SEMICONDUCTOR ELECTRONICS: MATERIALS, DEVICES AND SIMPLE CIRCUITS

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1. The conductivity of intrinsic semiconductor germanium at 27° is 2.13 mho m^{-1} and mobilities of electrons and holes are 0.38 and 0.18 m^{2}V^{-1}s^{-1} respectively. The density of charge carriers is

(a) 2.37×10^{19} m^{-3} (b) 3.28×10^{19} m^{-3}

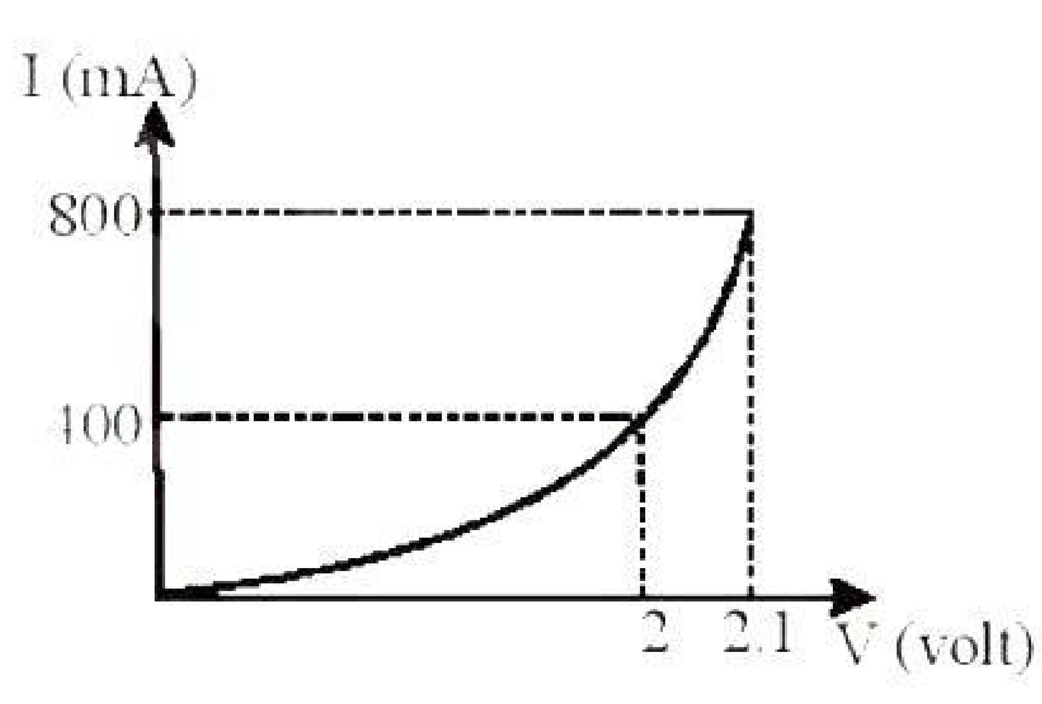
(c) 7.83×10^{19} m^{-3} (d) 8.47×10^{19} m^{-3}

2. Pure Silicon at 500 K has equal electron (n_e) and hole (n_h) concentration of 1.5×10^{16} m^{-3}. Doping by indium increases n_h to 4.5×10^{22} m^{-3}. The n_e in the doped silicon is

(a) 9×10^5 (b) 5×10^9

(c) 2.25×10^{11} (d) 3×10^{19}

3. The I-V characteristic of a P-N junction diode is shown below. The approximate dynamic resistance of the p-n junction when a forward bias of 2 volt is applied is



(a) 1 Ω (b) 0.25 Ω

(c) 0.5 Ω (d) 5 Ω

4. A zener diode of voltage V_Z (= 6V) is used to maintain a constant voltage across a load resistance R_L (= 1000 Ω) by using a series resistance R_s (= 100Ω). If the e.m.f. of source is E (= 9 V), what is the power being dissipated in Zener diode ?

(a) 0.144 watt (b) 0.324 watt

(c) 0.244 watt (d) 0.544 watt

5. The electric conductivity of an intrinsic semiconductor increases when the electromagnetic waves of wavelength equal or shorter than 3895 nm is incident on it. The band gap of the semiconductor is

(a) 1.2 eV (b) 0.3 eV

(c) 1.0 eV (d) 1.5 eV

6. What is the conductivity of a semiconductor sample having electron concentration of 5×10^{18} m^{-3}, hole concentration of 5×10^{19} m^{-3}, electron mobility of 2.0 m^2 V^{-1} s^{-1} and hole mobility of 0.01 m^2 V^{-1} s^{-1} ?

