

CBSE NCERT Solutions for Class 12 Physics Chapter 14

Back of Chapter Questions

14.1. In an n-type silicon, which of the following statement is true:

- (a) Electrons are majority carriers and trivalent atoms are the dopants.
- (b) Electrons are minority carriers and pentavalent atoms are the dopants.
- (c) Holes are minority carriers and pentavalent atoms are the dopants.
- (d) Holes are majority carriers and trivalent atoms are the dopants.

Solution: (c)

In an n-type of semiconductors, the electrons are the majority carrier, holes are minority carrier. The n-type semiconductor is obtained when pentavalent atoms are doped into silicon.

14.2. Which of the statements given in Exercise 14.1 is true for p-type semiconductors.

Solution:

The statement is (d) true.

It is because in a p-type semiconductor, the holes are the majority carriers and the electrons are the minority carriers. The p-type semiconductor is obtained when a trivalent atom is doped into silicon.

14.3. Carbon, silicon and germanium have four valence electrons each. These are characterised by valence and conduction bands separated by energy band gap respectively equal to $(E_g)_C$, $(E_g)_{Si}$ and $(E_g)_{Ge}$. Which of the following statements is true?

- (a) $(E_g)_{Si} < (E_g)_{Ge} < (E_g)_C$
- (b) $(E_g)_C < (E_g)_{Ge} > (E_g)_{Si}$
- (c) $(E_g)_C > (E_g)_{Si} > (E_g)_{Ge}$
- (d) $(E_g)_C = (E_g)_{Si} = (E_g)_{Ge}$

Solution: (c)

The energy band gap is maximum for carbon, for silicon and least for germanium out of the given three elements.

14.4. In an unbiased p-n junction, holes diffuse from the p-region to n-region because

- (a) free electrons in the n-region attract them.
- (b) they move across the junction by the potential difference.
- (c) hole concentration in p-region is more as compared to n-region.
- (d) All the above.

Solution: (c)

In unbiased p-n junction, holes diffuse from the p-region to n-region because hole concentration in p-region is more compared to n-junction. As the diffusion of charge carriers across the junction takes place from higher concentration to lower concentration.

14.5. When a forward bias is applied to a p-n junction, it

- (a) raises the potential barrier.
- (b) reduces the majority carrier current to zero.
- (c) lowers the potential barrier.
- (d) none of the above.

Solution: (c)

When we apply a forward bias on a p-n junction then the value of the potential barrier is lowered. Also, the potential barrier opposes the applied voltage. This reduces the potential barrier across the junction.

14.6. For transistor action, which of the following statements are correct:

- (a) Base, emitter and collector regions should have similar size and doping concentrations.
- (b) The base region must be very thin and lightly doped.
- (c) The emitter junction is forward biased and collector junction is reverse biased.
- (d) Both the emitter junction as well as the collector junction are forward biased.

Solution: (b), (c).

For a transistor, its junction is lightly doped and the base region is very thin. Also, the emitter junction of a transistor must be forward-biased and collector junction should be reverse-biased.

14.7. For a transistor amplifier, the voltage gain

- (a) remains constant for all frequencies.
- (b) is high at high and low frequencies and constant in the middle frequency range.
- (c) is low at high and low frequencies and constant at mid frequencies.
- (d) none of the above.

Solution: (c)

For a transistor amplifier, the voltage gain is low at high and low frequencies and constant at mid frequencies. It is constant at mid-frequency range only.

- 14.8.** In half-wave rectification, what is the output frequency if the input frequency is 50 Hz. What is the output frequency of a full-wave rectifier for the same input frequency?

Solution:

Given:

Input frequency = 50 Hz

We know that for a half-wave rectifier, the output frequency is equal to the input frequency.

∴ Output frequency = 50 Hz

And for a full-wave rectifier, the output frequency is twice the input frequency.

∴ Output frequency = $2 \times 50 = 100$ Hz

- 14.9.** For a CE-transistor amplifier, the audio signal voltage across the collected resistance of $2 \text{ k}\Omega$ is 2 V. Suppose the current amplification factor of the transistor is 100, find the input signal voltage and base current if the base resistance is $1 \text{ k}\Omega$.

