MINISTRY OF HIGHER EDUCATION AND SIENTIFIC RESEARCh - SAWA UNIVERSITY - ENGINEERING COLLEGE -PHYSICS DEPT. SECOND STAGE 2.nd COURSE

جامعة ساوة الاهلية

كلية التقنيات الهندسية

القسم: الفيزياء الطبية والعلاج الاشعاعي

المرحلة الثانية /الفصل الثاني

عنوان المحا ضرة:

the types of semiconductoers

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رقم المحا ضرة (2)

بسم الله الرحمن الرحيم

IN THE NAME OF GOD, THE MOST GRACIOUS, THE MOST MERCIFUL

Department of Physics and Radiotherapy

In order to increase current carriers ,we have to add the specific impurities ((dopant)) a substance used to produce a desired electrical characteristic in a semiconductor.

There two types of impurities (dopant) “” Pentavalent and Trivalet”” impurities ,when we add pentavalent impurities .we obtain “”N-type semiconductor. while ,we add trivalent ,we obtain P-Type semiconductor.

N-type semiconductor.

The n-type semiconductor is an intrinsic semiconductor doped with atoms of Group (V) which have (5) elecrons such as phosphorus (P), arsenic (As), or antimony (Sb) as an impurity. While , Silicon of Group IV has four valence electrons.

If a small amount of phosphorus is added to a pure silicon crystal, one of the valence electrons of phosphorus becomes free to move around (free electron*) as a surplus electron. When this free electron is attracted to the “+” electrode and moves, current flows. as shown in figure (8) below.

So this free electron is the carrier of an n-type semiconductor.

