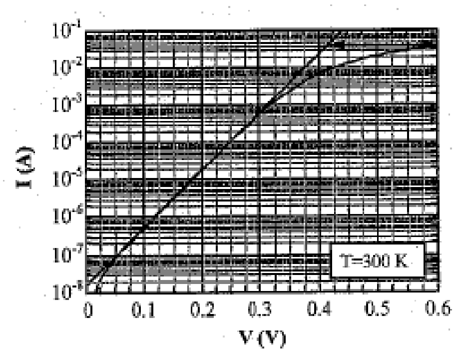
At low frequencies: $C_p \approx \dfrac{C}{(1+r_sG)^2}$; $G_p \approx \dfrac{G}{(1+r_sG)}$

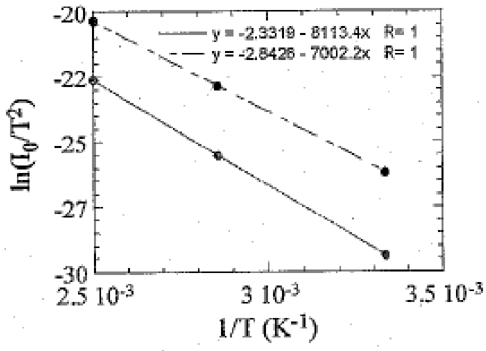
From conductance curve, G < 10^{-4} S at low f, hence, r_sG << 1 and with $C_p \approx C/(2\pi f r_s C)^2$ at high f.
This gives C = 125 pF. From the conductance curve, knowing r_s and C, G = 10^{-5} S.

$$\boxed{r_s = 400\ \Omega,\ C = 125\ \text{pF},\ G = 10^{-5}\ \text{S}}$$

[Chapter3]

3.3 From the I-V curve: Deviation from ideal at I=0.04 A is 0.18 V, leading to r_s=0.18/0.04=4.5 Ω
Slope=15.2=q/2.3nkT leading to n=1.1.





For low V, we can neglect the "Ir_s" in the exponent; furthermore, the I_o values are obtained by extrapolation to V=0.
Hence we have $I = I_o = AA^*T^2 \exp(-q\phi_B/kT) \Rightarrow \ln(I/T^2) = \ln(AA^*) - q\phi_B/kT$
and a plot of $\ln(I/T^2)$ vs. 1/T has an intercept of $\ln(AA^*)$ and a slope of $-q\phi_B/k$.

For device 1 we have from the intercept $\ln(AA^*)$=-2.33 or AA^*=0.1 leading to A^*=97 A/cm²·K², and from the slope=-8113 we find ϕ_B=-slopek/q giving ϕ_B=0.7 V with q=1.
$V_{bi}=\phi_B-V_o$, where $qV_o=E_g/2-(E_F-E_i)$. $E_F-E_i=(kT/q)\ln(N_D/n_i)$ giving V_o=0.204 V. For device 1 with V=0, V_{bi}=0.495 V and

Φ_{B1}=0.7 V (same as from the I-V data) using the capacitance expression $C = A\sqrt{\dfrac{K_s\varepsilon_o qN_D}{2(V_{bi}-V)}}$

For C_2 we have $C_2 = \dfrac{A}{2}\left(\sqrt{\dfrac{K_s\varepsilon_o qN_D}{2(\phi_{B1}-V_o)}} + \sqrt{\dfrac{K_s\varepsilon_o qN_D}{2(\phi_{B2}-V_o)}}\right) = \dfrac{C_1}{2} + \dfrac{A}{2}\sqrt{\dfrac{K_s\varepsilon_o qN_D}{2(\phi_{B2}-V_o)}}$

Substituting numerical values gives V_{bi}=0.395 V and ϕ_{B2}=0.6 V.

$$\boxed{n = 1.1,\ r_s = 4.5\ \Omega,\ A^* = 97\ \text{A/cm}^2\cdot\text{K}^2,\ \phi_{B1} = 0.7\ \text{V},\ \phi_{B2} = 0.6\ \text{V}}$$

3.13 $\ln(I) = \ln(AA^*T^2\exp(-q\phi_B/kT) + \dfrac{qV}{nkT}$; $slope = \dfrac{d\ln(I)}{dV} = \dfrac{q}{nkT}$

Since only the slope is affected, it must be caused by a change in diode ideality factor **n**.

3.17 The TLM test structure below gave the R_T values in the graph.
(a) Determine R_{sh}, R_C, ρ_C, and t.
The slope = 500 = $R_{sh}/Z \Rightarrow R_{sh}$ = 5 Ω/square. The y-intercept is $2R_c$ = 0.447 ⇒ R_c = 0.224 Ω,
the x-intercept is $2L_T$ = 8.94x10^{-4}
⇒ $\rho_c = 10^{-6}$ Ω-cm². Knowing $R_{sh} = 1/qN_D\mu t$ we find $N_D = 10^{20}$ cm^{-3}.
(b) Plot for $\rho_c = 10^{-7}$ Ω-cm².

$$\boxed{R_{sh} = 5\ \Omega/\text{square},\ R_c = 0.224\ \Omega,\ \rho_c = 10^{-6}\ \Omega\text{-cm}^2,\ N_D = 10^{20}\ \text{cm}^{-3}}$$