Solution:

Given:

Collector resistance, $R_C = 2 \text{ k}\Omega = 2000 \Omega$

Audio signal voltage across the collector resistance, $V = 2 \text{ V}$

Current amplification factor of the transistor, $\beta = 100$

Base resistance, $R_B = 1 \text{ k}\Omega = 1000 \Omega$

Input signal voltage = V_i

Base current = I_B

We have the amplification relation as: $\frac{V}{V_i} = \beta \frac{R_C}{R_b}$

Voltage amplification, $V_i = V \frac{R_b}{\beta R_C} = \frac{2 \times 1000}{100 \times 2000} = 0.01 \text{ V}$

Base resistance, $R_B = \frac{V_i}{I_B} = \frac{0.01}{1000} = 10 \mu\text{A}$

- 14.10.** Two amplifiers are connected one after the other in series (cascaded). The first amplifier has a voltage gain of 10 and the second has a voltage gain of 20. If the input signal is 0.01 volt, calculate the output ac signal.

Solution:

Given:

The voltage gain of the first amplifier, $V_1 = 10$

The voltage gain of the second amplifier, $V_2 = 20$

The voltage of the input signal, $V_i = 0.01 \text{ V}$

The voltage of output AC signal = V_o

The total voltage gain of a two-stage amplifier is given by the product of voltage gains of both the stages,

$$\text{i.e., } V = V_1 \times V_2 = 10 \times 20 = 200$$

It can be calculated by the relation: $V = V_o/V_i$

$$V_o = V \times V_i = 200 \times 0.01 = 2 V$$

- 14.11.** A p-n photodiode is fabricated from a semiconductor with band gap of 2.8 eV. Can it detect a wavelength of 6000 nm?

Solution:

Given:

The energy band gap of the given photodiode, $E_g = 2.8 \text{ eV}$

The wavelength, $\lambda = 6000 \text{ nm} = 6000 \times 10^{-9} \text{ m}$

The energy of a photon is given by the relation $E = hc/\lambda$

Where, $h = \text{Planck's constant} = 6.626 \times 10^{-34} \text{ J s}$

$c = \text{Speed of light} = 3 \times 10^8 \text{ m/s}$

$$E = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{6000 \times 10^{-9}} = 3.313 \times 10^{-20} \text{ J}$$

But $1.6 \times 10^{-19} \text{ J} = 1 \text{ eV}$

$$E = 3.313 \times 10^{-20} \text{ J}$$

$$\therefore E = 3.313 \times 10^{-20} \text{ J} = 3.313 \times 10^{-20} / 1.6 \times 10^{-19} = 0.207 \text{ eV}$$

The energy of wavelength 6000 nm is 0.207 eV, which is less than 2.8 eV (the energy band gap of a photodiode). Hence, the photodiode cannot detect the signal.

Additional Exercises

- 14.12.** The number of silicon atoms per m^3 is 5×10^{28} . This is doped simultaneously with 5×10^{22} atoms per m^3 of Arsenic and 5×10^{20} per m^3 atoms of Indium. Calculate the number of electrons and holes. Given that $n_i = 1.5 \times 10^{16} m^{-3}$. Is the material n-type or p-type?

Solution:

Number of silicon atoms, $N = 5 \times 10^{28} \text{ atoms/m}^3$

Number of arsenic atoms, $n_{As} = 5 \times 10^{22} \text{ atoms/m}^3$

Number of indium atoms, $n_{In} = 5 \times 10^{20} \text{ atoms/m}^3$

Number of thermally generated electrons, $n_i = 1.5 \times 10^{16} \text{ electrons/m}^3$

Number of electrons, $n_e = 5 \times 10^{22} - 1.5 \times 10^{16} \approx 4.99 \times 10^{22}$

Number of holes = n_h

In thermal equilibrium, the concentrations of electrons and holes in a semiconductor are related as: $n_e n_h = n_i^2$

$$\text{Therefore, } n_h = \frac{n_i^2}{n_e} = \frac{(1.5 \times 10^{16})^2}{4.99 \times 10^{22}} \approx 4.51 \times 10^9$$

Therefore, the number of electrons is approximately 4.99×10^{22} and the number of holes is about 4.51×10^9 . Since the number of electrons is more than the number of holes, the material is an n-type semiconductor.

- 14.13.** In an intrinsic semiconductor the energy gap E_g is 1.2 eV. Its hole mobility is much smaller than electron mobility and independent of temperature. What is the ratio between conductivity at 600K and that at 300K? Assume that the temperature dependence of intrinsic carrier concentration n_i is given by $n_i = n_0 \exp\left(-\frac{E_g}{2k_B T}\right)$ where n_0 is a constant.

