ECE 442 Midterm Exam Solutions

1.

a) Built-in potential \( V_{ei} = \frac{KT}{q} \ln \left( \frac{N_A N_D}{n_i^2} \right) \)

Therefore,
\[ N_D = 10^{16} \text{ cm}^{-3} \text{ and } N_A = 10^{17} \text{ cm}^{-3} \]
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No difference in \( V_{ei} \)

b) High-frequency application requires low reverse recovery, which is proportional to the minority carrier lifetime.
So I would choose material “A” with 100 ns lifetime.

c) Thickness of the oxide effects \( \rightarrow \) oxide capacitance. Most important device parameter that would be suspected is \( V_{th} \) (threshold voltage) because \( V_{th} \) is a function of \( C_{ox} \)
d) Parasitic \( C_{GD} \) is same for both MOSFETs. For \( dv/dt \) induced turn-on

\[ \frac{dV}{dt}_{\text{max}} = \frac{V_{th}}{R_G C_{GD}} \]
Now, identical MOSFET \( \rightarrow \) same \( V_{th} \)
So the circuit with lower \( R_G \), i.e. circuit ‘A’ will be larger \( dv/dt_{\text{max}} \), i.e. higher \( dv/dt \) handling capability.

e) Parasitic BJT turns on when resistive dropping the P-base region \( \text{> } V_{th} \)
\( 10^{18} \text{ cm}^{-3} \) doping will have lessen P-base resistance, because resistivity \( \rho \propto \frac{1}{n} \)
So MOSFET with \( 10^{18} \text{ cm}^{-3} \) P-base doping has less chance of malfunction.

2.

a) Superjunction structure
b) Higher P-base doping \( \rightarrow \) higher \( V_{th} \)

c) \( P_{\text{cond}} = I^2 R_{on} \), \( P_{sw} = \frac{1}{2} VI \left[ t_r + t_f \right] f_{sw} \)
For MOSFET A, \( P_{\text{cond}} = I^2 R_{on} = 20 \text{ W} \), \( P_{sw} = \frac{1}{2} VI \left[ t_r + t_f \right] f_{sw} = 200 \text{ W} \)
For MOSFET B, \( P_{\text{cond}} = I^2 R_{\text{on}} = 30 \text{W} \), \( P_{\text{sw}} = \frac{1}{2} V I \left[ t_r + t_f \right] f_{\text{sw}} = 120 \text{W} \)

So the total loss \( P_{\text{tota}} > P_{\text{tolB}} \)

3.

a) 

Increasing reverse voltage \( \Rightarrow \) increasing depletion width \( W_d \)

\[ C_{\text{jun}} \propto \frac{1}{W_d} \]

So, the junction capacitance decreases with increasing reverse voltage.

b) Diodes designed for high-frequency need to have low \( \tau_n \) and \( \tau_p \) to reduce reverse recovery loss.

But reverse saturation current \( \propto \frac{1}{\sqrt{\tau_n}} \frac{1}{\sqrt{\tau_p}} \), so they tend to have high reverse saturation current.