

The University of Windsor

ELEC2250: Physical Electronics

Summer 2020

Lab Seven

Effects of Forward and Reverse Bias on the
Electrostatic Variables of an Abrupt p-n Junction



Monday, August 3, 2020

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Results for doping concentrations $N_A = N_D = 1e15$

Input the p-side doping, $N_A = 1e15$

Input the n-side doping, $N_D = 1e15$

$V_0 = 0.5754$

Bias voltage, V (Smaller than V_0 for forward bias) = 0.5

COMPUTATIONAL RESULTS

$N_A = 1.0000e+15$

$N_D = 1.0000e+15$

$V = 0.5000$

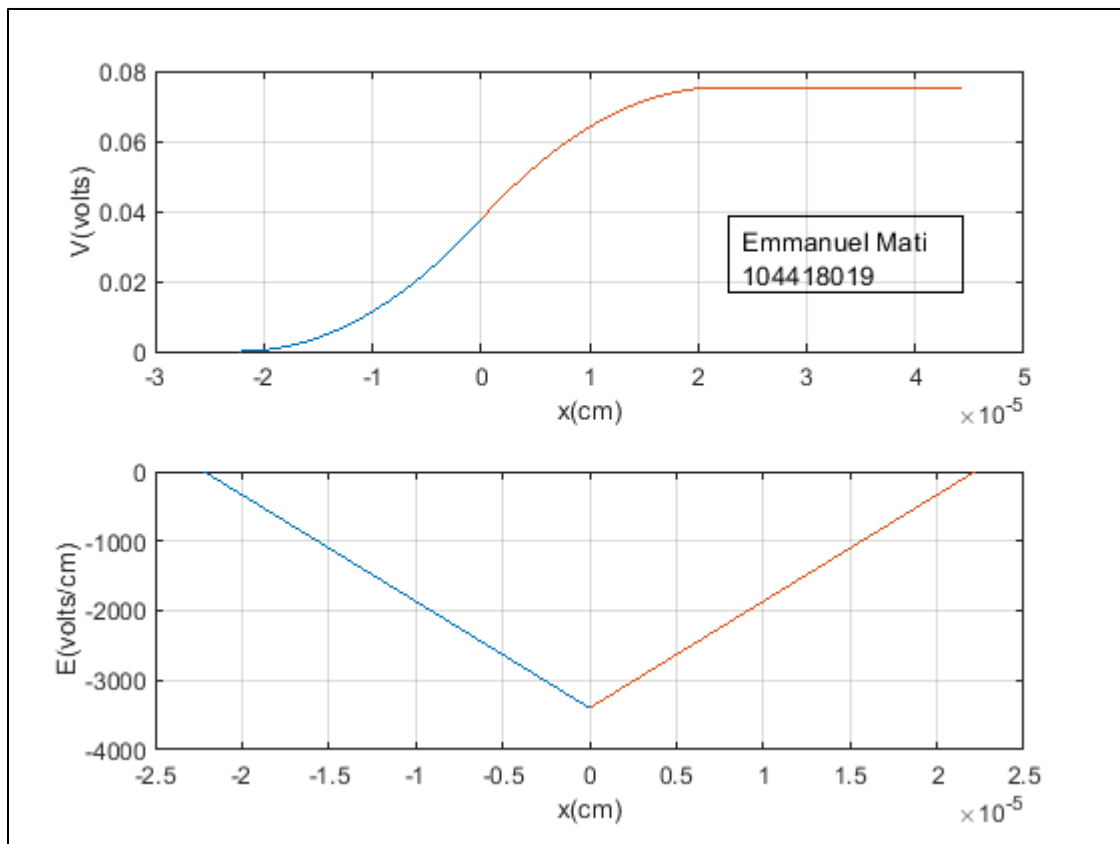
$V_0 = 0.5754$

$x_n = 2.2184e-05$

$x_p = 2.2184e-05$

$W = 4.4368e-05$

$E_0 = -3.3973e+03$



Input the p-side doping, $N_A = 1e15$

Input the n-side doping, $N_D = 1e15$

$V_0 = 0.5754$

Bias voltage, V (Smaller than V_0 for forward bias) = 0

COMPUTATIONAL RESULTS

$N_A = 1.0000e+15$

$N_D = 1.0000e+15$

$V = 0$

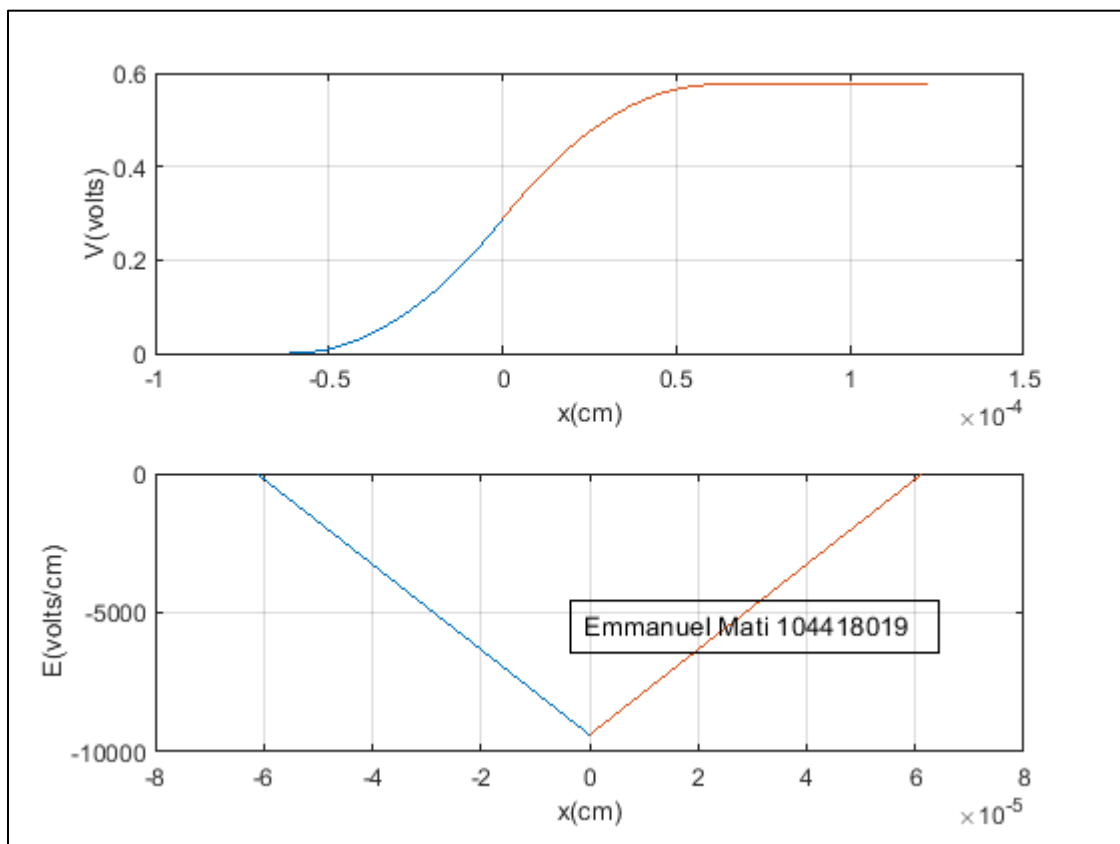
$V_0 = 0.5754$

$x_n = 6.1295e-05$

$x_p = 6.1295e-05$

$W = 1.2259e-04$

$E_0 = -9.3869e+03$



Input the p-side doping, $N_A = 1e15$

Input the n-side doping, $N_D = 1e15$

$V_0 = 0.5754$

