SEMICONDUCTOR

Challenging **MCQ** questions by The Physics Cafe

Compiled and selected by The Physics Cafe

1 **(a)** Explain the origin of the depletion region in a p-n junction.

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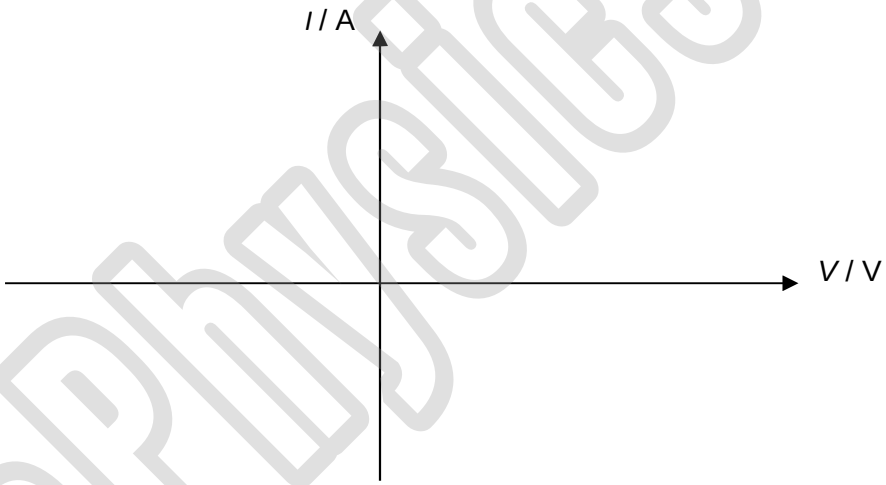
…… [4]

(b) Sketch the *I*-*V* characteristic of a p-n junction in the diagram below [1]



(c) Explain how a p-n junction operates in a forward biased connection.

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…… [3]

Ans **(a)** A *p*-*n* junction is formed when a *p*-type semiconductor is joined to an *n*-type semiconductor.

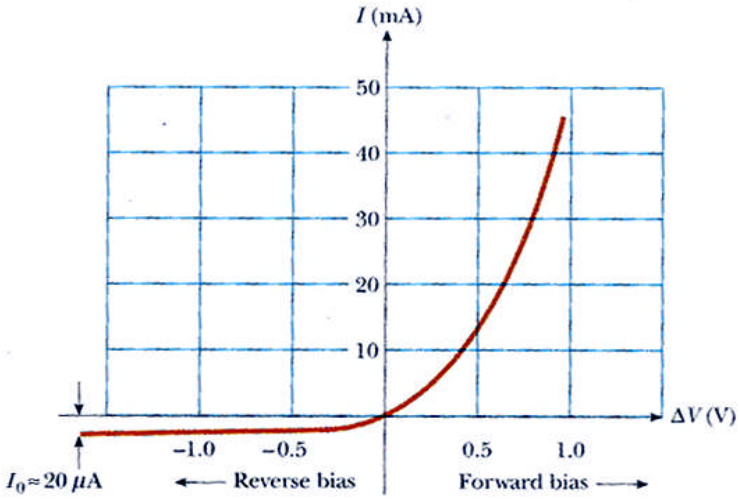
When the junction is formed, the difference in concentration of electrons between the *n*-side and the *p*-side leads to mobile ***n*-side** donor **electrons diffusing across** the junction and **filling** the **holes** in the ***p*-side**.. [B1]

As the ***n*-side donor electrons diffuse** across the junction, they **leave behind immobile positive ions** (recall that both an *n*-type and a *p*-type semiconductor on their own are electrically neutral). Similarly, the **filling of a hole** in the *p*-type **makes a negative ion**. [B1]

Since the **two sides** of the depletion region each **carry a net charge**, an **internal electric field** is **set up within** the **depletion region**. [B1]

As **diffusion** of the *n*-side donor electrons to the *p*-side **continues**, the **depletion region widens** and the **difference in charge between the *n*-side and the *p*-side builds up**. Eventually, the **internal electric field** becomes **so strong** (10^4 – 10^6 V cm^{-1}) that it **prevents further diffusion** of the electrons across the junction and ensures that there is no current when no external potential difference is applied. [B1]

(b)



Current increases exponentially with increasing forward bias passing through the origin.