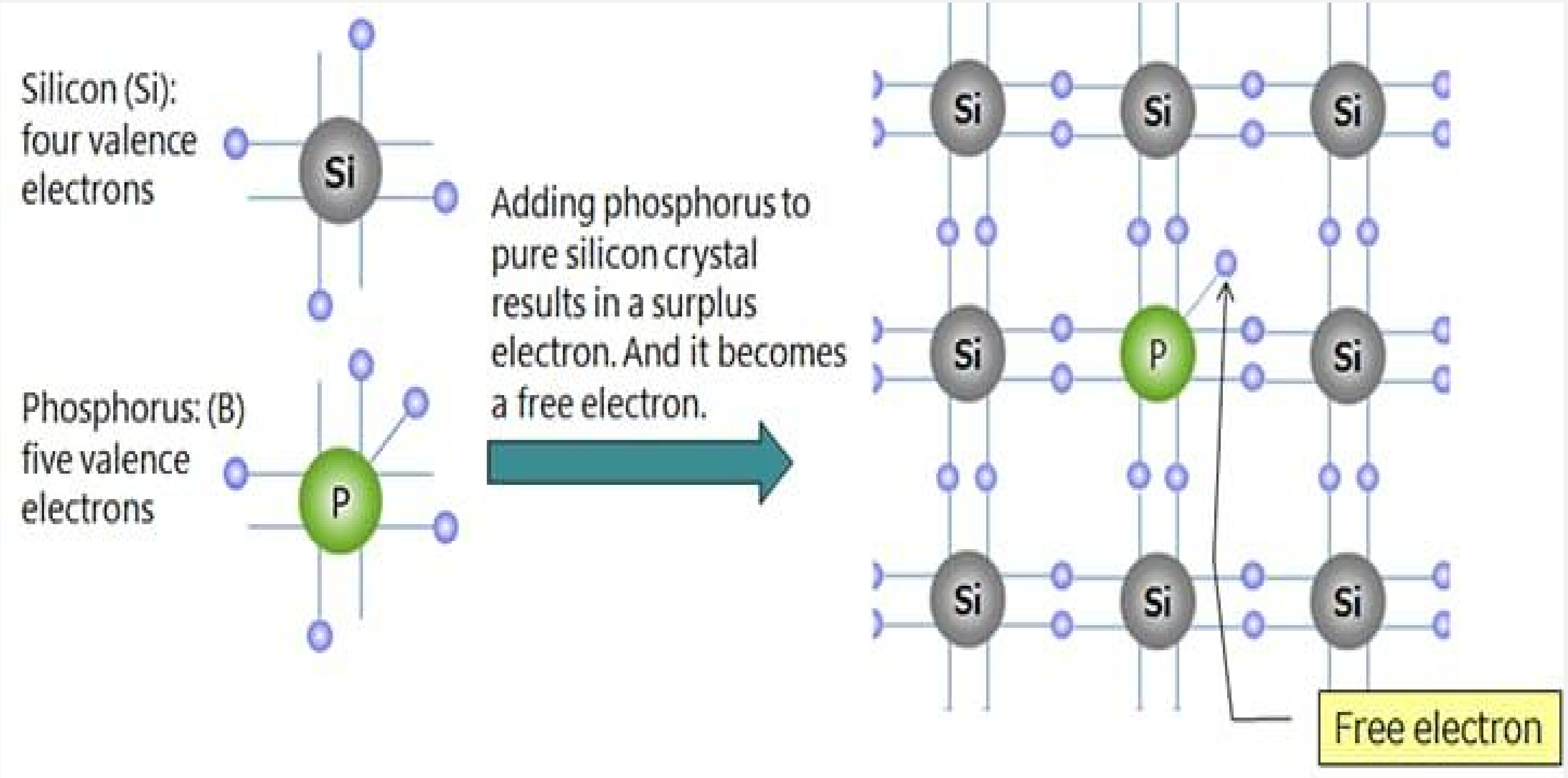

Fig. (8) pure silicon doped with phosphous atom

P-type semiconductor.

The p-type semiconductor is an intrinsic semiconductor doped with boron (B) or indium (In). Silicon of Group IV has four valence electrons and boron of Group III has three valence electrons. If a small amount of boron is doped to a single crystal of silicon, valence electrons will be insufficient at one position to bond silicon and boron, resulting in holes* that lack electrons. When a voltage is applied in this state, the neighboring electrons move to the hole, so that the place where an electron was present becomes a new hole, and the holes appear to move to the "–" electrode in sequence. as shown in Figure (9)

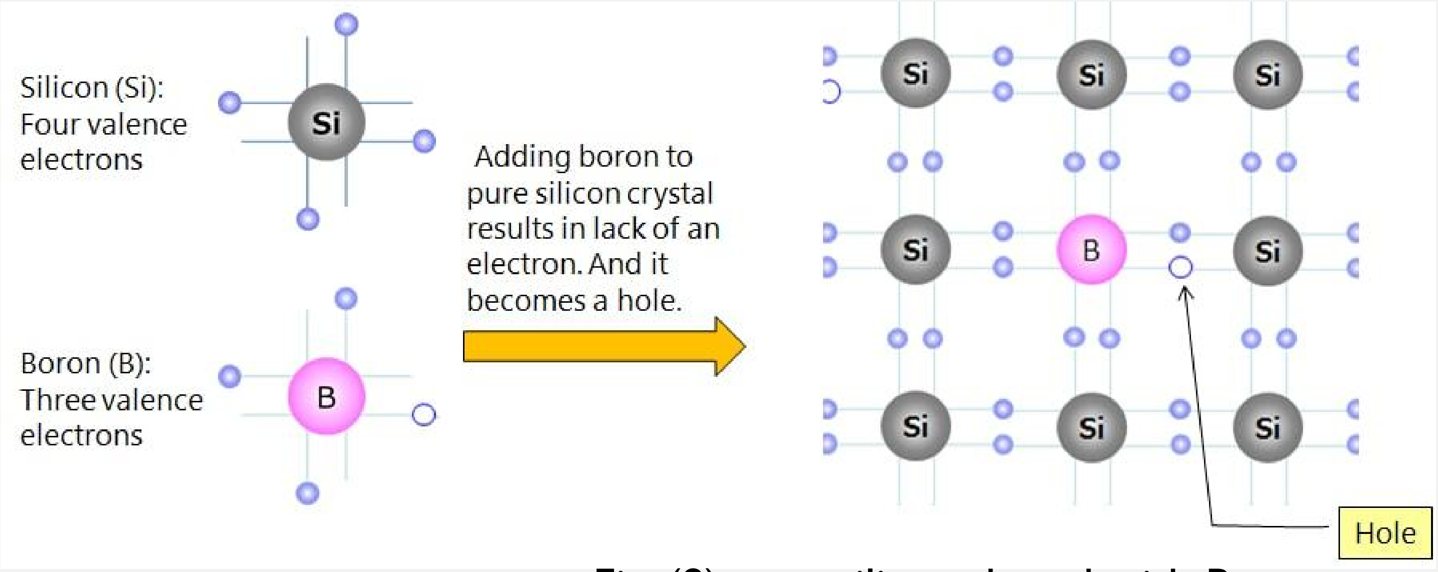

Fig. (8) pure silicon doped with Boron atom

This hole is the carrier of a p-type semiconductor.