Bias voltage, V (Smaller than V_0 for forward bias) = -10

COMPUTATIONAL RESULTS

$N_A = 1.0000e+15$

$N_D = 1.0000e+15$

$V = -10$

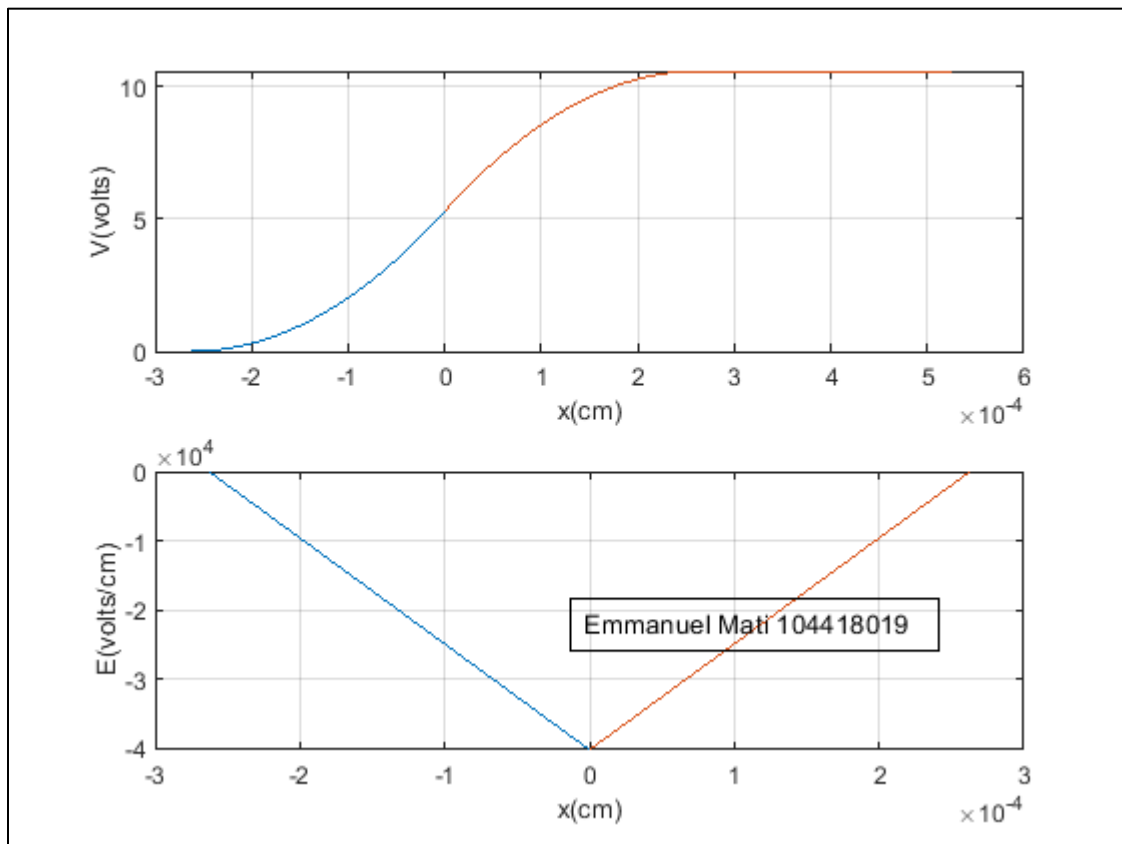
$V_0 = 0.5754$

$x_n = 2.6278e-04$

$x_p = 2.6278e-04$

$W = 5.2557e-04$

$E_0 = -4.0244e+04$



Results for doping concentrations $N_A = N_D = 1e16$

Input the p-side doping, $N_A = 1e16$

Input the n-side doping, $N_D = 1e16$

$V_0 = 0.6946$

Bias voltage, V (Smaller than V_0 for forward bias) = 0.5

COMPUTATIONAL RESULTS

$N_A = 1.0000e+16$

$N_D = 1.0000e+16$

$V = 0.5000$

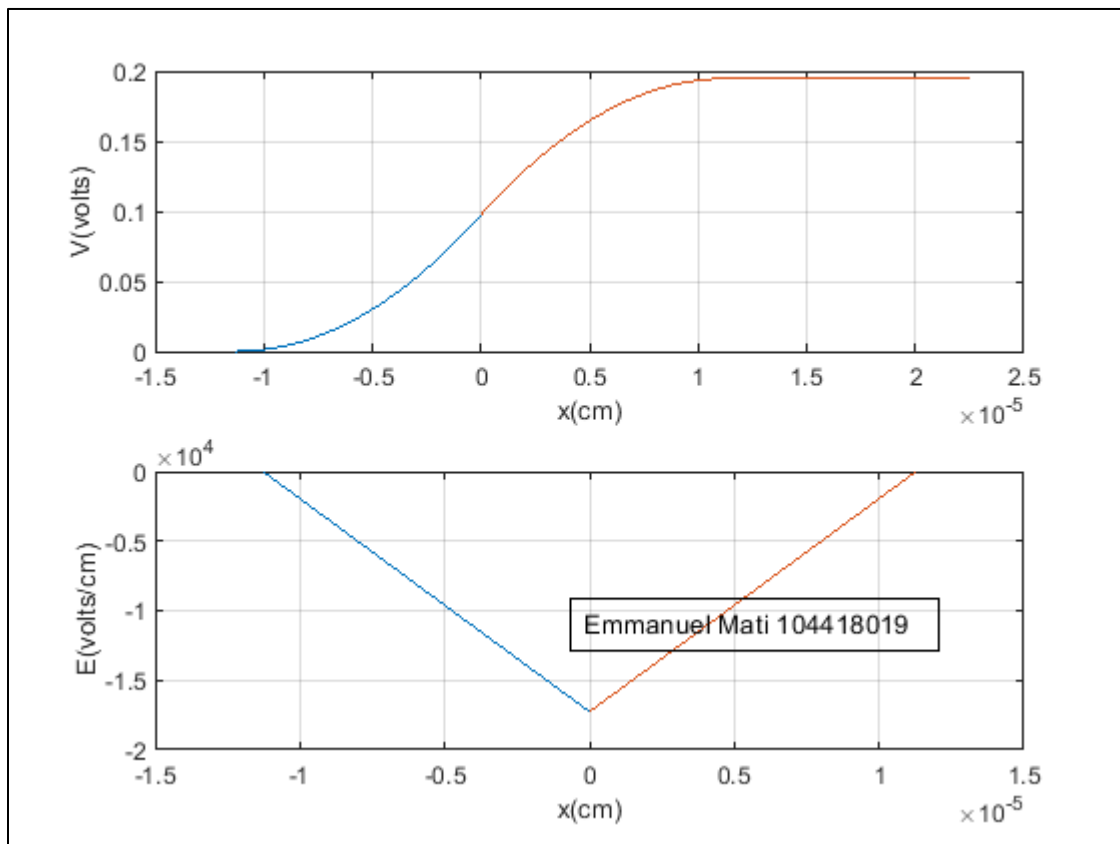
$V_0 = 0.6946$

$x_n = 1.1274e-05$

$x_p = 1.1274e-05$

$W = 2.2547e-05$

$E_0 = -1.7265e+04$



Input the p-side doping, $N_A = 1e16$

Input the n-side doping, $N_D = 1e16$

$V_0 = 0.6946$

Bias voltage, V (Smaller than V_0 for forward bias) = 0

COMPUTATIONAL RESULTS

$N_A = 1.0000e+16$

$N_D = 1.0000e+16$

$V = 0$

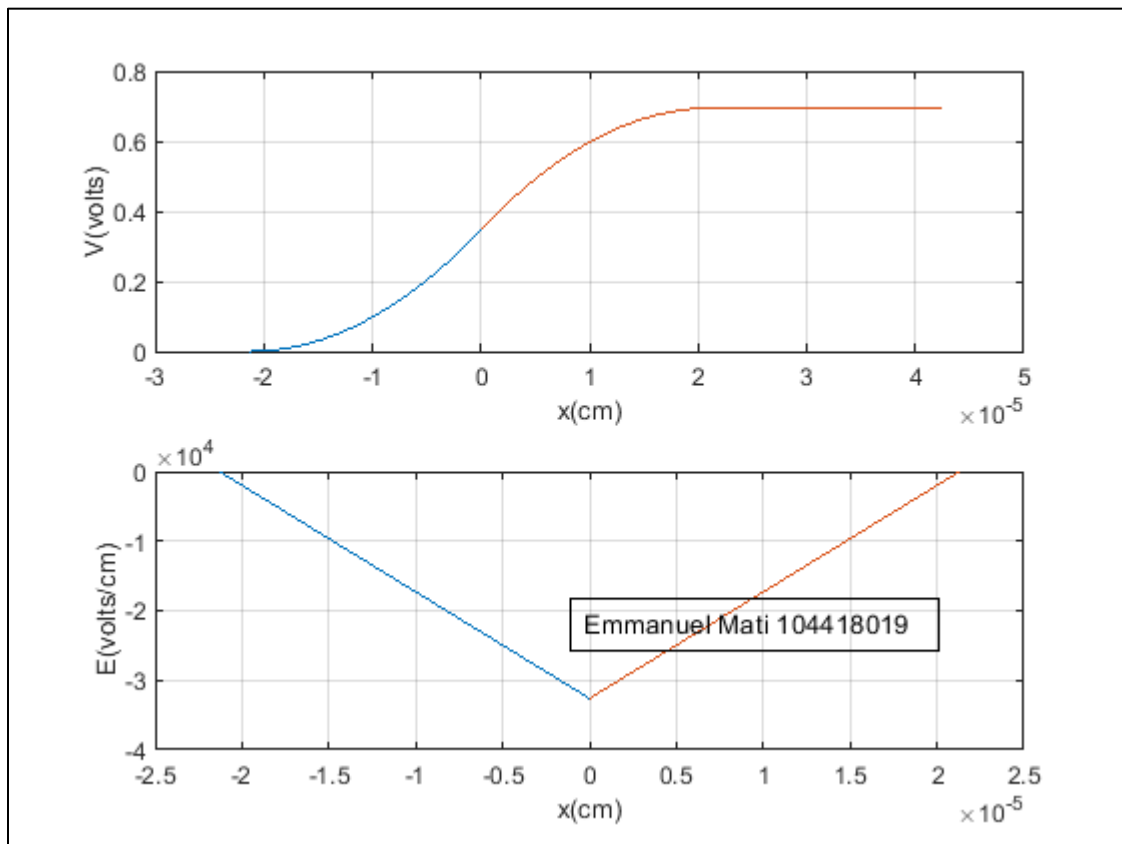
$V_0 = 0.6946$

$x_n = 2.1298e-05$

$x_p = 2.1298e-05$

$W = 4.2595e-05$

$E_0 = -3.2616e+04$



Input the p-side doping, $N_A = 1e16$

Input the n-side doping, $N_D = 1e16$

$V_0 = 0.6946$

