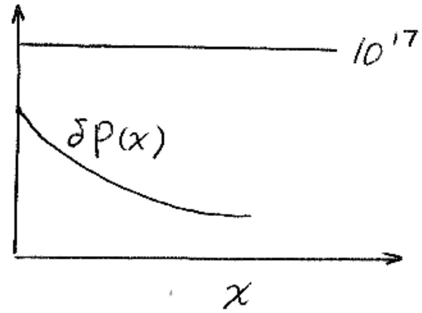
4.1. (a) $\delta p(x) = \Delta p\, e^{-\frac{x}{L_p}}$ ......(1)



$\because\ \delta p(x=0) = \Delta p = 5\times10^{16}\ cm^{-3}$ ....(2)

$\therefore\ \delta p(x) = 5\times10^{16} e^{-\frac{x}{L_p}}$ ......(3)

$L_p = \sqrt{D_p \cdot \tau_p}$ ......(4)

$D_p = \frac{k_B T}{e}\mu_p = 0.0258\ Volt \times 500\ cm^2 \cdot V^{-1} \cdot s^{-1} = 12.94\ cm^2/s$

$\tau_p = 10^{-10}\ s$

So, $L_p = \sqrt{12.94 \times 10^{-10}} = 3.60\times10^{-5}\ cm$ ...... (5)

Then $\delta p\ (x = 1000\mathring{A}) = 5\times10^{16} e^{-\frac{1000\mathring{A}\times10^{-8}\ cm/\mathring{A}}{3.60\times10^{-5}\ cm}}$

$\delta p\ (x = 1000\mathring{A}) = 3.79\times10^{16}\ cm^{-3}$ ....(6)

And $\boxed{p = N_a + \delta p = 10^{17} + 3.79\times10^{16} = 1.379\times10^{17}\ cm^{-3}}$

(b). $p = N_v \exp\left[-\frac{F_p - E_v}{k_B T}\right]$ ......(7)

$N_v = 2\left(\frac{2\pi m_p^* k_B T}{h^2}\right)^{3/2}$ ....(8)

$N_v = 2\times\left(\frac{2\times3.14\times0.81\times9.31\times10^{-31}\times1.38\times10^{-23}\times300}{(6.63\times10^{-34})^2}\right)^{3/2}$ ....(9)

$N_v = 1.04\times10^{19}$ ......(10)

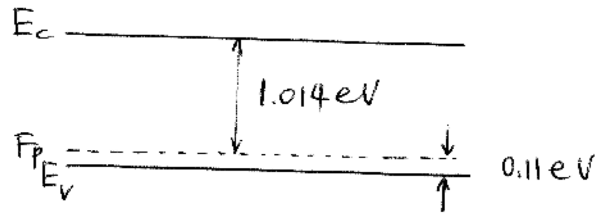
Insert eq. (10) into eq. (7) and rearrange, we get

$$F_p - E_v = k_B T \ln \frac{N_v}{p} = 0.0258 \ln \frac{1.04\times10^{19}}{1.379\times10^{17}} = 0.11 \text{ eV}$$

At 300 K, $E_g = E_c - E_v = 1.124$ eV

So, $F_p - E_v - E_g = F_p - E_v - E_c + E_v = F_p - E_c$

and $\boxed{F_p - E_c = 0.11 - 1.124 = -1.014 \text{ eV}}$



(c). Current

$$I = q D_p A \cdot \left.\frac{d\,\delta p(x)}{dx}\right|_{x=0}$$

$$I = 1.6\times10^{-19} \times 12.94 \times 0.5 \times \left.\frac{d}{dx}\left(e^{-\frac{x}{L_p}}\right)\right|_{x=0} \cdot \quad 5\times10^{16}$$

$$= 5.176\times10^{-2} \cdot \left(-\frac{1}{L_p}\right)$$

$$= -1.438\times10^{3} \text{ A}$$

(d) charge stored

$$Q = q\int_0^\infty A \cdot \delta p(x)\, dx = qA\cdot\Delta p \cdot \int_0^\infty e^{-\frac{x}{L_p}}\, dx$$

$$= qA\cdot\Delta p \cdot (-L_p) \int_0^\infty e^{-\frac{x}{L_p}}\, d\left(e^{-\frac{x}{L_p}}\right)$$

$$= qA\cdot\Delta p \cdot L_p$$

So, $$Q = 1.6\times10^{-19} \times 0.5 \times 5\times10^{16} \times 3.60\times10^{-5}$$