P-N Junction

The **p–n junction** is a combination of two types of semiconductor materials, p-type and n-type, The p-side or the positive side of the semiconductor has an excess of holes, and the n-side or the negative side has an excess of electrons.as show in Figure (10)

Hence, there is a difference in the concentration of holes and electrons at the two sides of a junction. The holes from the p-side diffuse to the n-side, and the electrons from the n-side diffuse to the p-side. These give rise to a diffusion current across the junction

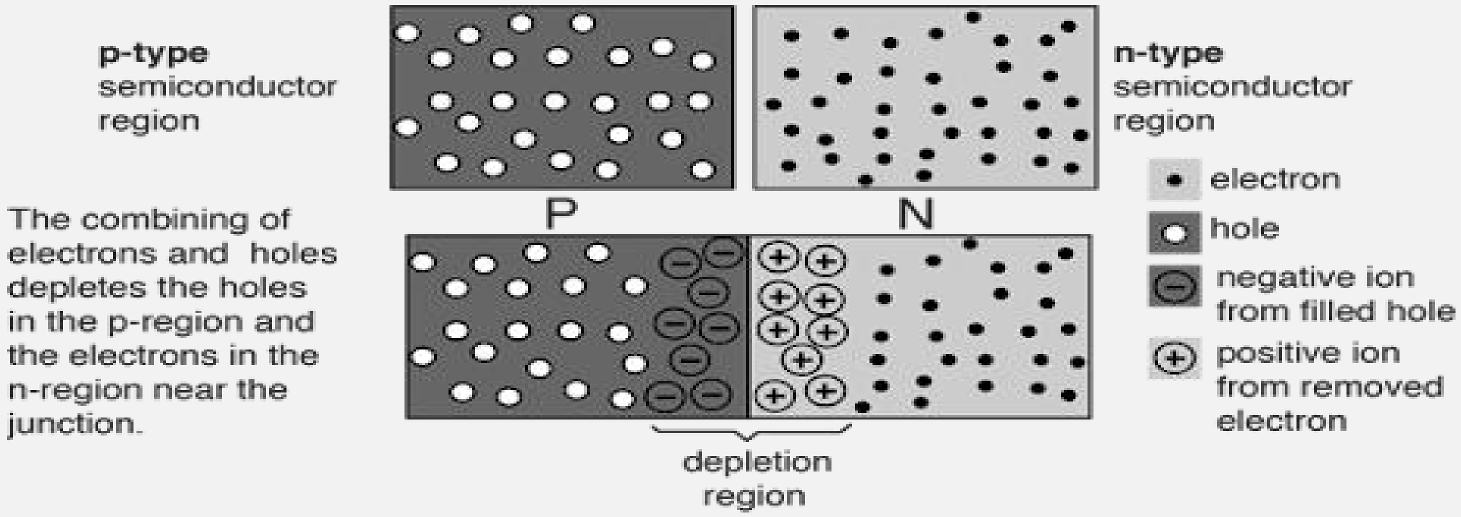

Fig. (10) P-N Junction (befor diffusion and after diffusion)

Majority And Minority Carriers In N-type Semiconductors

* On the N - side, the electrons are the dominant carriers and so are called majority carriers, while the holes are the minority carriers.

Majority And Minority Carriers In P-type Semiconductors

* On the p side,the holes are the dominant carriers and so are called majority carriers

. A few thermally generated electrons will also exist in the p side; these are termed minority carriers.