Bias voltage, V (Smaller than V_0 for forward bias) = -10

COMPUTATIONAL RESULTS

$N_A = 1.0000e+16$

$N_D = 1.0000e+16$

$V = -10$

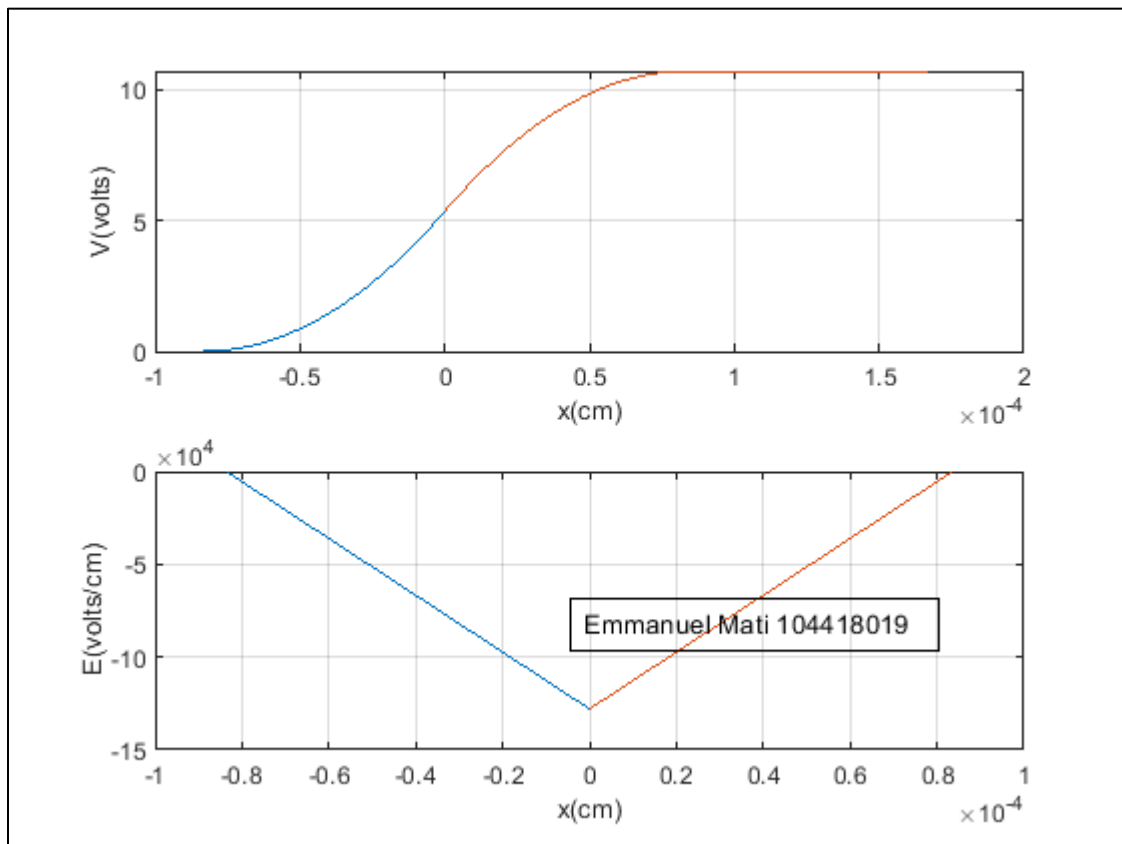
$V_0 = 0.6946$

$x_n = 8.3567e-05$

$x_p = 8.3567e-05$

$W = 1.6713e-04$

$E_0 = -1.2798e+05$



Results for doping concentrations $N_A = N_D = 1e17$

Input the p-side doping, $N_A = 1e17$

Input the n-side doping, $N_D = 1e17$

$V_0 = 0.8139$

Bias voltage, V (Smaller than V_0 for forward bias) = 0.5

COMPUTATIONAL RESULTS

$N_A = 1.0000e+17$

$N_D = 1.0000e+17$

$V = 0.5000$

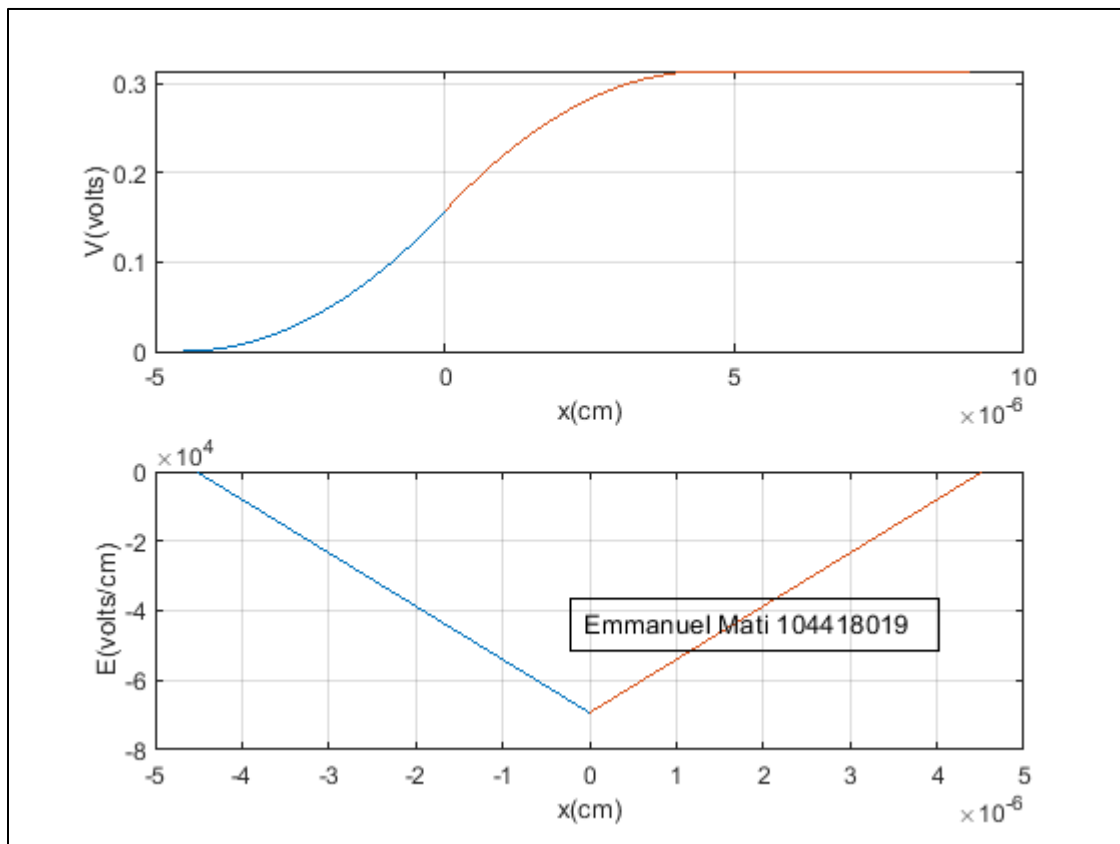
$V_0 = 0.8139$

$x_n = 4.5275e-06$

$x_p = 4.5275e-06$

$W = 9.0550e-06$

$E_0 = -6.9335e+04$



Input the p-side doping, $N_A = 1e17$

Input the n-side doping, $N_D = 1e17$

$V_0 = 0.8139$

Bias voltage, V (Smaller than V_0 for forward bias) = 0

COMPUTATIONAL RESULTS

$N_A = 1.0000e+17$

$N_D = 1.0000e+17$

$V = 0$

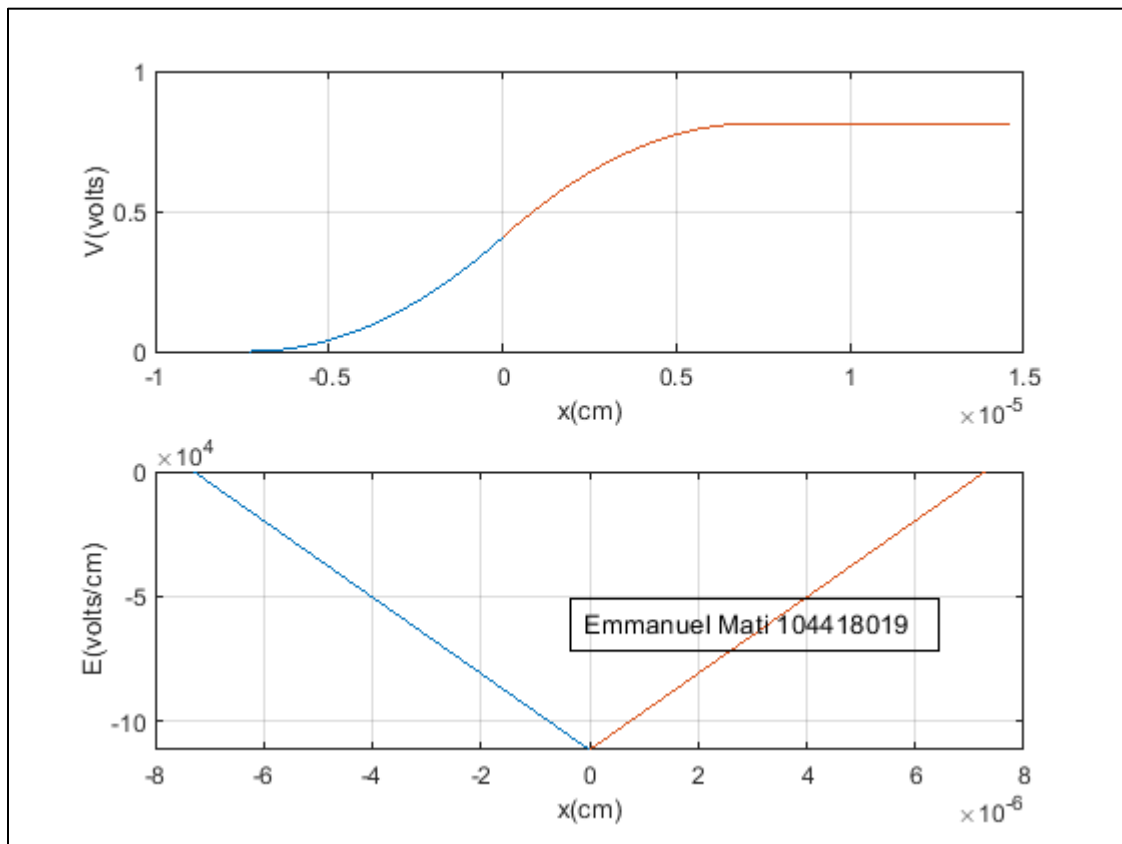
$V_0 = 0.8139$

$x_n = 7.2902e-06$

$x_p = 7.2902e-06$

$W = 1.4580e-05$

$E_0 = -1.1164e+05$



Input the p-side doping, $N_A = 1e17$

Input the n-side doping, $N_D = 1e17$