(Take charge of electron as 1.6×10^{-19} C)

(a) 1.68 $(\Omega - m)^{-1}$ (b) 1.83 $(\Omega - m)^{-1}$

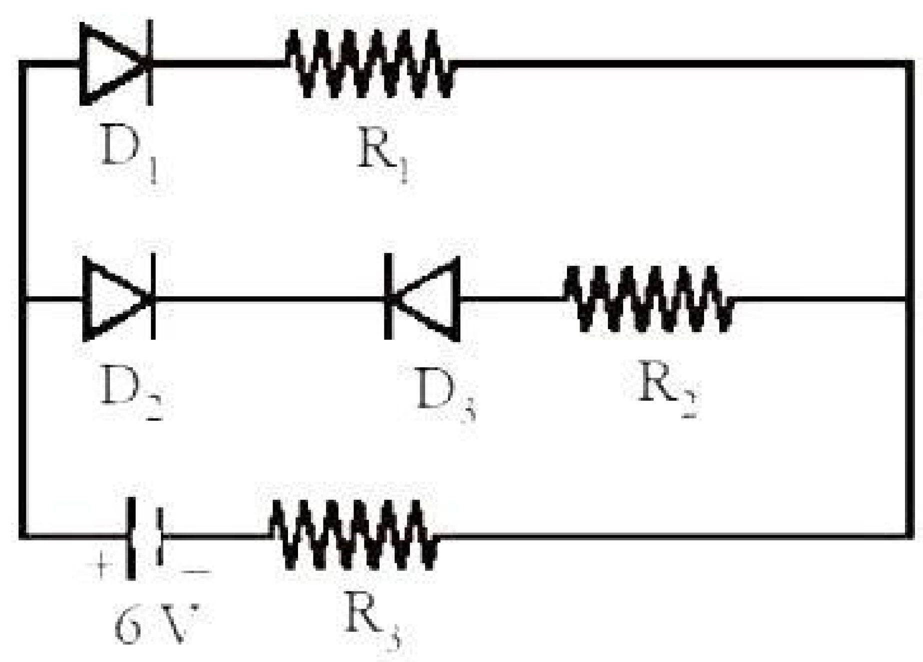
(c) 0.59 $(\Omega - m)^{-1}$ (d) 1.20 $(\Omega - m)^{-1}$

7. A p-n photodiode is made of a material with a band gap of 2.0eV. The minimum frequency of the radiation that can be absorbed by the material is nearly

(a) $1 \times 10^{14}\,Hz$ (b) $20 \times 10^{14}\,Hz$

(c) $10 \times 10^{14}\,Hz$ (d) $5 \times 10^{14}\,Hz$

8. Figure shows a circuit in which three identical diodes are used. Each diode has forward resistance of 20 Ω and infinite backward resistance. Resistors $R_1 = R_2 = R_3 = 50\ \Omega$. Battery voltage is 6 V. The current through R_3 is :



(a) 50 mA

(b) 100 mA

(c) 60 mA

(d) 25 mA

9. In a transistor, a change of 8.0 mA in the emitter current produces a change of 7.8 mA in the collector current. What change in the base current is necessary to produce the same change in the collector current?

(a) 50 μA (b) 100 μA

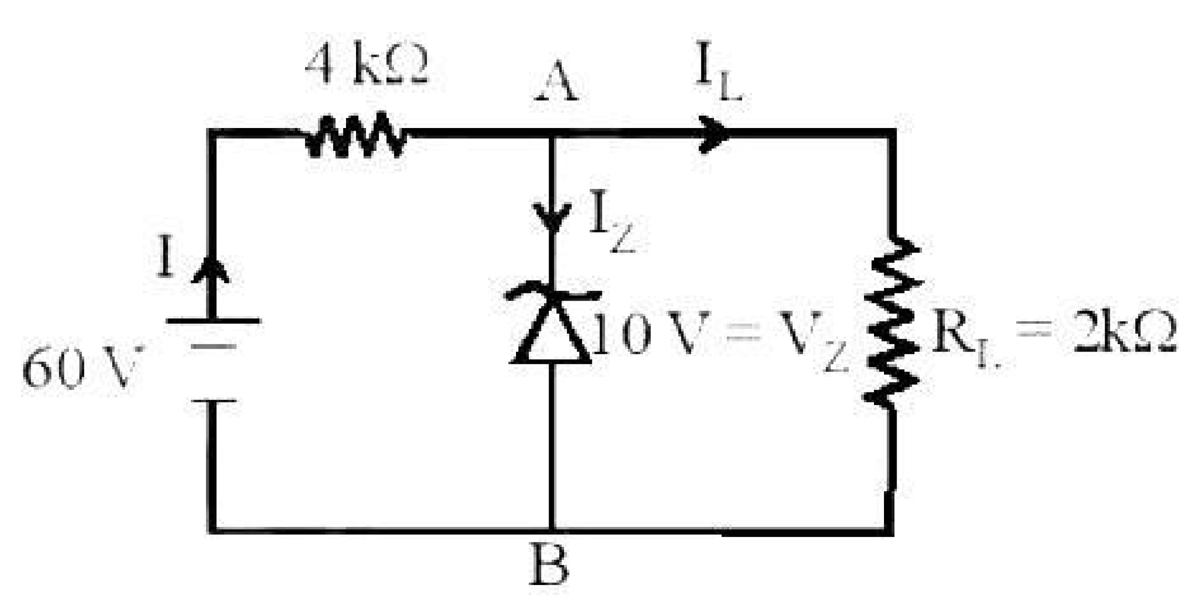
(c) 150 μA (d) 200 μA

10. In a *CE* transistor amplifier, the audio signal voltage across the collector resistance of 2 kΩ is 2 V. If the base resistance is 1 kΩ and the current amplification of the transistor is 100, the input signal voltage is :

(a) 0.1 V (b) 1.0 V

(c) 1mV (d) 10 mV

11. A Zener diode is connected to a battery and a load as shown below:



The currents, I, I_Z and I_L are respectively.