(c) p-side connected to positive terminal and n side connected to negative terminal of voltage source [B1]

The **internal potential difference** (due to the difference in charge between the *n*-side and the *p*-side) **decreases** as **its polarity is opposite to the polarity of the external voltage source.**

The depletion zone becomes narrower and no longer effectively inhibits the flow of electron [B1] This allows current to flow

2 **(a)** State the charge (positive, negative or neutral) on each of the following:

p-type semiconductor: ……

n-type semiconductor: …… [1]

(b) A semiconductor diode is made up of a p-type semiconductor joined with an n-type semiconductor.

Explain the formation of the depletion region in the semiconductor diode.

You may draw a diagram if you wish.

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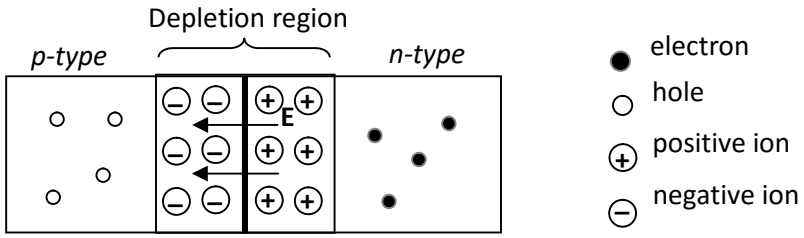
…… [3]

Ans **(a)** neutral

neutral

(b) Clearly labelled diagram with mobile electrons and +ve ions in n-type, mobile holes and –ve ions in p-type, correct arrow for E, shown



Due to a concentration gradient across the junction, the mobile electrons of the n-type side nearest the junction diffuse to the p-type side, leaving behind a region of fixed positive ions.

Similarly, mobile holes from the p-type side diffuse to the n-type side, leaving behind fixed negative ions.

At the junction, the electrons recombine with the holes creating a depletion zone of fixed positive ions and negative ions, which are depleted of mobile charge carriers.

The fixed positive ions in n-type and fixed negative ions in p-type create an internal electric field (E_{int}) from the n-type side to the p-type side, which opposes further diffusion of both electrons and holes.

Any 3 points

3 **(a)** Fig. 5.1 shows a p-type semiconductor placed in contact with another of n-type.

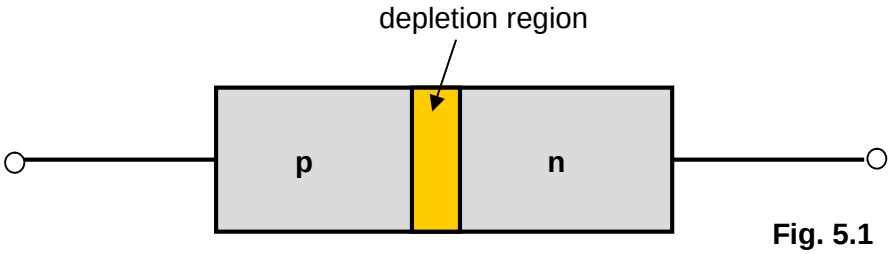


Fig. 5.1

Describe the origin of the depletion region at the junction.

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[2]

(b) Describe how band theory is used to explain the difference between the conduction properties of insulators and intrinsic semiconductors.

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[3]

Ans **(a)** Due to concentration gradient, the mobile electrons from the n-side and the mobile holes from the p-side diffuse across the junction resulting in the n-side with a positive charge layer, and the p-side with a negative charge layer. [1]

The positive and negative charge layers on the 2 sides of the junction set up an electric field which prevents any further movement of charge, resulting in a depletion layer. [1]

(b) In insulators, the filled valence band is separated from empty conduction band by a large energy gap ~ 10 eV. Few or no electrons have enough energy to cross the gap. [1]

In intrinsic semiconductor, the energy gap is small, only ~1eV. [1]

At low temperatures, semiconductor behaves like insulators. At high temperatures, electrons from valence band have sufficient energy to jump to conduction band, resulting in conduction of current. [1]