State Examination Commission – Physics Higher Level, 2009

Question 12b

A semiconductor diode is formed when small quantities of phosphorus and boron are added to adjacent layers of a crystal of silicon to increase its conduction.
Explain how the presence of phosphorus and boron makes the silicon a better conductor. (6)
What happens at the boundary of the two adjacent layers? (9)
Describe what happens at the boundary when the semiconductor diode is (i) forward biased, (ii) reverse biased. (9)
Give a use of a semiconductor diode. (4)

A semiconductor diode is formed when small quantities of phosphorus and boron are added to adjacent layers of a crystal of silicon to increase its conduction.
Explain how the presence of phosphorus and boron makes the silicon a better conductor. (6)

Phosphorous is pentavalent and increases the number of electrons available for conduction when added as a dopant to pure silicon. When added we end up with n-type semiconductor

Boron is trivalent and increases the number of holes available for conduction when added as a dopant to pure silicon. When added we end up with p-type semiconductor

What happens at the boundary of the two adjacent layers? (9)

Electrons drift from n-type into p-type, across the boundary, where they combine with holes forming a depletion layer that is a negative region. Holes do the reverse at the boundary. The formation of the negative and positive region , either side of the boundary, causes a difference in potential known as the junction voltage.

Describe what happens at the boundary when the semiconductor diode is (i) forward biased, (ii) reverse biased. (9)

(i) Forward bias: When the positive terminal of the battery is connected to p-type, and negative to n-type, the electrons in the n-type are repelled and move towards the junction, likewise, the holes in the p-type are repelled and also move towards the junction. At the junction electron-hole recombination occurs – the depletion layer decreases. In the meantime, the negative of the battery provides a fresh supply of electrons to the n-material, and the positive terminal pulls off electrons from the p-material, forming new holes in the process. Consequently, a continual flow of charge, a current, is maintained.
(ii) Reverse bias: When the negative terminal of the battery is connected to p-type, and positive to n-type, the battery forces electrons into the n-type and holes into the p-type away from the junction, increasing the junction voltage until it opposes the battery potential (increased depletion layer). Very little current can then be sustained through the device – it is non-conducting.

Give a use of a semiconductor diode. (4)

Conversion of a.c. to d.c. In a rectifier