$V_0 = 0.8139$

Bias voltage, V (Smaller than V_0 for forward bias) = -10

COMPUTATIONAL RESULTS

$N_A = 1.0000e+17$

$N_D = 1.0000e+17$

$V = -10$

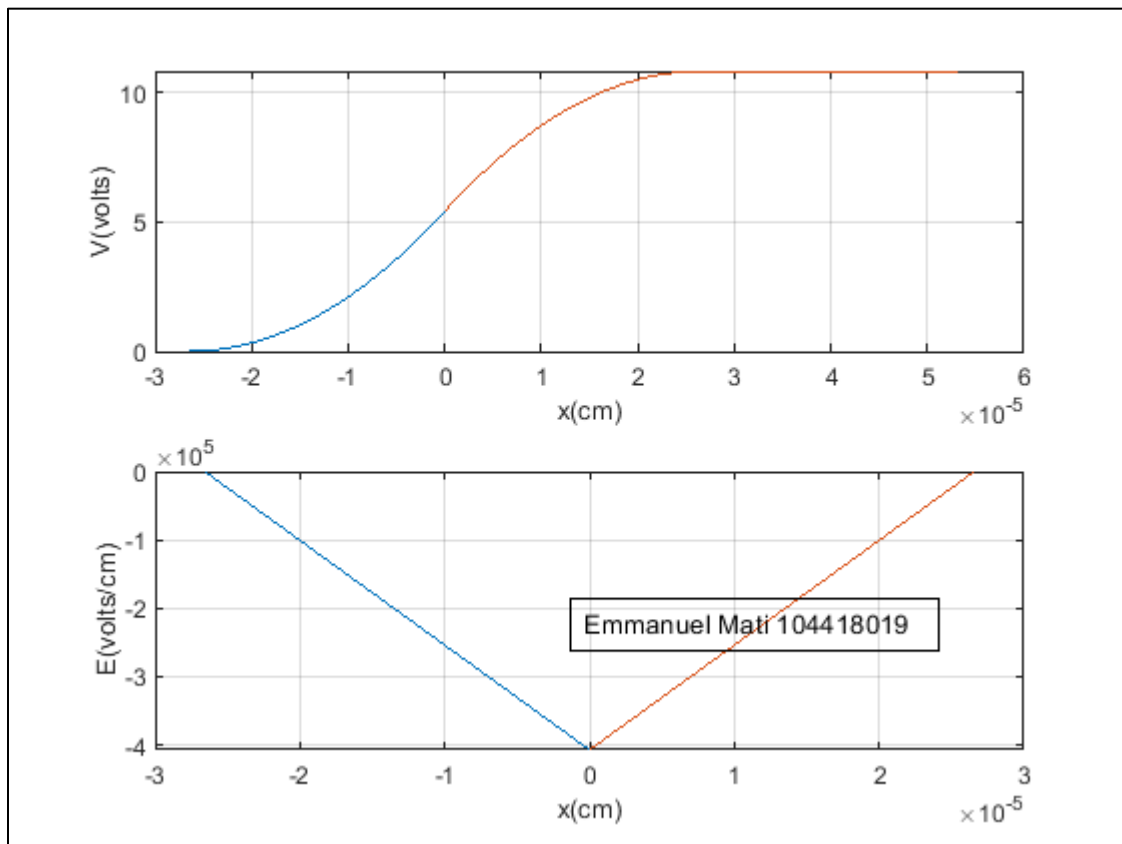
$V_0 = 0.8139$

$x_n = 2.6573e-05$

$x_p = 2.6573e-05$

$W = 5.3146e-05$

$E_0 = -4.0695e+05$



Results for doping concentrations $N_A = N_D = 1e18$

Input the p-side doping, $N_A = 1e18$

Input the n-side doping, $N_D = 1e18$

$V_0 = 0.9332$

Bias voltage, V (Smaller than V_0 for forward bias) = 0.5

COMPUTATIONAL RESULTS

$N_A = 1.0000e+18$

$N_D = 1.0000e+18$

$V = 0.5000$

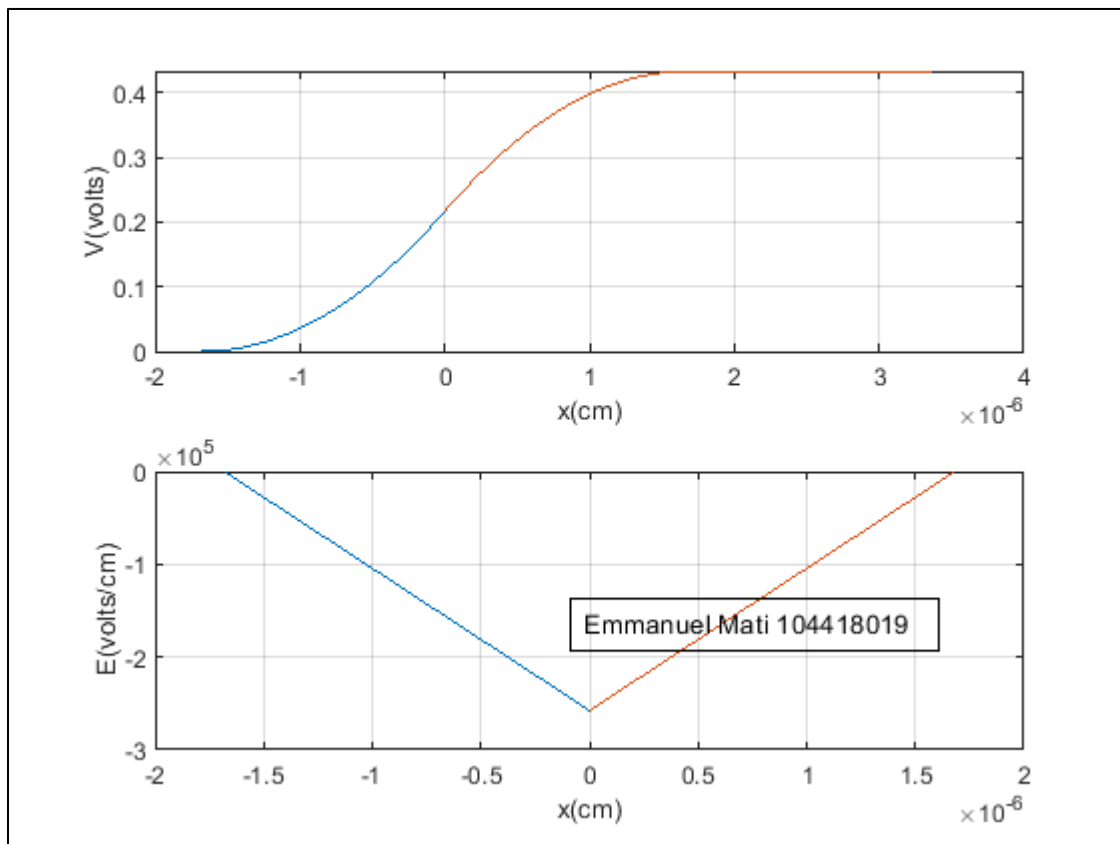
$V_0 = 0.9332$

$x_n = 1.6819e-06$

$x_p = 1.6819e-06$

$W = 3.3637e-06$

$E_0 = -2.5757e+05$



Input the p-side doping, $N_A = 1e18$

Input the n-side doping, $N_D = 1e18$

$V_0 = 0.9332$

Bias voltage, V (Smaller than V_0 for forward bias) = 0

COMPUTATIONAL RESULTS

$N_A = 1.0000e+18$

$N_D = 1.0000e+18$

$V = 0$

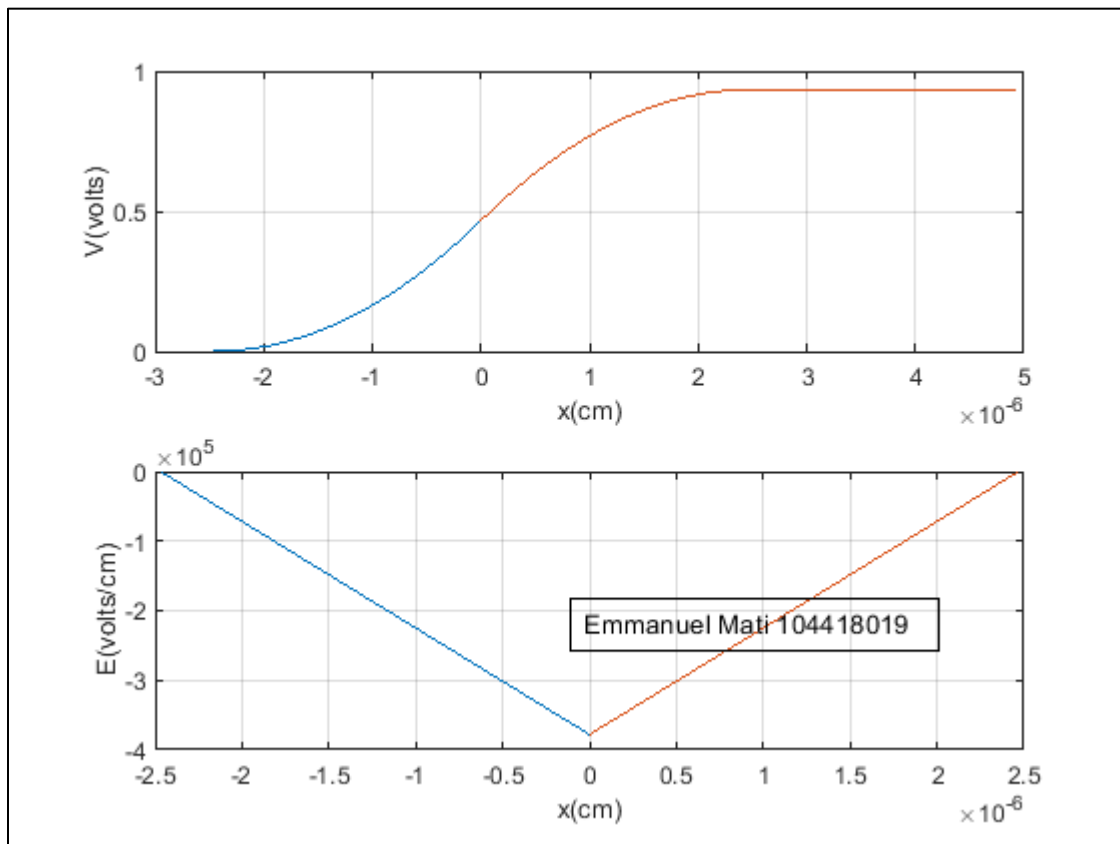
$V_0 = 0.9332$

$x_n = 2.4685e-06$

$x_p = 2.4685e-06$

$W = 4.9370e-06$

$E_0 = -3.7804e+05$



Input the p-side doping, $N_A = 1e18$

Input the n-side doping, $N_D = 1e18$