Drift And diffuisin Current (Holes And electrons)

Diffusion current: **Typically,** The movement of carriers from regions of higher concentration to regions of lower concentration is called **diffusion current**

Drift current **:minority carriers will flow across the junction. on the other words ,minority electrons will flow from P side to N side and minority holes will move from N sideto P side. This movement of minority carriers due the electric field across the junction is called drift current**

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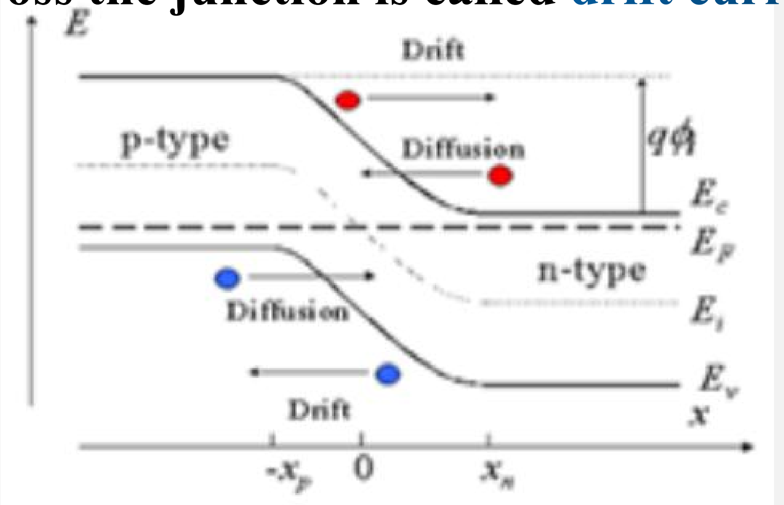

Fig . (11) Drift And diffuisin Current (Holes And electrons)

at equilibrium state , the net current (diffusion and drift current) is zero for both electrons and holes because the diffusion current is equal and opposite to the drift current for both carriers.

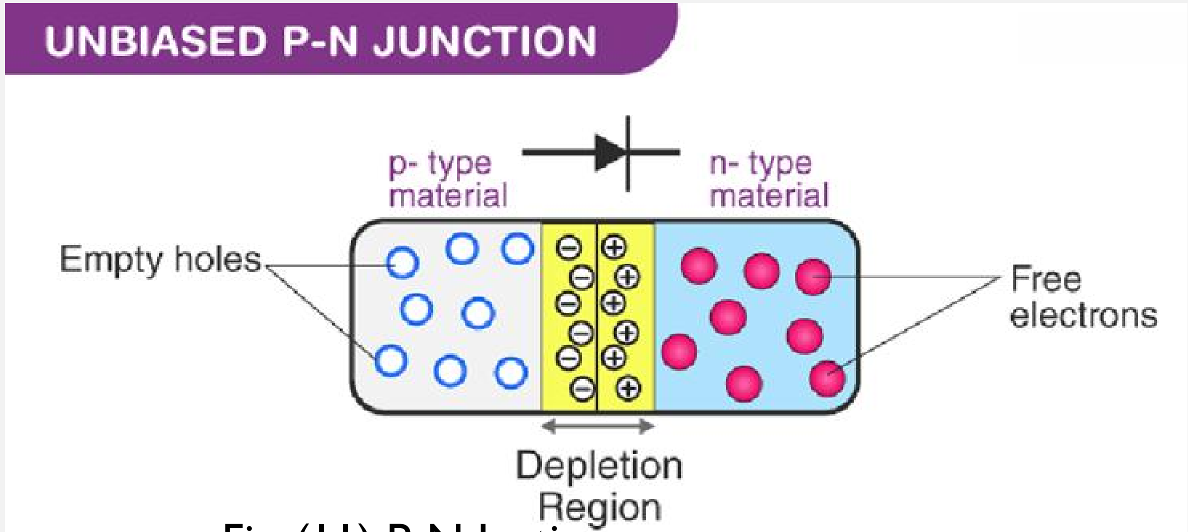

Fig. (11) P-N Juction

Biasing States for the P-N Junction Diode

(a) Forward Bias

The positive terminal of the voltage potential is connected to the p-type while the negative terminal is connected to the n-type. as shown in fig (12) below:

The depletion region's resistance (r_f) becomes negligible when the applied large voltage . In silicon, at the voltage of approximatly equal to 0.7 V, the resistance of the depletion region becomes completely negligible " $r_f = 0\ \Omega$ "

the barrier potential depends on the nature of semiconductor material its value is 0.7v for silicon and 0.3v for germanium, across the deplation layer.