(a) 15 mA, 5 mA, 10 mA

(b) 15 mA, 7.5 mA, 7.5 mA

(c) 12.5 mA, 5 mA, 7.5 mA

(d) 12.5 mA, 7.5 mA, 5 mA

12. In a common emitter configuration with suitable bias, it is given than R_L is the load resistance and R_{BE} is small signal dynamic resistance (input side). Then, voltage gain, current gain and power gain are given, respectively, by:

(β is current gain, I_B, I_C, I_E are respectively base, collector and emitter currents)

(a) $\beta\dfrac{R_L}{R_{BE}}, \dfrac{\Delta I_E}{\Delta I_B}, \beta^2\dfrac{R_L}{R_{BE}}$

(b) $\beta^2\dfrac{R_L}{R_{BE}}, \dfrac{\Delta I_C}{\Delta I_B}, \beta\dfrac{R_L}{R_{BE}}$

(c) $\beta^2\dfrac{R_L}{R_{BE}}, \dfrac{\Delta I_C}{\Delta I_E}, \beta^2\dfrac{R_L}{R_{BE}}$

(d) $\beta\dfrac{R_L}{R_{BE}}, \dfrac{\Delta I_C}{\Delta I_B}, \beta^2\dfrac{R_L}{R_{BE}}$

13. The input resistance of a silicon transistor is 100 Ω. Base current is changed by 40 μA which results in a change in collector current by 2 mA. This transistor is used as a common emitter amplifier with a load resistance of 4 kΩ. The power gain of the amplifier is :