Solution:

Given

$$\text{Energy gap } (E_g) = 1.2 \text{ eV}$$

The temperature dependence of intrinsic carrier concentration n_i is given by

$$n_i = n_0 \exp\left(-\frac{E_g}{2k_B T}\right)$$

At temperature $T_1 = 600 \text{ K}$,

$$n_1 = n_0 \exp\left(-\frac{E_g}{2k_B \times 600}\right) \quad \dots \quad (1)$$

At temperature $T_1 = 300 \text{ K}$,

$$n_2 = n_0 \exp\left(-\frac{E_g}{2k_B \times 300}\right) \quad \dots \quad (2)$$

By dividing equation (1) and (2)

$$\frac{n_1}{n_2} = \frac{n_0 \exp\left(-\frac{E_g}{2k_B \times 600}\right)}{n_0 \exp\left(-\frac{E_g}{2k_B \times 300}\right)}$$

$$\Rightarrow \frac{n_1}{n_2} = \exp\left(-\frac{E_g}{2k_B} \left(\frac{1}{600} - \frac{1}{300}\right)\right)$$

$$\Rightarrow \frac{n_1}{n_2} = \exp\left(\frac{E_g}{2k_B} \left(\frac{1}{600}\right)\right) = \exp\left(\frac{1.2 \text{ eV}}{2 \times 8.62 \times 10^{-5} \text{ eV K}^{-1} \times 600 \text{ K}}\right)$$

$$\Rightarrow \frac{n_1}{n_2} = \exp(11.6)$$

$$\Rightarrow \frac{n_1}{n_2} = 1.091 \times 10^5$$

Hence, the ratio of conductivity at 600 K and 300 K is 1.091×10^5 .

14.14. In a p-n junction diode, the current I can be expressed as

$$I = I_0 \exp\left(\frac{eV}{k_B T} - 1\right)$$

where I_0 is called the reverse saturation current, V is the voltage across the diode and is positive for forward bias and negative for reverse bias, and I is the current through the diode, k_B is the Boltzmann constant (8.6×10^{-5} eV/K) and T is the absolute temperature. If for a given diode $I_0 = 5 \times 10^{-12}$ A and $T = 300$ K, then

- What will be the forward current at a forward voltage of 0.6 V?
- What will be the increase in the current if the voltage across the diode is increased to 0.7 V?
- What is the dynamic resistance?
- What will be the current if reverse bias voltage changes from 1 V to 2 V?

Solution:

Given:

The current I in a p-n junction diode, $I = I_0 \exp\left(\frac{eV}{k_B T} - 1\right)$

$$I_0 = 5 \times 10^{-12} \text{ A}$$

$$T = 300 \text{ K}$$

$$K_B = 8.6 \times 10^{-5} \text{ eV/K}$$

- (a) Forward voltage 0.6 V

$$I = 5 \times 10^{-12} \exp\left(\frac{0.6}{8.6 \times 10^{-5} \times 300} - 1\right)$$

$$\Rightarrow I = 5 \times 10^{-12} \exp(22.25) = 0.0231 \text{ A}$$

The forward current in the diode is 0.0231 A.

- (b) Forward voltage 0.7 V

$$I = 5 \times 10^{-12} \exp\left(\frac{0.7}{8.6 \times 10^{-5} \times 300} - 1\right)$$

$$\Rightarrow I = 5 \times 10^{-12} \exp(26.13) = 1.116 \text{ A}$$

The forward current in the diode is 1.116 A.

- (c) Dynamic Resistance is given as the ratio of change in voltage and change in current.

$$\text{Dynamic Resistance} = \frac{\text{change in voltage}}{\text{change in current}} = \frac{0.7 - 0.6}{1.116 - 0.0231} = \frac{0.1}{1.093} = 0.091 \Omega$$

- (d) If we change the reverse bias voltage from 1 V to 2 V, then the current will remain the same as I_0 in both cases. Hence, the dynamic resistance in reverse bias will be infinite.

14.15. You are given the two circuits as shown in Fig. 14.44. Show that circuit (a) acts as OR gate while the circuit (b) acts as AND gate.

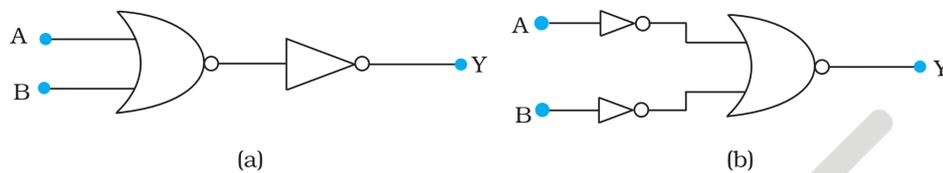


FIGURE 14.44

Solution:

- (a) The left half of the circuit is NOR gate and the right half is NOT.