Effects of temperature on barrier voltage

Barrier potential depends on temperatures of P-N junction .Increasing of temperature causes decreasing in barrier potential and vise versa.For each one temperaure degree ,the variation in barrier valtage equal to:

$$\triangle v = -0.0025(\triangle T) \quad \text{-------------------} \quad (1)$$

Example :

Calculate the barrier potential of silicon diode at (75 C°)

Solution :

the standerd barrie voltage of silicon diode = 0.7v

room temperature = (25 C^{o})

from equation (1)

$\triangle v = -0.0025(\triangle T)$

$\triangle v = V_2 - V_1$

$\triangle T = T_2 - T_1$

$V_2 - V_1 = -0.0025 (T_2 - T_1)$

V_2 - 0.7v =-0.0025 (75-25)

V_2 = 0.7v -0.0025 (75-25)

=0.7v -0.125v

= 0.575v

Homework :

Calculate the barrier potential of Germanium diode at (0 C^{o})

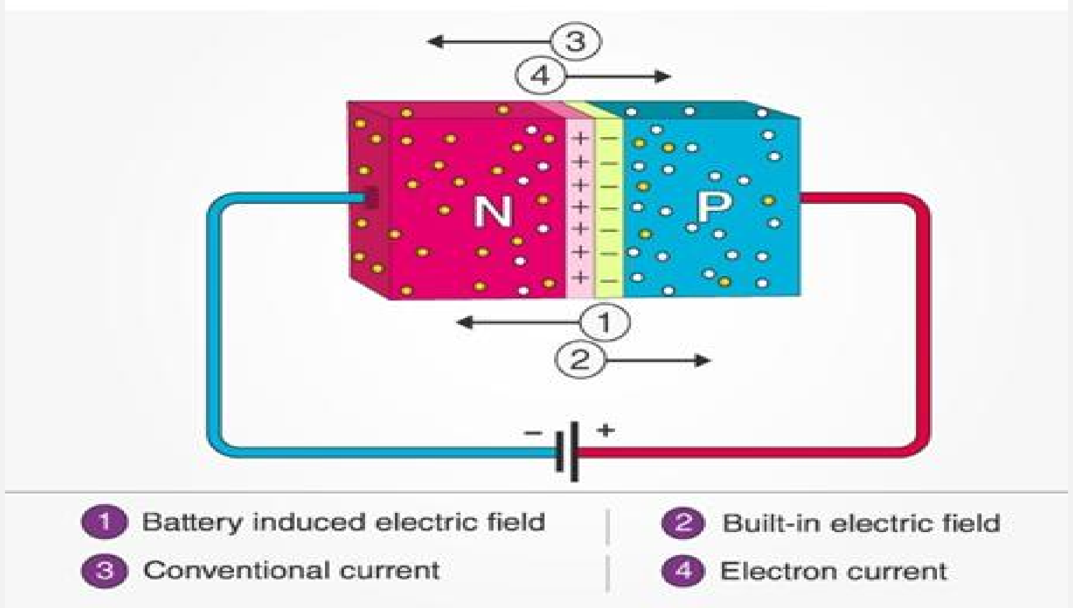

Fig.(12) Forward Bais

(b) Reverse Bias

In the negative terminal of the voltage potential is connected to the p-type and the positive is connected to the n-type. as shown in fig (13)