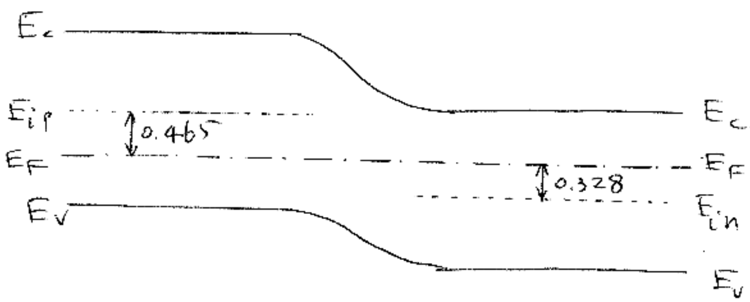
$$\boxed{Q = 1.44\times10^{-7}\ C}$$

5.9. (a) $$E_{ip} - E_F = k_B T \ln\left(\frac{N_a}{n_i}\right) = 0.0258 \ln \frac{10^{18}}{1.5\times10^{10}}$$

$$\boxed{E_{ip} - E_F = 0.465\ eV}$$

$$E_F - E_{in} = k_B T \ln \frac{N_d}{n_i} = 0.0258 \ln \frac{5\times10^{15}}{1.5\times10^{10}}$$

$$\boxed{E_F - E_{in} = 0.328\ eV}$$



$$V_o = E_{ip} - E_{in} = 0.465 + 0.328 = 0.793\ eV$$

(b). $$V_o = k_B T \ln \frac{N_a \cdot N_d}{n_i^2} = 0.0258 \ln \frac{10^{18}\times5\times10^{15}}{(1.5\times10^{10})^2}$$

$$\boxed{V_o = 0.793\ eV}$$

5.15.

$$\mathcal{E}_0 = -\frac{q}{\epsilon} N_a \cdot x_{p_0}$$

$$x_{p_0} = \left[\frac{2\epsilon V_0}{q}\left(\frac{N_d}{N_a(N_a+N_d)}\right)\right]^{1/2}$$

$$\mathcal{E}_0 = -\frac{q}{\epsilon} \cdot N_a \cdot \left[\frac{2\epsilon V_0}{q}\left(\frac{N_d}{N_a(N_a+N_d)}\right)\right]^{1/2}$$

$$= -\frac{q}{\epsilon} \cdot \left(\frac{2\epsilon V_0}{q}\right)^{1/2} \left[\frac{N_a^{\cancel{2}}\ N_d}{\cancel{N_a}(N_a+N_d)}\right]^{1/2}$$

$$= -\left(\frac{2qV_0}{\epsilon}\right)^{1/2} \left[\frac{1}{\frac{1}{N_d}+\frac{1}{N_a}}\right]^{1/2}$$

For $N_d \gg N_a$, $\frac{1}{N_d} \ll \frac{1}{N_a}$, $\frac{1}{N_d}+\frac{1}{N_a} \approx \frac{1}{N_a}$

$$\mathcal{E}_0 \simeq -\left(\frac{2qV_0}{\epsilon}\right)^{1/2} (N_a)^{1/2}$$

For $N_d \ll N_a$,

$$\mathcal{E}_0 \simeq -\left(\frac{2qV_0}{\epsilon}\right)^{1/2} (N_d)^{1/2}$$

The peak electric field $\mathcal{E}_0$ is controlled by the smaller value of N_d and N_a.