(a) 10^5 (b) 10^3

(c) 10^6 (d) 10^2

14. With increasing biasing voltage of a photodiode, the photocurrent magnitude :

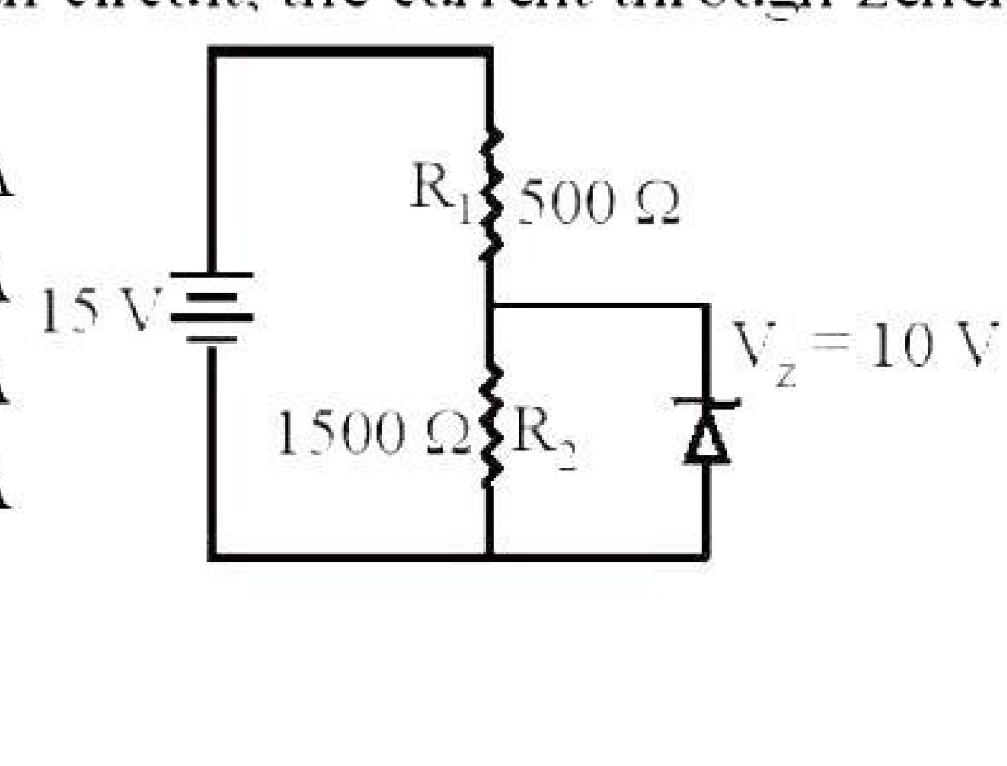
(a) remains constant

(b) increases initially and after attaining certain value, it decreases

(c) Increases linearly

(d) increases initially and saturates finally

15. In the given circuit, the current through zener diode is:



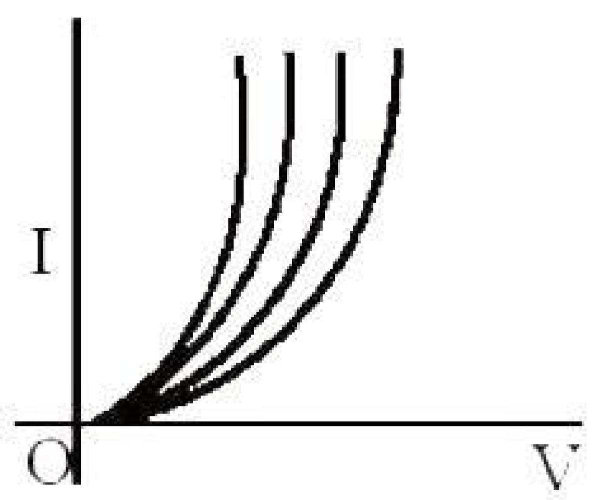
(a) 2.5mA

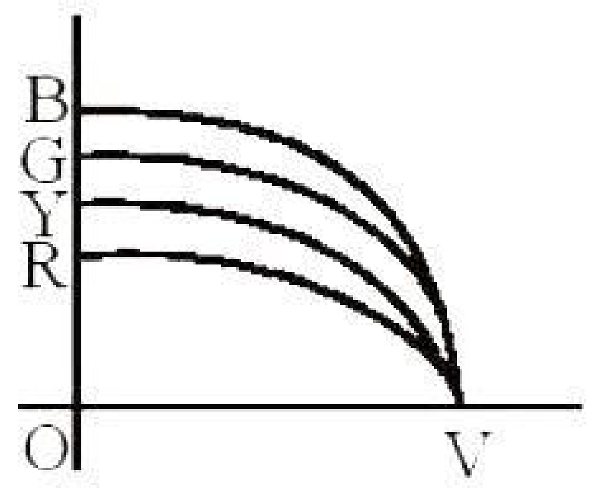
(b) 3.3mA

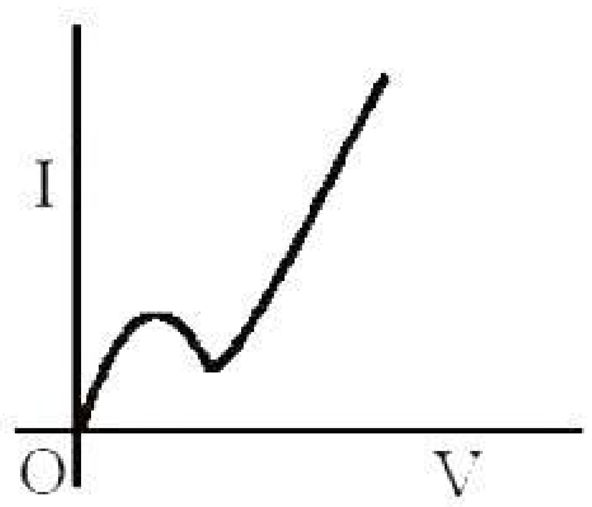
(c) 5.5mA

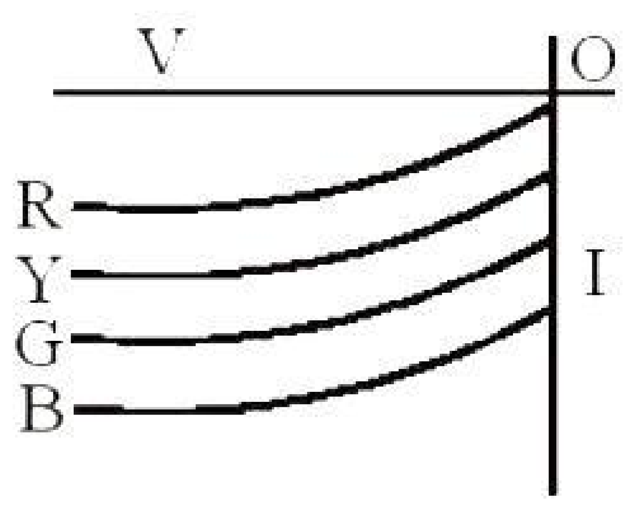
(d) 6.7mA

16. The I-V characteristic of an LED is

(a) 

(b) 

(c) 

(d) 

17. A pure semiconductor has equal electron and hole concentration of 10^{16} m^{-3}. Doping by gallium increases n_h to 5×10^{22} m^{-3}. Then, the value of n_e in the doped semiconductor is

(a) $10^6/m^3$ (b) $10^{22}/m^3$

(c) $2 \times 10^6/m^3$ (d) $2 \times 10^9/m^3$

18. A diode having potential difference 0.5 V across its junction which does not depend on current, is connected in series with resistance of 20Ω across source. If 0.1 A current passes through resistance then what is the voltage of the source?

(a) 1.5 V (b) 2.0 V

(c) 2.5 V (d) 5 V

19. A common emitter amplifier has a voltage gain of 49, an input impedance of 100Ω and an output impedance of 490Ω. The power gain of the amplifier is

(a) 500 (b) 499

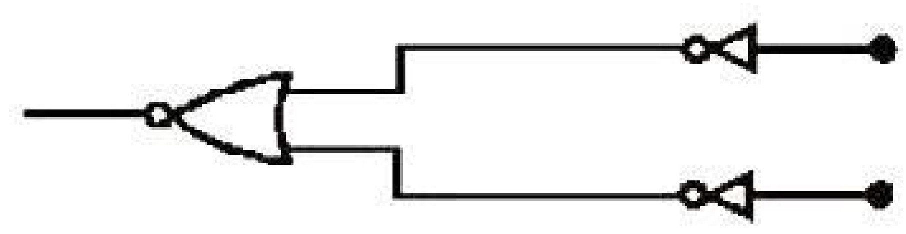
(c) 490 (d) 501

20. If the given transistor is used as an amplifier then for input resistance of 80Ω and load resistance of 16kΩ, the output voltage corresponding to the input voltage of 12mV will be

