Q1

(a)

$$e^{q\Phi_n/(kT)} = 10^{19-(10-(10-17))} = 10^{16}$$
$$\Phi_i = 16\ln(10)\frac{kT}{q} = 0.9533\ V$$

$$x_d = [\frac{2\epsilon_{Si}}{q}\Phi_i(1/N_a + 1/N_d)]^{0.5} = 0.1116\ \mu m$$
$$x_p = \frac{N_d}{N_a + N_d} = 0.1105\ \mu m$$
$$x_n = \frac{N_a}{N_a + N_d} = 0.0011\ \mu m$$

$$E_{max} = \frac{-qN_a x_p}{\epsilon_{Si}} = -1.715 \times 10^5\ V/cm$$

(b) When $V_a = 1\ V$

$$C_j = \frac{A\epsilon_{Si}}{x_d}\frac{1}{\sqrt{1 + \frac{V_a}{\Phi_i}}} = 3.241 \times 10^{-12}\ F$$

When $V_a = 10\ V$

$$C_j = \frac{A\epsilon_{Si}}{x_d}\frac{1}{\sqrt{1 + \frac{V_a}{\Phi_i}}} = 1.369 \times 10^{-12}\ F$$

The capacitance decrease when the reverse bias increases. $C_j \times \sqrt{V_a}$ changed little when they change.

(c)

$$\mu_p = 150cm^2/(Vs) \qquad D_p = \frac{kT}{q}\mu_p = 3.881\ cm^2/s$$
$$\mu_n = 750cm^2/(Vs) \qquad D_p = \frac{kT}{q}\mu_p = 19.401\ cm^2/s$$
$$L_p = 3.5\mu m \qquad L_n = 75\ \mu m$$
$$I_p = qAn_i^2(\frac{D_p}{L_p N_d} + \frac{D_n}{L_n N_a})(e^{\frac{-qV_a}{kT}} - 1) = 1.3134\ A$$

Q2

(a)

$$I_D = I_S(e^{\frac{q(V_in - V_out)}{kT}} - 1)$$

When $V_{in} - V_{out} \to 0$, *i.e.* $\frac{q(V_in - V_out)}{kT} \to 0$,we have

$$e^{\frac{q(V_in - V_out)}{kT}} \to 1 + \frac{q(V_in - V_out)}{kT}$$

so $I_D \to I_S \times \frac{q(V_in - V_out)}{kT}$ when $V_{in} - V_{out} \to 0$, *i.e.* their relationship is Linear.

Code:

```
Voltage Divider - DC
.model Dbreak D Is=1e-16 Rs=0 N=1 TT=0 Cjo=0pF
.DC vin -2 2 0.01
vin 1 0
d1 1 2 Dbreak
r1 2 0 1.0k
.end
```

Graph:

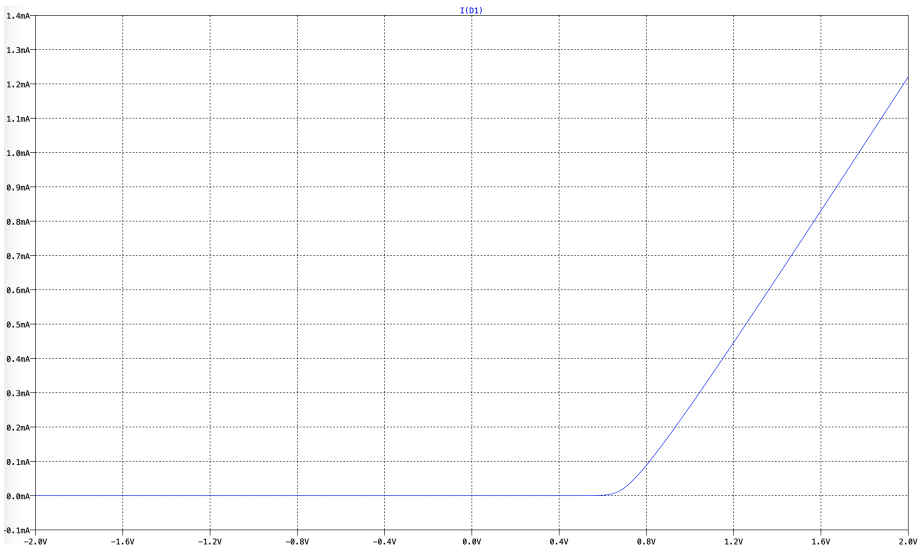

Figure 1: 2_b

(b) According to property of diode, $V_out \geq 0$. And we have $V_{out} + V_D = V_{in}$. In the first half period, when V_{in} is small, V_D is much larger than V_{out}, so there is a "delay" of increase. When V_{in} is large enough, V_{in} and V_{out} behave similarly. In the second half period, $V_{in} < 0$ but $V_out \geq 0$, so $V_{out} = 0$.

Code:

```
Voltage Divider - Sine
.model Dbreak D Is=1e-16 Rs=0 N=1 TT=0 Cjo=0pF
vin 1 0 sin (0.0V 2.0V 60) ac 1.0 dc 0.0
d1 1 2 Dbreak
r1 2 0 1.0k
.control
tran 0.1ms 30ms
plot v(1) v(2)
.end
```

Graph:

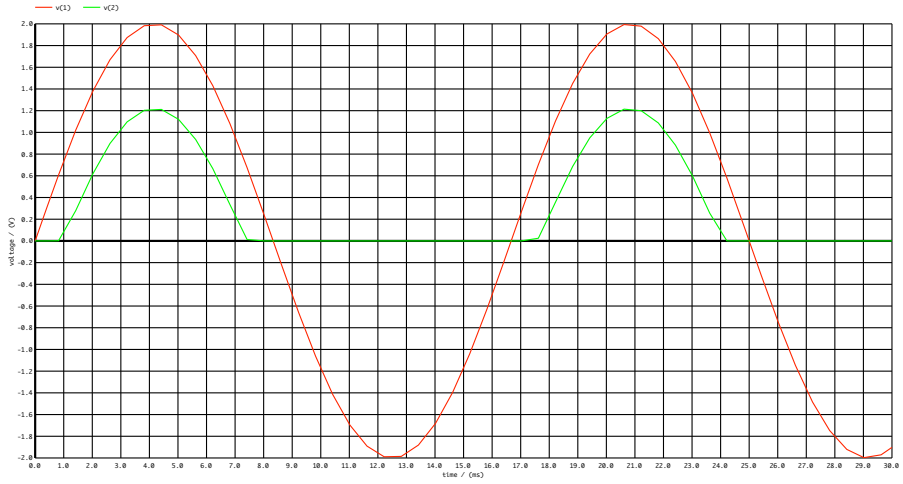

Figure 2: 2_b