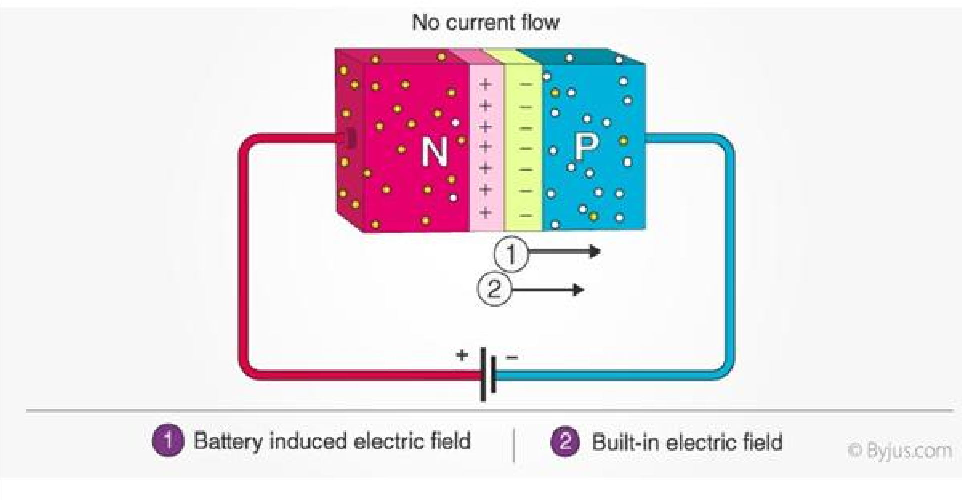

Fig.(13) Reverse Bais

Types of currents in reverse bais

There are four types of currents in reverse bais :

1- Minority carriers current

2-Surface- leakage current

3- Ephemeral acrossing current

The formula used in the P-N junction to find barrier potential as in following equation:

$$V_B = \frac{kT}{q} \ln \left[\frac{ND * NA}{(ni)^2}\right] \qquad \text{-------------------------- (2)}$$

k ≡ poltsman constant

T≡ Temperature degree

q≡ electron charge

ND * NA ≡ are the impurities concentrations.

ni ≡ is the intrinsic concentration

VB≡ barrier potential≡

Example (1) calculate the barrier potental if you have :

Nd=10^{15} cm^{-3}

Na=10^{18} cm^{-3}

room temperature = 27 c

ni = 1.45 x 10^{10} cm^{-3}

Solution :

$$V_B = \frac{kT}{q}\ln(\frac{N_d N_a}{n_i^2}) \quad ,T = 300K, q = 1.6\times10^{-19}C, k = 1.38\times10^{-23} J/K$$

$$V_B = \frac{(1.38\times10^{-23})\times300}{1.6\times10^{-19}}\ln[\frac{(10^{15})\times(10^{18})}{(1.45\times10^{10})^2}]$$

$$V_B = 258.75\times10^{-4}\ln[\frac{10^{33}}{2.1025\times10^{20}}]$$

$$V_B = 0.025875\times\ln[4.756\times10^{12}]$$

$$V_B = 0.7553\ V$$

Carrier Lifetime (τ)

The carrier lifetime (or simply the lifetime) is generally referred to as the time during which a charge carrier is free to move and so to contribute to electric conduction. We can define τ_n as the time that an excited electron spends in the conduction band and τ_p as the time that an excited hole spends in the valence band . Supposing that a uniform excitation generates G electron–hole pairs per second per unit volume in a solid, then the generated electron and hole densities in the conduction band and valence band are, respectively:

$\Delta n = G\tau_n$ and $\Delta p = G\tau_p$

In the steady state, the rate of generation is equal to the rate of trapping. thus we have

$\Delta n = \Delta p$

then

$\tau_n = \tau_p$

Quiz (Group B)

Answer with true or false symbol for the following

1- Conduction Band is a delocalized band of energy levels in acrystalline solid which is partly filled with electrons.

2-Bohr's atomic model came into existence with the refusing of Rutherford's model of an atom

3- An intrinsic semiconductor, also called a pure semiconductor.

4-The number of charge carriers is therefore determined by the properties of the material itself instead of the amount of impurities

5- the number of electons in fourth shell are 23 electrons.

6-In the steady state, the rate of generation is equal to the rate of trapping.

7- In the steady state, the rate of generation is equal to the rate of trapping, leads to $\tau_n = \tau_p$.

8-Increasing of temperature causes Increasing in barrier potential

Quiz Group A

1- at equilibrium state , the net current (diffusion and drift current) is zero

2- The movement of carriers from regions of higher concentration to regions of lower concentration is called Drift current

3-On the N - side, the electrons are the dominant carriers and so are called majority carriers

4-On the p side,the holes are the dominant carriers and so are called minority carriers

5-the barrier potential not depends on the nature of semiconductor material

6- difference in the concentration of holes and electrons at the two sides of a junction causes diffuion of both electrons and Holes across the junction .

7-Barrier potential depends on temperatures of P-N junction

8- decreasing of temperature causes Increasing in barrier potential

انتهى .... شكرا لاستماعكم