(a) 37.5mV (b) 37500 V

(c) 300 V (d) 300mV

21. Figure consists of two NOT gates followed by a NOR gate. This combination is equivalent to a single



(a) NAND gate (b) AND gate

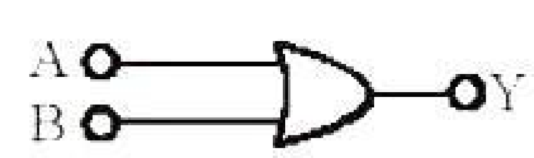
(c) OR gate (d) XOR gate

22. The load resistance and the input resistance of a CE amplifier are respectively 10 kΩ and 2 kΩ. If β of the transistor is 49, the voltage gain of the amplifier is

(a) 125 (b) 150

(c) 175 (d) 245

23. A logic gate and its truth table are shown below:



A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

The gate is :

(a) NOR (b) AND

(c) OR (d) NOT

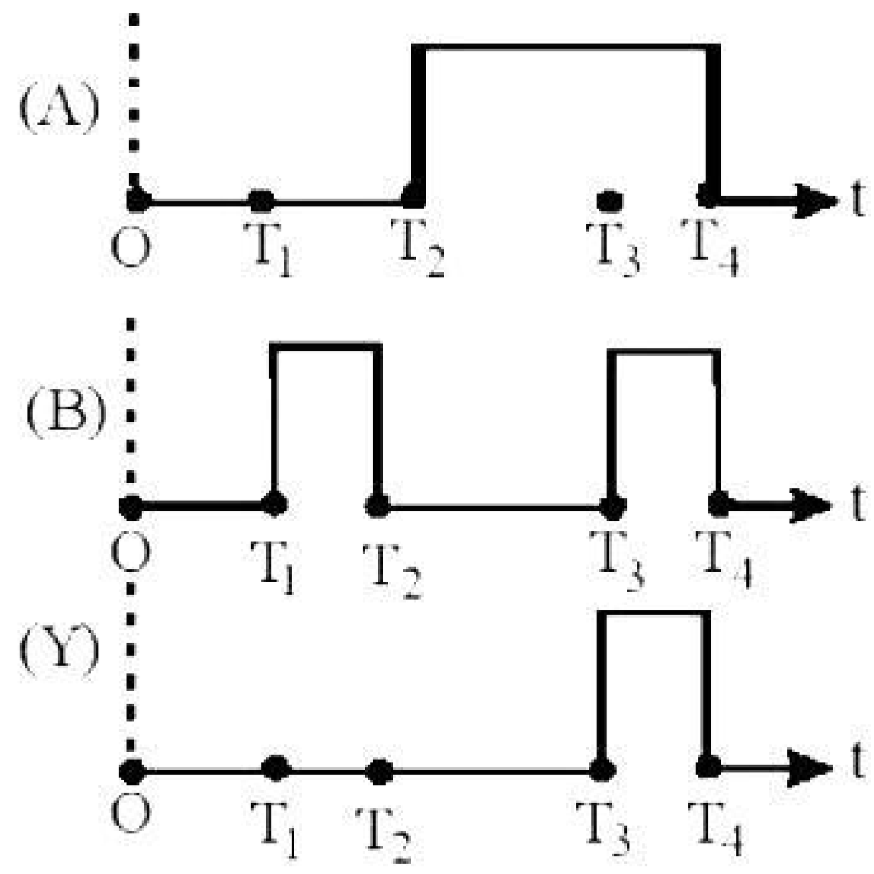
24. The given figure shows the wave forms for two inputs A and B and that for the output Y of a logic circuit. The logic circuit is a/an.

(a) AND gate

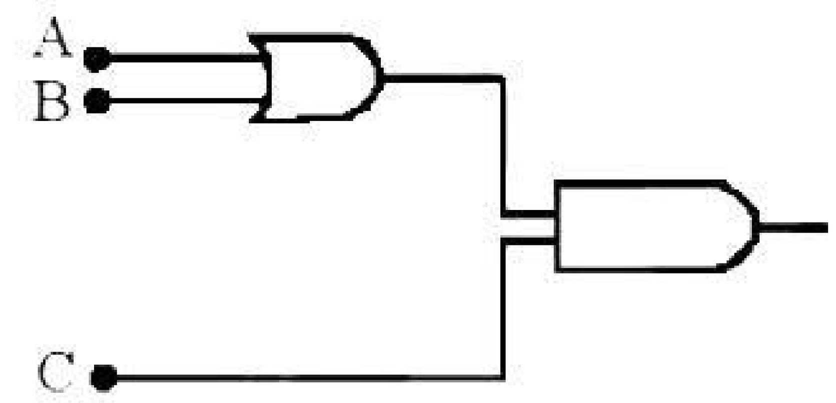
(b) OR gate

(c) NAND

(d) NOT gate



25. To get an output 1 from the circuit shown in the figure, the input must be



(a) A = 0, B = 1, C = 0 (b) A=1, B=0, C=0

(c) A = 1, B = 0, C = 1 (d) A=1, B=1, C=0

ANSWER KEY																		
1	(a)	**4**	(a)	**7**	(d)	**10**	(d)	**13**	(a)	**16**	(a)	**19**	(c)	**22**	(d)	**25**	(c)
2	(b)	**5**	(b)	**8**	(a)	**11**	(d)	**14**	(d)	**17**	(d)	**20**	(c)	**23**	(c)		
3	(b)	**6**	(a)	**9**	(d)	**12**	(d)	**15**	(b)	**18**	(c)	**21**	(b)	**24**	(a)		