$V_0 = 0.9332$

Bias voltage, V (Smaller than V_0 for forward bias) = -10

COMPUTATIONAL RESULTS

$N_A = 1.0000e+18$

$N_D = 1.0000e+18$

$V = -10$

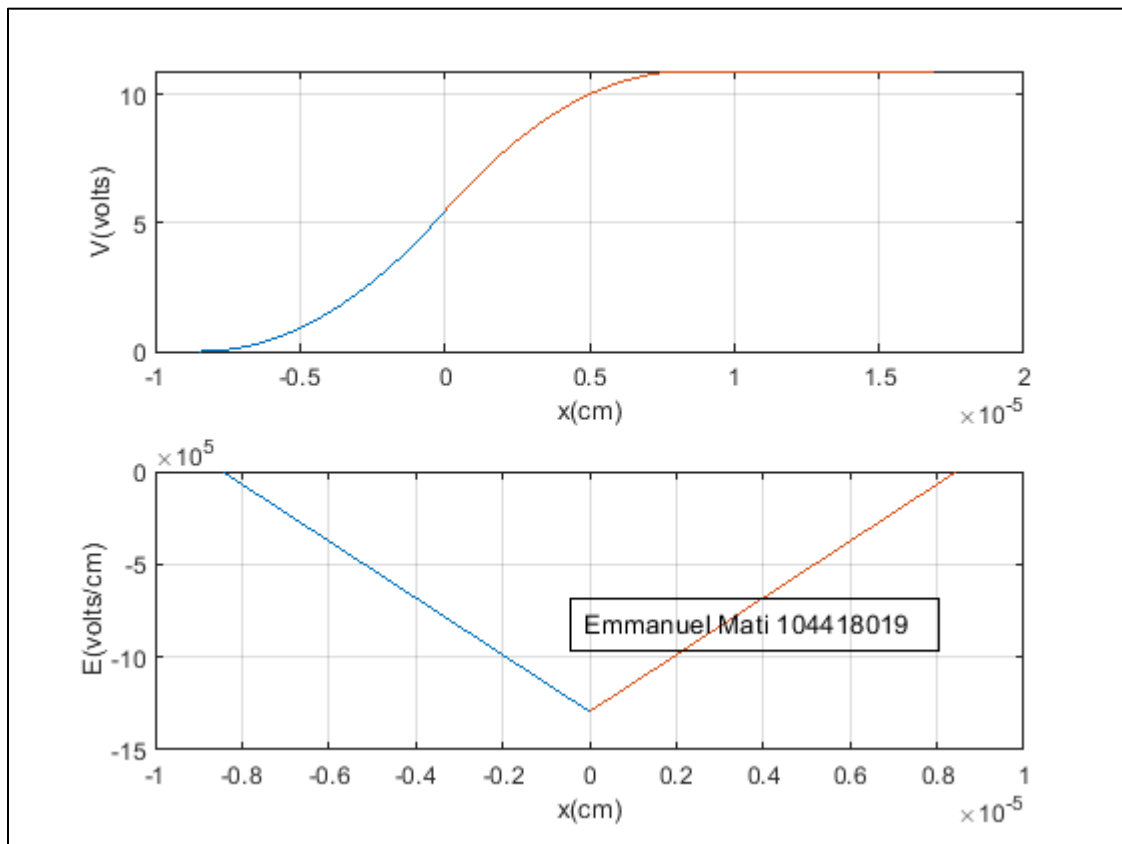
$V_0 = 0.9332$

$x_n = 8.4494e-06$

$x_p = 8.4494e-06$

$W = 1.6899e-05$

$E_0 = -1.2940e+06$



Results for doping concentrations $N_A = 1e15$ & $N_D = 1e18$

Input the p-side doping, $N_A = 1e15$

Input the n-side doping, $N_D = 1e18$

$V_0 = 0.7543$

Bias voltage, V (Smaller than V_0 for forward bias) = 0.5

COMPUTATIONAL RESULTS

$N_A = 1.0000e+15$

$N_D = 1.0000e+18$

$V = 0.5000$

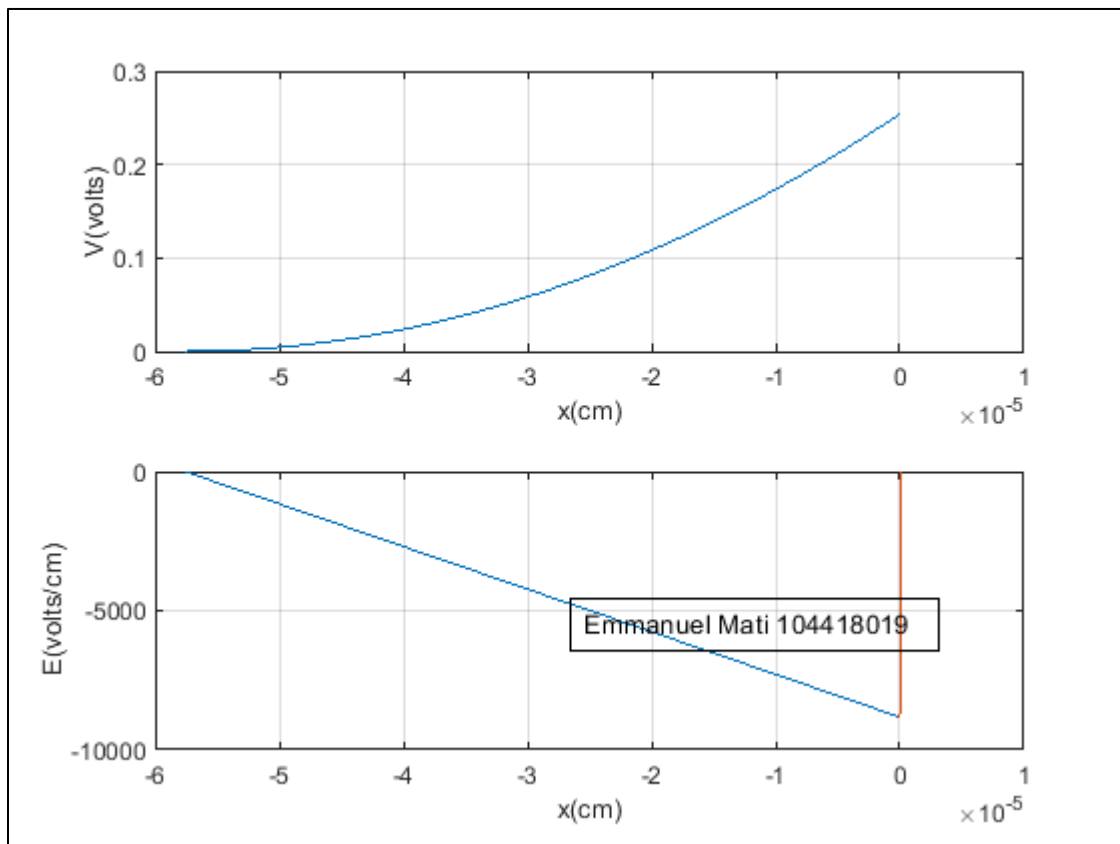
$V_0 = 0.7543$

$x_n = 5.7597e-08$

$x_p = 5.7597e-05$

$W = 5.7655e-05$

$E_0 = -8.8207e+03$



Input the p-side doping, $N_A = 1e15$

Input the n-side doping, $N_D = 1e18$

$V_0 = 0.7543$

Bias voltage, V (Smaller than V_0 for forward bias) = 0

COMPUTATIONAL RESULTS

$N_A = 1.0000e+15$

$N_D = 1.0000e+18$

$V = 0$

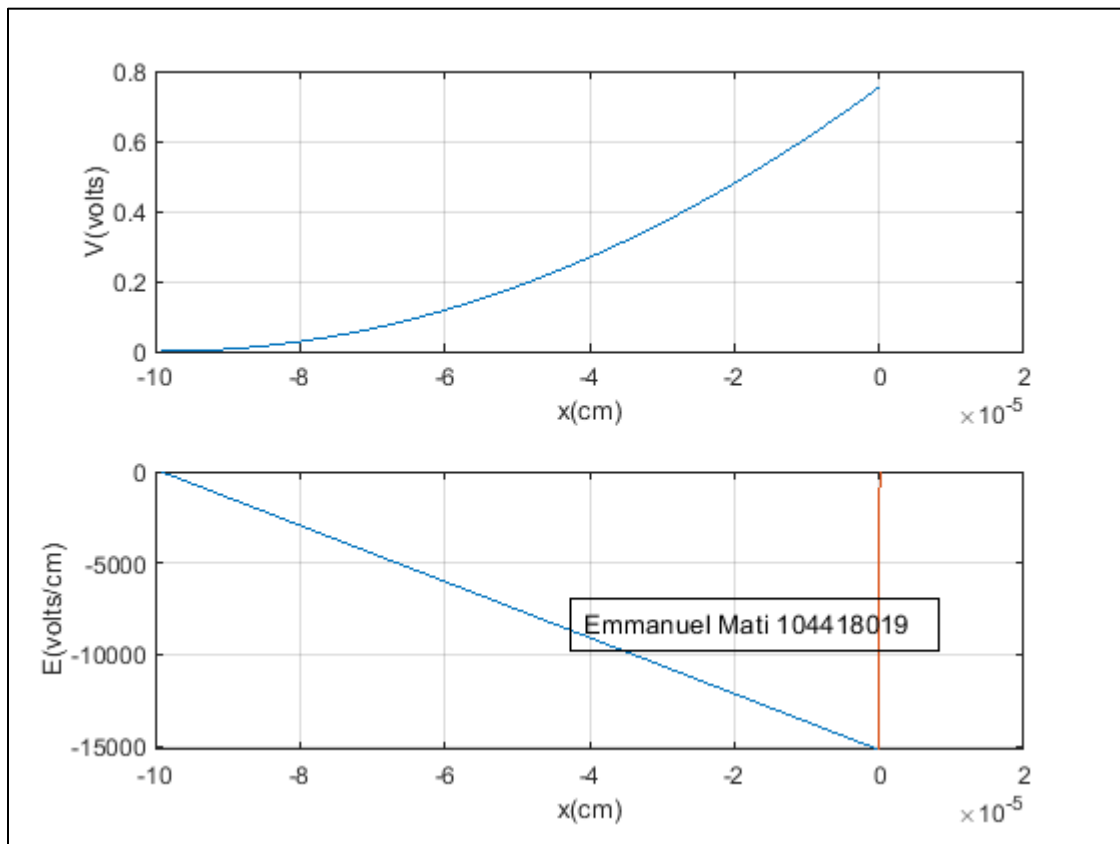
$V_0 = 0.7543$

$x_n = 9.9201e-08$

$x_p = 9.9201e-05$

$W = 9.9300e-05$

$E_0 = -1.5192e+04$



Input the p-side doping, $N_A = 1e15$

Input the n-side doping, $N_D = 1e18$