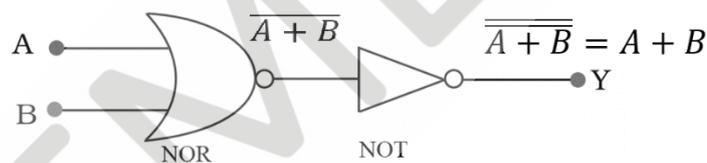
Hence the output from the NOR gate will be $\overline{A + B}$

Again the output of this signal through NOT gate will be,

$$\overline{\overline{A + B}} = A + B$$

$$\therefore Y = A + B$$

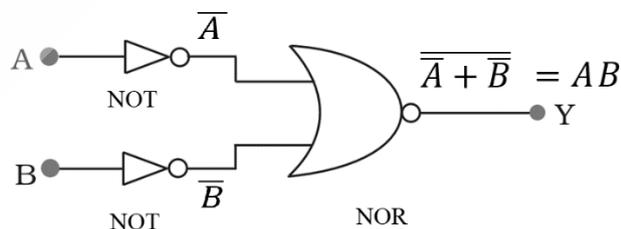
Hence the circuit is an OR gate.



- (b) The output of this logic gate is NOR gate over the output of two NOT gate.

$$\therefore Y = \overline{\overline{A + B}} = \overline{\overline{A} \cdot \overline{B}} = A \cdot B$$

Hence the circuit is an AND gate.



14.16. Write the truth table for a NAND gate connected as given in Fig. 14.45.

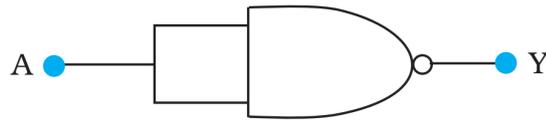


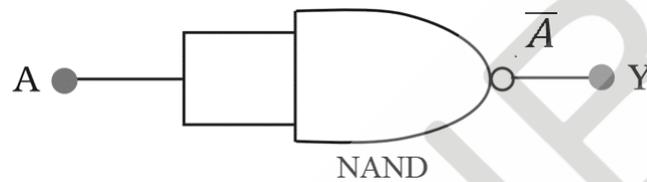
FIGURE 14.45

Hence identify the exact logic operation carried out by this circuit.

Solution:

A is the two input for the NAND gate. Hence its output will be

$$Y = \overline{A \cdot A} = \overline{A} + \overline{A} = \overline{A}$$



The truth table can be drawn as

A	$Y = \overline{A}$
0	1
1	0

14.17. You are given two circuits as shown in Fig. 14.46, which consist of NAND gates. Identify the logic operation carried out by the two circuits.

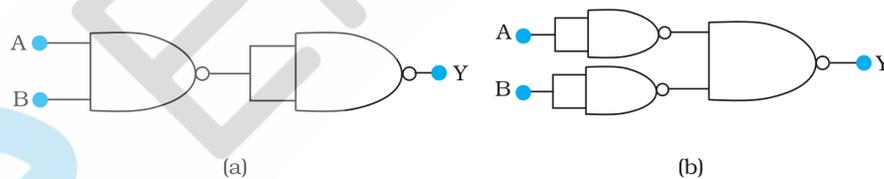
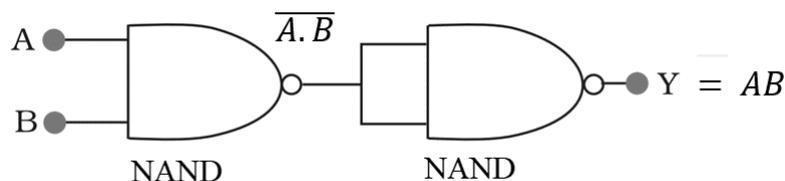


FIGURE 14.46

Solution:

(a) The output from the 1st NAND gate will be $\overline{A \cdot B}$. Now the output from the second NAND gate will be $\overline{(\overline{A \cdot B}) \cdot (\overline{A \cdot B})}$

$$\therefore Y = \overline{(\overline{A \cdot B}) \cdot (\overline{A \cdot B})} = AB + AB = AB$$



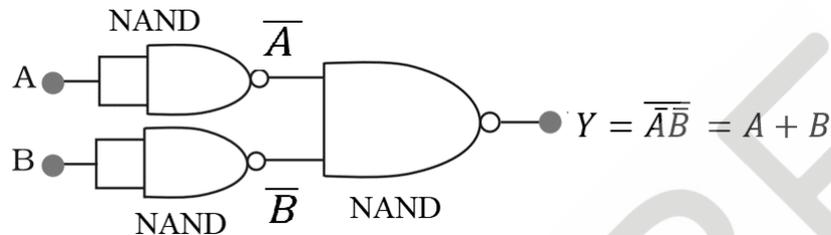
(b) For the 1st two NAND gate, the output will be

$$Y_1 = \overline{A \cdot A} = \overline{A} + \overline{A} = \overline{A}$$

$$\text{And } Y_2 = \overline{B \cdot B} = \overline{B} + \overline{B} = \overline{B}$$

The final output will be

$$Y = \overline{\overline{A} \cdot \overline{B}} = \overline{\overline{A}} + \overline{\overline{B}} = A + B$$



14.18. Write the truth table for circuit given in Fig. 14.47 below consisting of NOR gates and identify the logic operation (OR, AND, NOT) which this circuit is performing.