28 Semiconductor Electronics: Materials, Devices and Simple Circuits

1. **(a)** Conductivity, $\sigma = \frac{1}{\rho} = e(n_e\mu_e + n_h\mu_h)$

ie, $2.13 = 1.6 \times 10^{-19}(0.38 + 0.18)\, n_i$

(Since in intrinsic semi-conductor, $n_e = n_h = n_i$)

$\therefore$ density of charge carriers,

$$n_i = \frac{2.13}{1.6 \times 10^{-19} \times 0.56} = 2.37 \times 10^{19}\, m^{-3}.$$

2. **(b)** $n_i^2 = n_e \cdot n_h$

3. **(b)** $R = \frac{\Delta V}{\Delta I} = \frac{2.1 - 2}{(800 - 400) \times 10^{-3}} = \frac{1}{4} = 0.25\,\Omega$

4. **(a)** Here, $E = 9V$; $V_Z = 6$; $R_L = 1000\Omega$ and $R_s = 100\Omega$,

Potential drop across series resistor

$V = E - V_Z = 9 - 6 = 3V$

Current through series resistance R_S is

$$I = \frac{V}{R} = \frac{3}{100} = 0.03\text{ A}$$

Current through load resistance R_L is

$$I_L = \frac{V_Z}{R_L} = \frac{6}{1000} = 0.006\text{ A}$$

Current through Zener diode is

$I_Z = I - I_L = 0.03 - 0.006 = 0.024$ amp.

Power dissipated in Zener diode is

$P_Z = V_Z I_Z = 6 \times 0.024 = 0.144$ Watt

5. **(b)** Forbidden energy gap

$$\Rightarrow \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{3895 \times 10^{-9} \times 1.6 \times 10^{-19}}$$

$= 0.003 \times 10^2\text{ eV} = 0.3\text{ eV}$

6. **(a)** The conductivity of semiconductor

$\sigma = e(\eta_e\mu_e + \eta_h\mu_h)$

$= 1.6 \times 10^{-19}(5 \times 10^{18} \times 2 + 5 \times 10^{19} \times 0.01)$

$= 1.6 \times 1.05 = 1.68$

7. **(d)**

8. **(a)** Here, diodes D_1 and D_2 are forward biased and D_3 is reverse biased. Therefore current through R_3

$$i = \frac{V}{R'} = \frac{6}{120} = \frac{1}{20}\text{ A} = 50\text{ mA}$$

9. **(d)**

10. **(d)** Given, $R_C = 2\text{ k}\Omega$

$V_C = 2\text{ V}$

$R_B = 1\text{ k}\Omega$

$\beta = 100$

$$\frac{V_C}{V_i} = \beta.\frac{R_C}{R_B} \Rightarrow \frac{2}{V_i} = 100 \cdot \frac{2}{1}$$