$V_0 = 0.7543$

Bias voltage, V (Smaller than V_0 for forward bias) = -10

COMPUTATIONAL RESULTS

$N_A = 1.0000e+15$

$N_D = 1.0000e+18$

$V = -10$

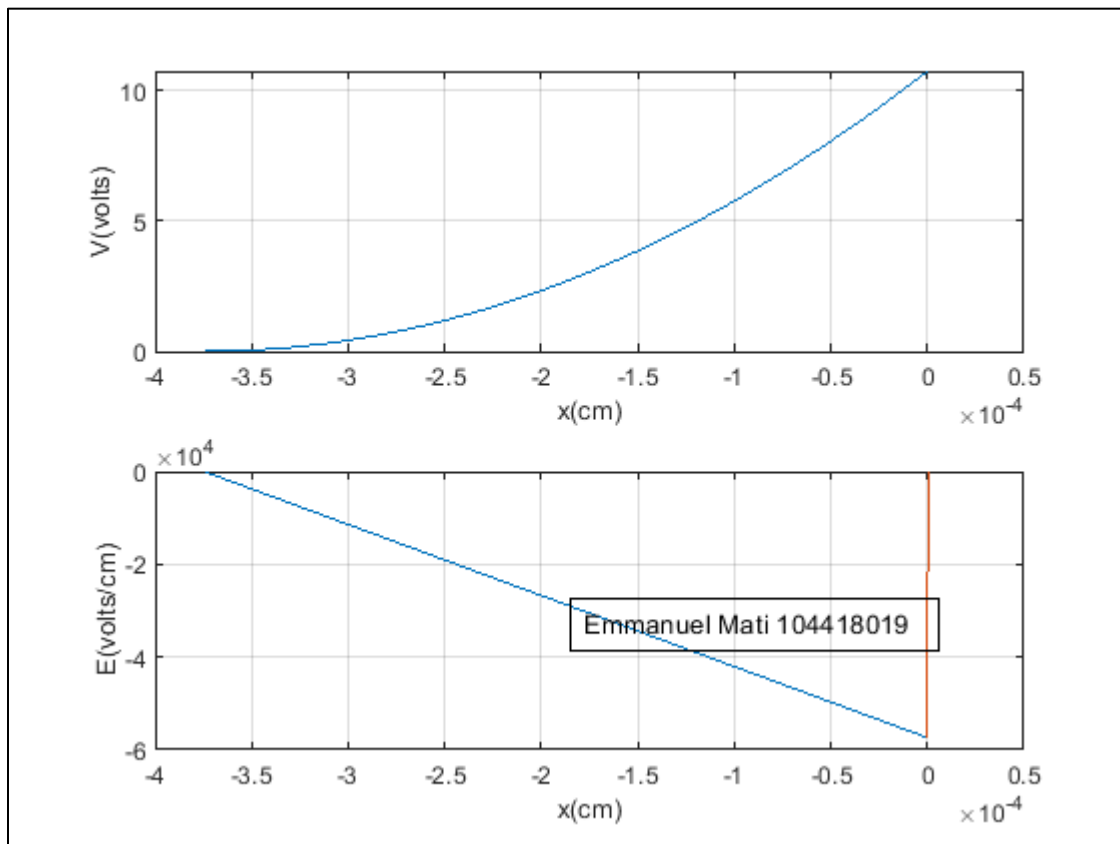
$V_0 = 0.7543$

$x_n = 3.7458e-07$

$x_p = 3.7458e-04$

$W = 3.7495e-04$

$E_0 = -5.7364e+04$



Results for doping concentrations $N_A = 1e18$ & $N_D = 1e15$

Input the p-side doping, $N_A = 1e18$

Input the n-side doping, $N_D = 1e15$

$V_0 = 0.7543$

Bias voltage, V (Smaller than V_0 for forward bias) = 0.5

COMPUTATIONAL RESULTS

$N_A = 1.0000e+18$

$N_D = 1.0000e+15$

$V = 0.5000$

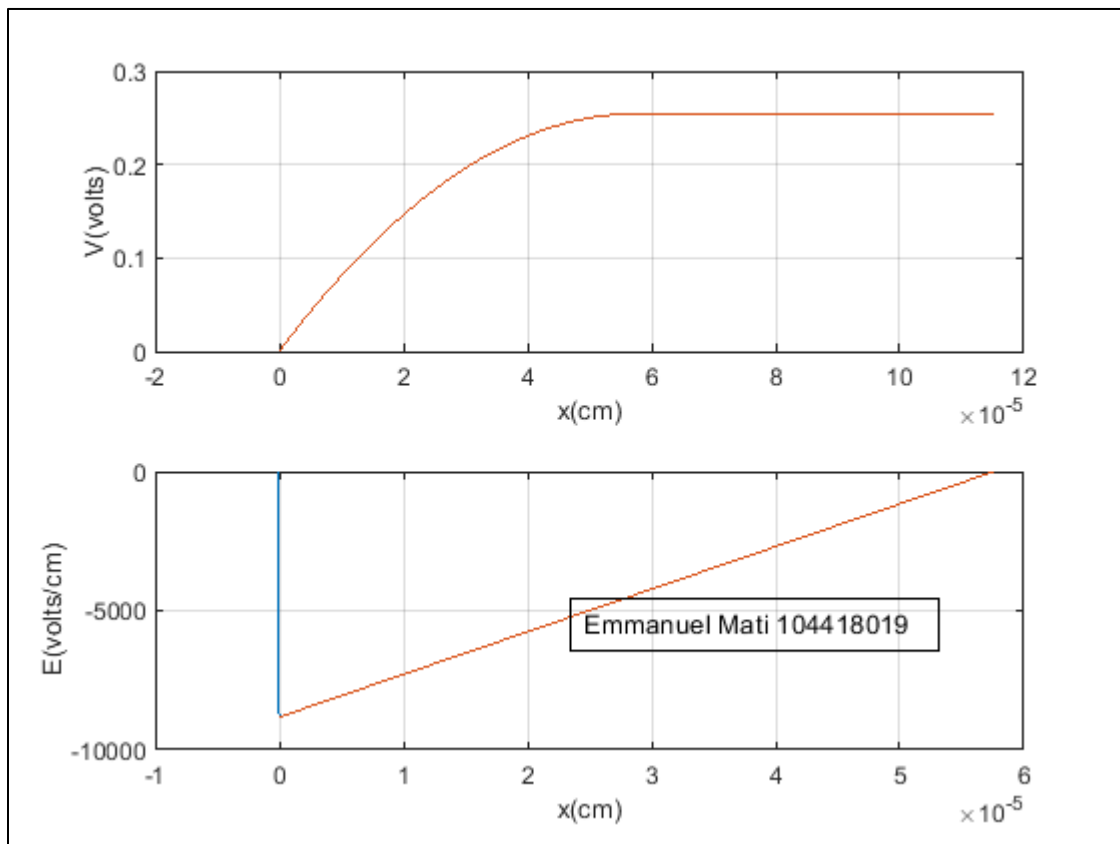
$V_0 = 0.7543$

$x_n = 5.7597e-05$

$x_p = 5.7597e-08$

$W = 5.7655e-05$

$E_0 = -8.8207e+03$



Input the p-side doping, $N_A = 1e18$

Input the n-side doping, $N_D = 1e15$

$V_0 = 0.7543$

Bias voltage, V (Smaller than V_0 for forward bias) = 0

COMPUTATIONAL RESULTS

$N_A = 1.0000e+18$

$N_D = 1.0000e+15$

$V = 0$

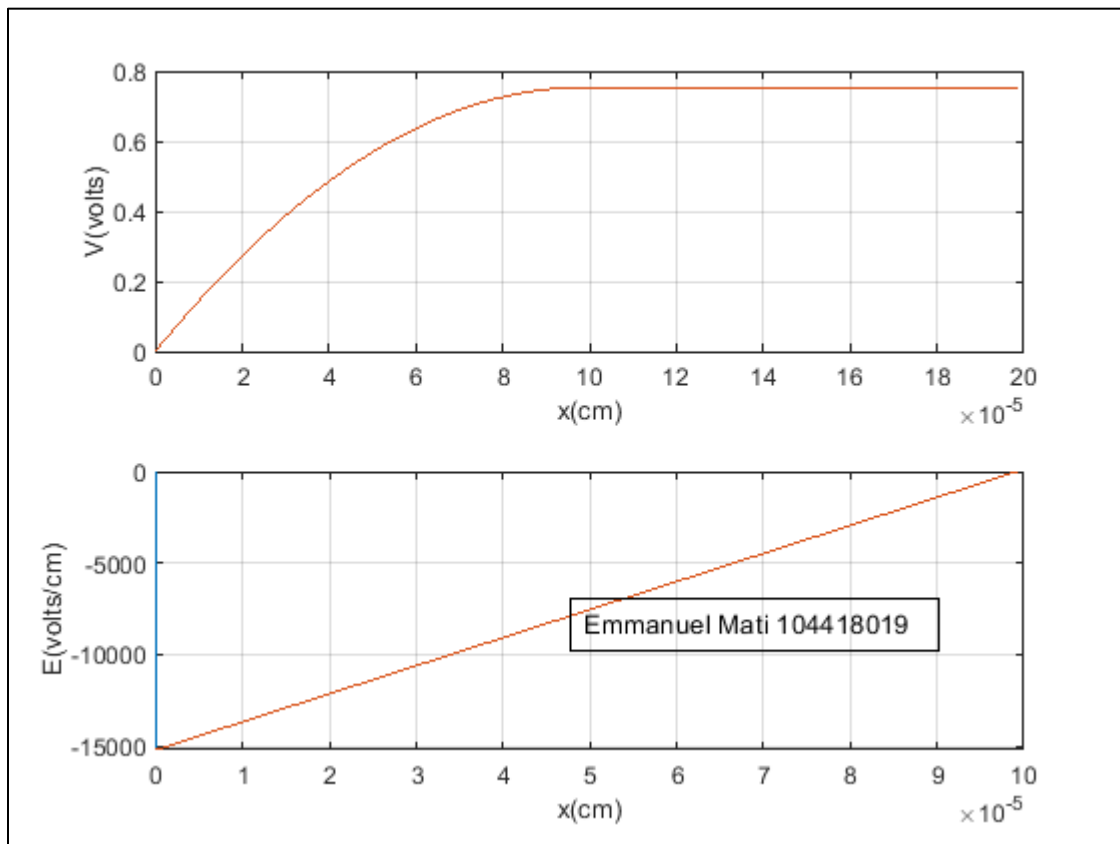
$V_0 = 0.7543$

$x_n = 9.9201e-05$

$x_p = 9.9201e-08$

$W = 9.9300e-05$

$E_0 = -1.5192e+04$



Input the p-side doping, $N_A = 1e18$