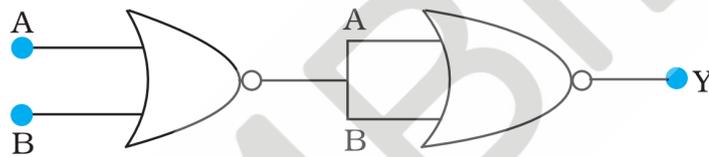


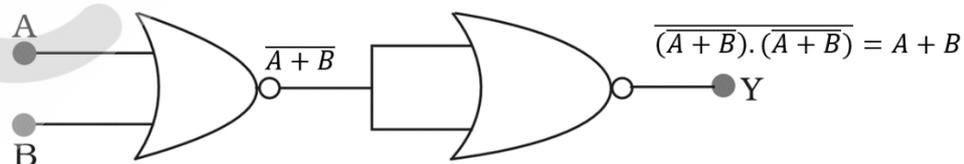
FIGURE 14.47

(Hint: $A = 0, B = 1$ then A and B inputs of second NOR gate will be 0 and hence $Y = 1$. Similarly work out the values of Y for other combinations of A and B . Compare with the truth table of OR, AND, NOT gates and find the correct one.)

Solution:

A and B are input for NOR gate, and the output will be $\overline{A + B}$.

The output from the second NOR gate will be $\overline{\overline{A + B} \cdot \overline{A + B}} = \overline{\overline{A + B}} + \overline{\overline{A + B}} = A + B$



The truth table of the following circuit is

A	B	Y = A + B
0	0	0
0	1	1

1	0	1
1	1	1

14.19. Write the truth table for the circuits given in Fig. 14.48 consisting of NOR gates only. Identify the logic operations (OR, AND, NOT) performed by the two circuits.

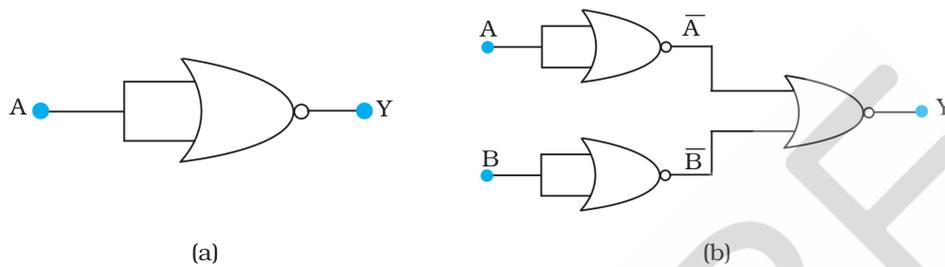


FIGURE 14.48

Solution:

(a) A is the two input for the NAND gate. Hence its output will be

$$Y = \overline{A \cdot A} = \overline{A} + \overline{A} = \overline{A}$$

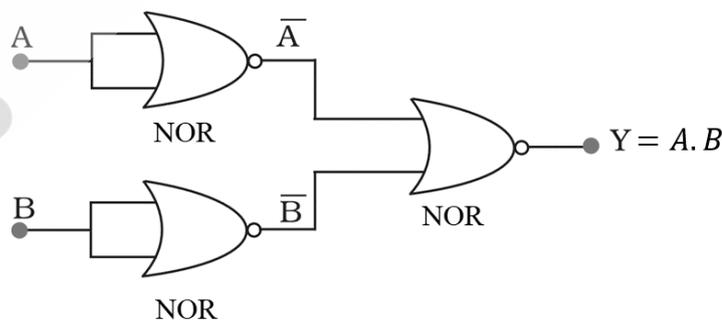


The truth table can be drawn as

A	$Y = \overline{A}$
0	1
1	0

(b) \overline{A} and \overline{B} are the input for the last NOR gate. Hence, the output will be

$$Y = \overline{\overline{A} + \overline{B}} = \overline{\overline{A}} \cdot \overline{\overline{B}} = A \cdot B$$



The truth table of the following circuit is

A	B	$Y = A \cdot B$
0	0	0

0	1	0
1	0	0
1	1	1

◆◆◆