$\Rightarrow V_i = 10\text{ mV}$

11. **(d)** Here, $R = 4\text{ k}\Omega = 4 \times 10^3\,\Omega$

$V_i = 60\text{ V}$

Zener voltage $V_z = 10\text{ V}$

$R_L = 2\text{ k}\Omega = 2 \times 10^3\,\Omega$

Load current, $I_L = \frac{V_Z}{R_L} = \frac{10}{2 \times 10^3} = 5\text{ mA}$

Current through R, $I = \frac{V_i - V_Z}{R}$

$$= \frac{60 - 10}{4 \times 10^3} = \frac{50}{4 \times 10^3} = 12.5\text{ mA}$$

Fom circuit diagram,

$I = I_Z + I_L \Rightarrow 12.5 = I_Z + 5 \Rightarrow I_Z = 7.5\text{ mA}$

12. **(d)** Curent gain $\beta = \frac{\Delta I_C}{I_B}$

Voltage gain A_V = Current gain $\times$ Resistance gain

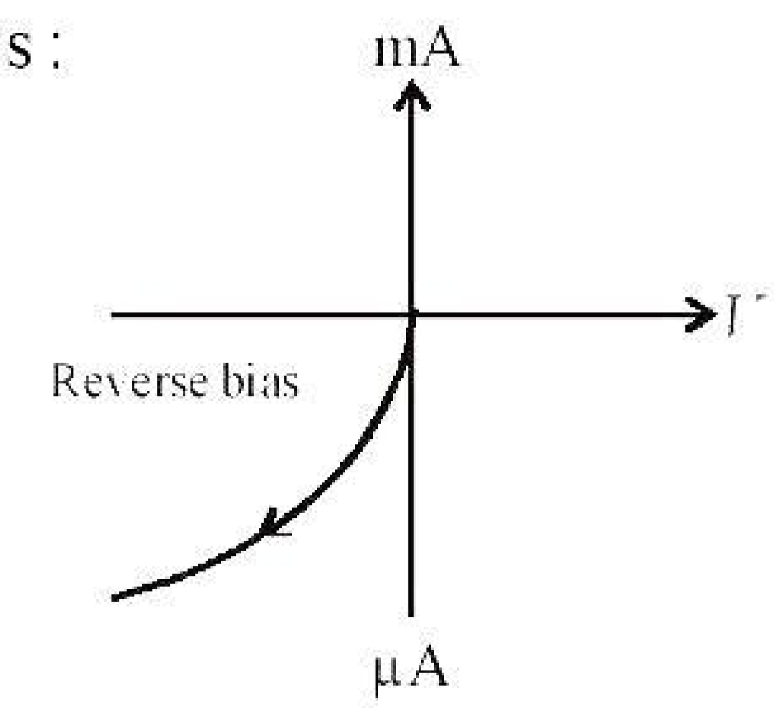
$\Rightarrow \beta \frac{R_L}{R_{BE}}$

Power gain A_p = (Current gain)^2 $\times$ Resistance gain

$\Rightarrow \beta^2 \frac{R_L}{R_{BE}}$

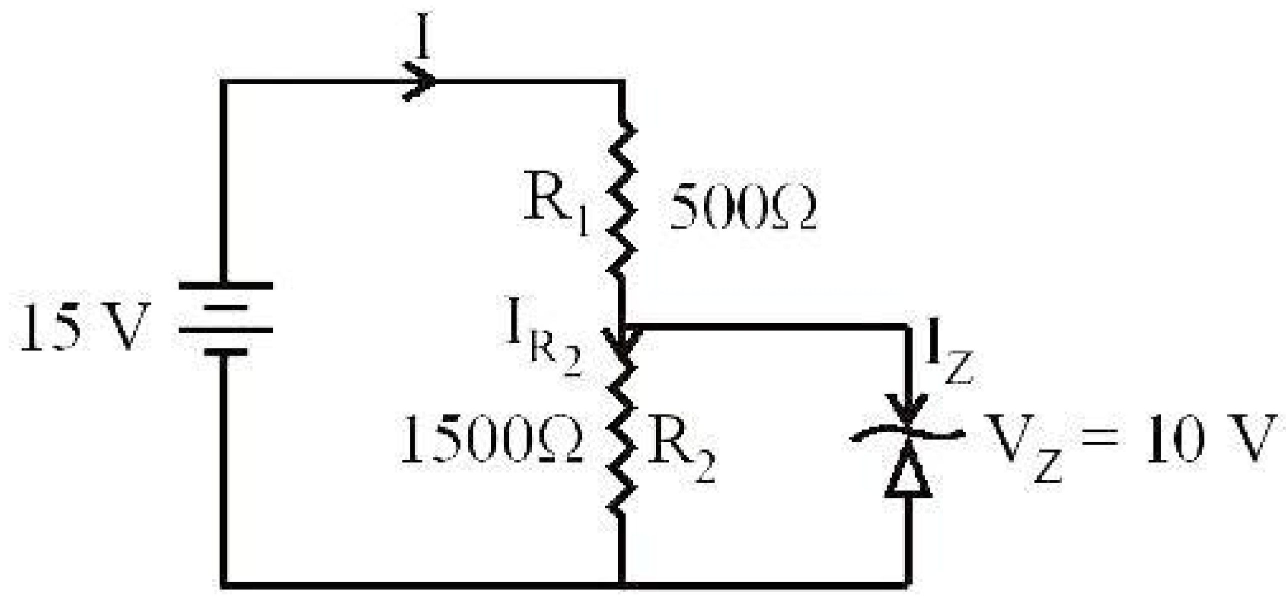
13. **(a)**

14. **(d)** I-V characteristic of a photodiode is as follows :



On increasing the biasing voltage of a photodiode, the magnitude of photocurrent first increases and then attains a saturation.

15. **(b)**



The voltage drop across R_2 is $V_{R_2} = V_Z = 10\,V$

The current through R_2 is

$$I_{R_2} = \frac{V_{R_2}}{R_2} = \frac{10\,V}{1500\Omega} = 0.667 \times 10^{-2}\,A$$