Input the n-side doping, $N_D = 1e15$

$V_0 = 0.7543$

Bias voltage, V (Smaller than V_0 for forward bias) = -10

COMPUTATIONAL RESULTS

$N_A = 1.0000e+18$

$N_D = 1.0000e+15$

$V = -10$

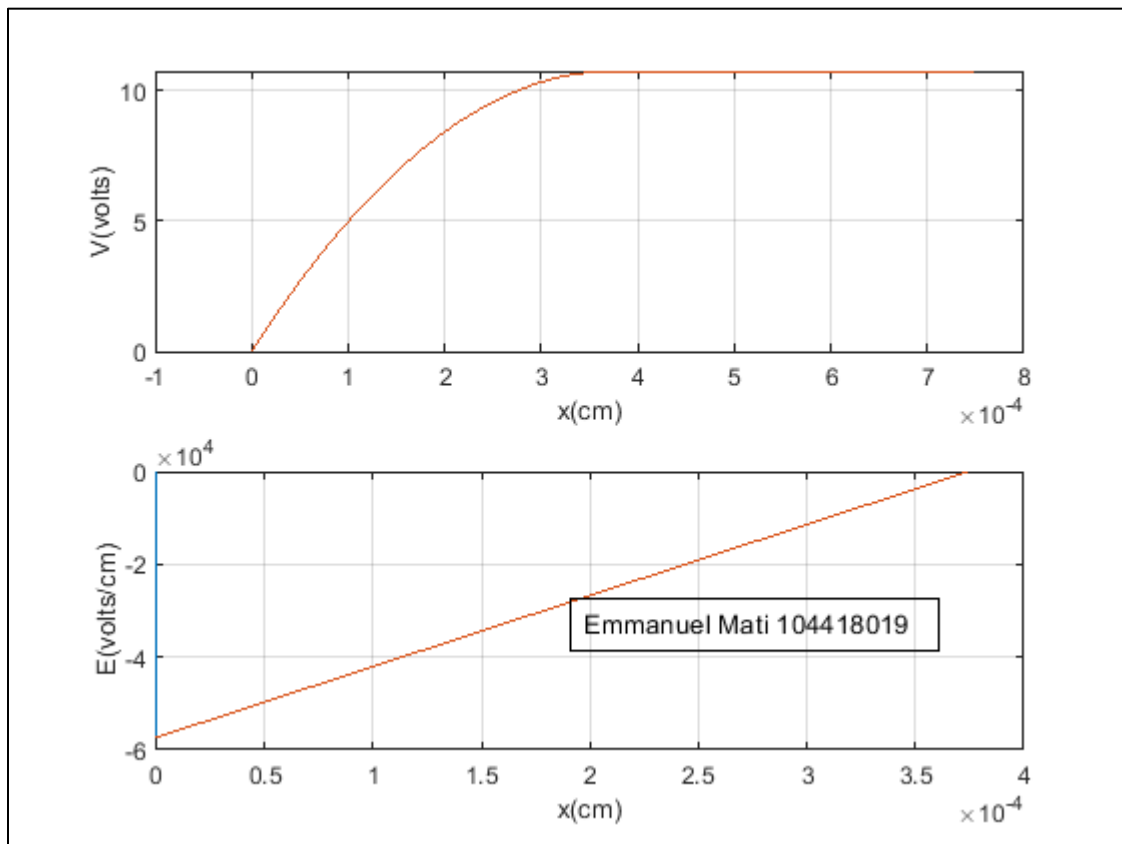
$V_0 = 0.7543$

$x_n = 3.7458e-04$

$x_p = 3.7458e-07$

$W = 3.7495e-04$

$E_0 = -5.7364e+04$



Summary of Observations

Bias Voltage V	NA	ND	V0	xn	xp	W	E0
0.5	1E+15	1E+15	0.5754	2.22E-05	2.22E-05	4.44E-05	-3.40E+03
	1E+16	1E+16	0.6946	1.13E-05	1.13E-05	2.25E-05	-1.73E+04
	1E+17	1E+17	0.8139	4.53E-06	4.53E-06	9.06E-06	-6.93E+04
	1E+18	1E+18	0.9332	1.68E-06	1.68E-06	3.36E-06	-2.58E+05
	1E+15	1E+18	0.7543	5.76E-08	5.76E-05	5.77E-05	-8.82E+03
	1E+18	1E+15	0.7543	5.76E-05	5.76E-08	5.77E-05	-8.82E+03
0	1E+15	1E+15	0.5754	6.13E-05	6.13E-05	1.23E-04	-9.39E+03
	1E+16	1E+16	0.6946	2.13E-05	2.13E-05	4.26E-05	-3.26E+04
	1E+17	1E+17	0.8139	7.29E-06	7.29E-06	1.46E-05	-1.12E+05
	1E+18	1E+18	0.9332	2.47E-06	2.47E-06	4.94E-06	-3.78E+05
	1E+15	1E+18	0.7543	9.92E-08	9.92E-05	9.93E-05	-1.52E+04
	1E+18	1E+15	0.7543	9.92E-05	9.92E-08	9.93E-05	-1.52E+04
-10	1E+15	1E+15	0.5754	2.63E-04	2.63E-04	5.26E-04	-4.02E+04
	1E+16	1E+16	0.6946	8.36E-05	8.36E-05	1.67E-04	-1.28E+05
	1E+17	1E+17	0.8139	2.66E-05	2.66E-05	5.31E-05	-4.07E+05
	1E+18	1E+18	0.9332	8.45E-06	8.45E-06	1.69E-05	-1.29E+06
	1E+15	1E+18	0.7543	3.75E-07	3.75E-04	3.75E-04	-5.74E+04
	1E+18	1E+15	0.7543	3.75E-04	3.75E-07	3.75E-04	-5.74E+04

Discussion

From looking at our summary of observations, we can quickly deduce some relations regarding how changing the bias voltage and doping concentrations can change contact potential V_0 , p-side (x_p) and n-side (x_n) penetration, Width W , and Electric Field E_0 . As the doping concentrations increased, so did the contact potential. Contact potential was not affected by a change in bias voltage. P-side and n-side penetrations increased when we made the bias voltage more negative and decreased when we increased their doping concentrations. Similarly, as the bias voltage increased positively, the widths decreased. Widths also decreased when increasing the doping concentrations. Lastly, the **Magnitudes** of the Electric fields ($|E_0|$) increased when we increased doping concentrations and also increased when we made the bias voltage more negative.