1) Assume that the bandgap for SiGe varies linearly with germanium fraction between that of Si and Ge.

   a) What approximate percentage of Ge would you use to obtain a bandgap of 0.9eV?

      \[ \approx 50\% \]

   b) Suppose you constructed a diode consisting of p-type SiGe with a bandgap of 0.9eV on n-type Si. Assume both sides are doped to 1E17 and that the electron affinity for SiGe and Si is identical.

      i) Sketch a band diagram for the above diode. Label all values as appropriate.

      ![Band Diagram]

      ii) Would you expect to have more electron current or hole current? Why?

         Should have more electron current, due to reduced barrier on conduction band side. (I also accepted an answer of no current due to equilibrium conditions, since I didn’t specify a bias)

      iii) Would you expect to breakdown voltage to be increased or reduced relative to a pure Si diode of similar doping? Why?

         Breakdown voltage is likely reduced since SiGe has a lower critical field than Si, resulting in increased likelihood of avalanche. Note that tunneling is probably not a problem in such a lightly doped device.
2) Consider a silicon PIN diode with doping on the P and N sides of ~1E18. Assume the I region is 5 microns long.

a) Sketch the band diagram for the above diode, with the P region on the left and the N region on the right. Label as appropriate.

b) Sketch the field vs. position plot for the above diode.

c) All else being equal, sketch the reverse bias IV characteristics for the above PIN diode and also for a PN diode with similar doping. Explain any differences, using equations as appropriate.

\[ V_{BR} \text{ will be larger since peak field is reduced. } I_{off} \text{ will be larger due to increased generation current, caused by larger depletion width } I_r = I_0 + A \frac{qnW_{dep}}{\tau_{dep}} \]

d) List two advantages of the PIN structure over a PN structure in rectification applications?

* Faster switching due to lower capacitance, and larger breakdown voltage due to reduced peak field.
e) PIN diodes are often used in photo-sensing applications.

i) Compare the sensitivity of a PIN diode to an equivalently doped PN diode. Give reasons.

*More sensitive due to larger depletion region, resulting in larger volume over which photons can be collected.*

ii) What phenomenon prevents us from making diodes with very wide I-regions? What is the consequence of this phenomenon on leakage-current and photodiode sensitivity? Give reasons.

*Recombination; as the depletion region gets too long, recombination in the I-region is no longer negligible. This results in increased leakage current and reduced sensitivity vis a vis an identical structure with no recombination.*

3) We often use the charge control relationship to model the transient behavior of diodes.

a) Suppose I were to add several trap states in the quasi-neutral regions of a diode. What would happen to the turn-off time? Give reasons.

*Turn-off time would reduce due to faster recombination of excess carriers.*

b) What is the consequence of adding these traps on (give reasons):

i) Leakage current:

*Leakage current will increase due to reduced L, resulting in increased I₀.*

ii) Drive current:

*Drive current will increase for the same reason as above.*