$= 6.67 \times 10^{-3}\,A = 6.67\,mA$

The voltage drop across R_1 is

$$V_{R_1} = 15V - V_{R_2} = 15V - 10V = 5V$$

The current through R_1 is

$$I_{R_1} = \frac{V_{R_1}}{R_1} = \frac{5\,V}{500\Omega} = 10^{-2}\,A$$

$= 10 \times 10^{-3}\,A = 10\,mA$

The current through the zener diode is

$$I_Z = I_{R_1} - I_{R_2} = (10 - 6.67)mA = 3.3\,mA$$

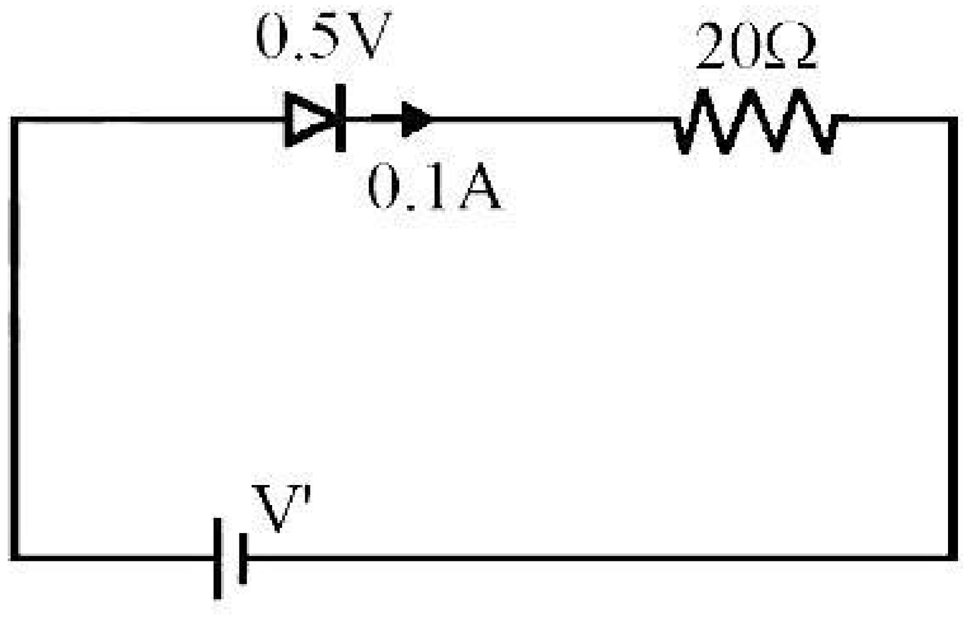
16. **(a)** For same value of current higher value of voltage is required for higher frequency hence (a) is correct answer.

17. **(d)** Here, $n_i = 10^{16}\,m^{-3}$, $n_h = 5 \times 10^{22}\,m^{-3}$

As $n_e n_h = n_i^2$

$$\therefore\ n_e = \frac{n_i^2}{n_h} = \frac{(10^{16}\,m^{-3})^2}{5 \times 10^{22}\,m^{-3}} = 2 \times 10^9\,m^{-3}$$

18. **(c)** $V' = V + IR = 0.5 + 0.1 \times 20 = 2.5\,V$



19. **(c)** Power gain = voltage gain × current gain

$$= V_G \cdot I_G = \frac{V_0}{V_i} \cdot \frac{I_0}{I_i}$$

$$= \frac{V_0^2}{V_i^2} \cdot \frac{R_i}{R_0} = 49 \times 49 \times \frac{100}{490} = 490$$

20. **(c)** Current gain, $\beta = \frac{\Delta I_C}{\Delta I_B} = \frac{(15-10)\text{ mA}}{(80-40)\ \mu A}$

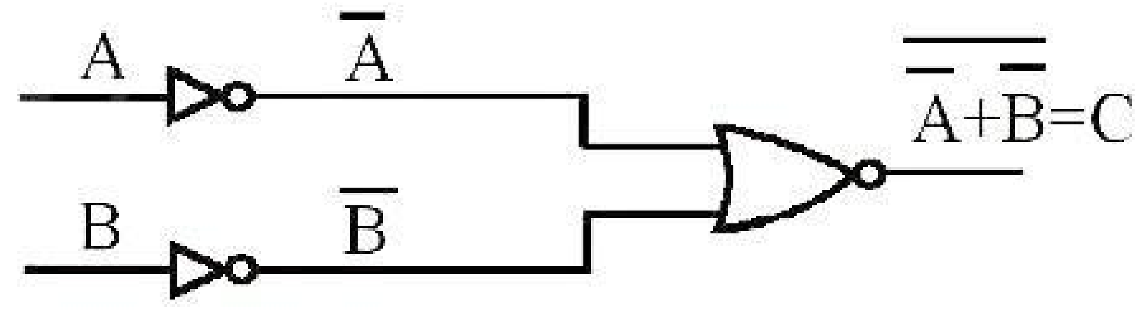
$$= \frac{5 \times 10^{-3}}{40 \times 10^{-6}} = \frac{5000}{40} = 125$$

Voltage gain, $A_V = \beta \frac{R_L}{R_{in}}$;

$$\frac{V_{out}}{V_{in}} = 125\left(\frac{16 \times 10^3}{80}\right)$$

$$V_{out} = 125 \times \frac{16000}{80} \times 12 \times 10^{-3} = 300V$$

21. **(b)**



A	B	$\bar{A}$	$\bar{B}$	$\bar{A}+\bar{B}$	C
0	0	1	1	1	0
0	1	1	0	1	0
1	0	0	1	1	0
1	1	0	0	0	1

≡ AND gate

22. **(d)** Output resistance, $R_0 = 10\,k\Omega$

Input resistance, $R_i = 2\,k\Omega$ and $\beta = 49$

Voltage gain, $A_V = \beta \times \frac{R_0}{R_i} = 49 \times \frac{10}{2} = 245$

23. **(c)** The truth table of OR gate is given as

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

24. **(a)** When both A and B are high between time T_3 and T_4 the output Y is high, otherwise zero. Thus the logic gate is AND gate

25. **(c)** A and B are the inputs of an OR gate. If A = 1, and B = 0, the output of OR gate will be 1. Now the output of OR gate along with C make the inputs of an AND gate.

Thus output of OR gate = 1, and C = 1, give the final output of AND gate as 1.